Springer Transactions in Civil and Environmental Engineering

N. A. Siddiqui
S. M. Tauseef
Kamal Bansal *Editors*

# Advances in Health and Environment Safety

## Select Proceedings of HSFEA 2016

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Kamal Bansal
Editors

# Advances in Health and Environment Safety

## Select Proceedings of HSFEA 2016

Springer

*Editors*
N. A. Siddiqui
Department of Health Safety and Environmental Engineering
College of Engineering, University of Petroleum and Energy Studies
Dehradun, Uttarakhand
India

Kamal Bansal
College of Engineering, University of Petroleum and Energy Studies
Dehradun, Uttarakhand
India

S. M. Tauseef
Environmental Research Institute
College of Engineering, University of Petroleum and Energy Studies
Dehradun, Uttarakhand
India

ISSN 2363-7633 ISSN 2363-7641 (electronic)
Springer Transactions in Civil and Environmental Engineering
ISBN 978-981-10-7121-8 ISBN 978-981-10-7122-5 (eBook)
https://doi.org/10.1007/978-981-10-7122-5

Library of Congress Control Number: 2017957210



Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

# Preface

Post industrialization, complexity of the processes and the technology that makes possible the production of variety of consumer products to support the growing population, has been increasing. Additionally, the perils of global warming and climate change have started to manifest in the form of severe environmental and health impacts.

The environmental impacts are clear in the form of shift in seasonal cycle, flash floods, droughts, scarcity of potable water, etc. As per World Health Organization (WHO) between the years 2030 and 2050, climate change is estimated to cause 250,000 additional deaths per year. The number of patients that are reporting health problems emanating from consumption or coming in contact with contaminated air and water is increasing every year.

It is estimated that world population will grow to 9.1 billion by 2050. In addition, economic progress, especially in developing world, would result in growing demand for natural resources. More number of people will be employed in manufacturing and allied sectors and exploitation of already stressed natural resources will reach its limit. Therefore, the importance of synergy between man and nature and man and his work environment cannot be overlooked. It is essential that sustainable means and ways are developed to meet the demands of growing population.

The importance of harmony between man and the environment is unquestionable. The importance of this harmony is even greater in the current scenario because, unlike past, the capacity of the environment to assimilate pollution caused by anthropogenic activities has reached its limit. We are now witness to global warming and climate change. This scenario is going to become even worst if course correction is not done immediately. Major stake-holders around the world are chalking out the plan to cut carbon emission and check global warming and climate change.

The same harmony is essential between man and his work environment. Prolonged exposure to hazards at work place and lack of ergonomics results in plethora of work related problems that call for immediate attention.

A major objective of this publication is to update ourselves with the latest developments in the field of health and environment safety, and inform on related opportunities and challenges.

This volume presents select papers on advances in the field of health and environment safety which were presented at the International conference on advances in the field of health, safety, fire, environment, allied sciences and Engineering (HSFEA 2016) from November 18–19, 2016, University of Petroleum and Energy Studies (UPES), Dehradun. The conference was attended by leading academic scientists, leading engineers, policy makers, budding scholars and graduate students. The contribution from the authors cover topics ranging from technology that assist in ensuring healthy safe environment to methods and means that need to be adopted to ensure sustainable development—use of renewable and alternate sources of energy, reduction and control of sources of pollutions, etc. Topics on methods that can be used for monitoring and measurements of climate change and global warming are also presented. Additionally, the importance of ensuring safety and healthy work environment, free from occupational health hazards, is stressed upon.

Dehradun, India

N. A. Siddiqui
S. M. Tauseef
Kamal Bansal

# Acknowledgements

This volume has benefitted from contributions from participants at the International conference on advances in the field of health, safety, fire, environment, allied sciences and Engineering (HSFEA 2016) from November 18–19, 2016, University of Petroleum and Energy Studies (UPES), Dehradun, and the support and input of a number of individuals and institutions.

We thank Dr. S. J. Chopra (Hon'ble Chancellor, UPES), Prof. Shrihari Honwad (Vice Chancellor, UPES) and Prof. Utpal Ghosh (CEO and President, UPES), for their support and encouragement. We are grateful to the Chief Guest for HSFEA 2016—Prof. V. K. Jain (Vice Chancellor, Doon University) for gracing the event with his presence, distinguished speakers—Senior Prof. S. A. Abbasi (Professor Emeritus UGC, Pondicherry University), Mr. Devendra Gill, Sr. Additional General Manager—Delhi Metro Railway Corporation, Dr. Tasneem Abbasi (Assistant Professor—Pondicherry University and concurrently visiting Associate Professor Worcester Polytechnic Institute, USA) and Dr. R. K. Sharma (General Manger—India Glycols Ltd) for their talks.

The organizers of HSFEA 2016 wish to thank all the reviewers for their valuable time and comments on the quality of the papers.

We acknowledge the support of our sponsors TATA Projects, Uttarakhand Jal Sansthan, Action for Sustainable, Efficacious Development and Awareness (ASEA), Akbar HSE, PARAM Environmental Solutions, SWAN Enviro, Uttrakhand Environment Protection and Pollution Control Board (UEPPCB).

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# About the Editors

**Dr. N. A. Siddiqui** is Professor at the University of Petroleum and Energy Studies (UPES) (2005–present). He holds a Master's degree in Environmental Sciences from Lucknow University, India (1996), and a Ph.D. in Environmental Biology from Awadhesh Pratap Singh University (APS) University, Rewa, India. Additionally, he has a number of professional certifications, e.g., a NEBOSH diploma, NEBOSH–IGC, IOSH Managing Safely, Lead Auditor OHSAS 18001, Lead Auditor ISO 14001 and GRAD-IOSH. Professor Siddiqui's research interests include occupational health, safety and environment. He has co-authored more than 100 papers and eight books and has organized a number of national and international seminars/conferences/MDPs. He has also worked on a number of major R&D projects.

**Dr. S. M. Tauseef** is Assistant Professor (SG) and Head of the Environmental Research Institute at the University of Petroleum and Energy Studies (UPES), India (2015–present). He holds an MS in Chemical Engineering (Process Design) from Sharif University of Technology, Iran (2008), and a Ph.D. in Environmental Engineering from Pondicherry University (PU) (2011). Prior to joining UPES, he worked as a Pool Officer (CSIR, Council of Scientific and Industrial Research) at PU (2012–2015). Dr. Tauseef's research interests include process safety, especially forecasting and consequence assessment of accidents in chemical process industries. He has developed methodologies for the application of computational fluid dynamics (CFD) to dense gas dispersion, vapor cloud explosions, and single and multiple pool fires. His other main interest is in solid waste management, especially the design of continuously operable vermireactor systems for assorted wastes, and high-rate anaerobic digesters. To date, he has published 25 journal articles, co-authored three books, filed three patents and presented papers at 21 conferences.

**Dr. Kamal Bansal** Professor and Dean, College of Engineering, University of Petroleum and Energy Studies (UPES) at Dehradun, India, has a career spanning more than 20 years, with extensive academic and industrial experience. He has been involved in managing the design, construction, testing and commissioning of a wide range of electrical control systems, machinery, equipment and substations.

Working as a consultant, he has contributed to several projects for Shell Global, Uttarakhand Renewable Energy Development Agency/Uttarakhand Jal Vidyut Nigam Ltd. (UREDA/UJVNL), the Ministry of New and Renewable Energy (MNRE), Confederation of Indian Industry (CII), Federation of Indian Chambers of Commerce and Industry (FICCI), Devika Consultants and MK Raju Consultants. He has been involved in a number of Clean Development Mechanism (CDM) projects for UREDA, Uttarakhand Power Corporation Limited (UPCL) and several other public and private organizations. Dr. Bansal has authored a number of research publications in journals of national and international repute.

# Health Assessment of Loktak Lake Using Diatoms as Biological Indicators

**Rachna Nautiyal and Prakash Nautiyal**

## 1 Introduction

Wetlands are precious freshwater resources. They are fragile ecosystems. A small change in the abiotic factors or composition of biotic can render them susceptible to damage. The large freshwater Loktak Lake is one such wetland, characterized by phumdis, the floating islands, which are the unique habitat of the endangered mammal, the brow-antlered deer popularly known as Sangai. Phumdis occur in sizes ranging from a few centimeters to about 2.5 m. This wetland is a Ramsar Site since 1990. The Keibul Lamjao National Park occupying an area of 40 sq km offers protection to the Sangai. The lake is shrinking due to soil erosion resulting from deforestation and shifting cultivation in the catchment [1]. The present study therefore proposes to determine the water quality vis-à-vis health of the Loktak Lake ecosystem. This will be useful in restoration efforts in order to maintain the benefits provided by this wetland. The results of this study will also provide a baseline data on the diatom flora and community, useful for comparing ecology of the lake in future. Diatom communities respond quickly and predictably to changes in water quality and are therefore employed as bio-indicators in aquatic monitoring programs in Europe, the USA, Canada, South America, and Australia [2–11].

R. Nautiyal (✉)
Zoology Department, Government P.G. College, Dakpathar,
Vikasnagar, Dehradun 248125, Uttarakhand, India
e-mail: rachnanautiyal@ymail.com

R. Nautiyal
RUSA Directorate, Uttarakhand Government, Dehradun 248001, Uttarakhand, India

P. Nautiyal
Department of Zoology and Biotechnology, H. N. B. Garhwal University
(A Central University), Srinagar, Uttarakhand, India
e-mail: lotic.biodiversity@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_1

## 2 Methodology

**Study Area**: Diatom samples were collected from the Loktak Lake at 24°30′37″ N to 93°47′08″ E and elevation of 772 masl. Substrate comprising small boulders, pebbles and cobbles, free-floating water hyacinth, partly decomposed roots and rhizomes, small twigs and grasses were sampled to record all possible species in the ecosystem. Epilithic diatoms were obtained from hard substrate by scraping $3 \times 3$ cm surfaces with the help of sharp razor and brush. The epiphytic diatoms were obtained by collecting sizeable portions of root, stem and leaves. Two replicates were obtained for each substrate and mixed to form one sample. The sample was preserved in 4% formalin. Diatoms were cleaned with the acid and $H_2O_2$. Permanent mount was prepared in Naphrax. Diatom species were identified at $\times 1500$ under bright field using NIKON 80i Trinocular Research Microscope and documented with DS-5M-LI digital camera. Diatom flora was recorded by identifying species, varieties, and forms using standard literature [12–17]. Species counts of 500 valves were made to determine relative abundance, species diversity, and evenness using Species Diversity and Richness software. The Van Dam, Hoffmann, Lange-Bertalot ecological values, and Leclercq Index were computed by OMNIDIA software.

## 3 Results and Discussion

The Loktak Lake is known as the lifeline of Manipur, owing to its socioeconomic and cultural values. A large number of fishermen depend directly on the lake resources for sustenance. Lake water is also used for generation of hydroelectric power by NHPC. A recent Union Planning Commission study stated that the habitat of the brow-antlered deer (*Cervus eldieldi,* locally called Sangai) has shrunk from 40 sq kms to only 6 sq kms today due to the Ithai Barrage commissioned in 1983. The bio-assessment of the water quality through diatom community to indicate the recent health of the Loktak Lake ecosystem thus becomes very important.

**Diatom flora**: The flora consisted of 115 species from 2 centrale and 39 pennale genera represented by 2 and 113 taxa, respectively (Appendix 1). Relatively more species of centric diatoms are known from lakes of Jammu & Kashmir [18, 19] and lentic waters from Gujarat [20]. Among the pennales, biraphid taxa constitute the bulk of the flora (86 taxa; 77%) while the araphid, monoraphid, and raphid species are few (26 taxa; 23%) as also evident from the other studies in India [13, 20–22] and also from outside of the Indian subcontinent [23–26]. The biraphid *Cymbella* and *Navicula* are the species-rich genera in the flora as observed not only in the above-said mountain waters but also from various parts of India [22, 27–29]. *Anomoeoneis styriaca* (Grun) Hustedt and *Brachysira vitrea* Ross are notable species in the flora that occur in Central Highland but not in the Himalayan waters [30].

**Diatom community**: The Loktak Lake shows remarkable variations in diatom community. In any community, usually some taxa attain >10% abundance but in this study no taxa attained 10% abundance attributed to high evenness in the community. Highest abundance was recorded for *Gomphonema parvulum* Kütz. (8.0%) which is an indicator of organically enriched waters and eutrophic state, as is good count of *Nitzschia palea* (Kütz) W. Smith also [31]. Other taxa figuring >5% category are *Gomphonema neonasutum* L-B & Reichardt, *Brachysira vitrea* (Grunow) Ross, and *Cocconeis placentula* Ehrenberg which are alkaliphilous and sensitive to very sensitive for pollution [31]. *B. vitrea* has rarely been recorded to gain more than 1% abundance in the natural waters and thus is notable for >5% abundance in this wetland. *Amphora veneta* Kütz and *Navicula cryptotenella* Lange-Bertalot are also indicators of the eutrophic state. The diatom taxa *Ulnaria ulna* (Nitzsch.) Compère indicate the presence of zinc and mercury hydragyrum in water. Also, diatoms such as *Navicula capitatoradiata* Germain, *Navicula cryptocephala* Kütz., *Navicula cryptotenella,* and *Nitzschia gracillis* Hantzsch are moderately tolerant forms [31]. The community appears to be highly diverse ($H = 5.63$) and even ($E = 0.82$) which could happen when a wide variety of nutrients are present in limiting amounts.

**Ecological values**: The examination of ecologic values shows considerable variations in the pH conditions. While majority of the community is represented by alkaliphilous and circumneutral forms, the alkalibiontic, acidobiontic, and acidophilus forms are notable because the last two categories have not been reported even from the organically enriched waters, e.g., Khanda Gad [32]. With respect to salinity conditions, 62.6% forms in the community belong to fresh-brackish state, a condition marked by presence of <500 mg/l chloride and salinity by <0.9%. Only 6.2% are freshwater diatoms (<100 mg/l chloride and <0.2% salinity). The presence of higher ecologic values even though meagerly indicates vicious conditions due to increasing salinity in the lake; 5.6% fresh-brackish diatoms (representing 500–1000 mg/l chloride and 0.9–1.8% salinity) and 3.3% brackish water diatom forms (1000–5000 mg/l chloride with 1.8–9.0% salinity).

For $N_2$ uptake metabolism, the lake was dominated by 28.8% $N_2$ autotrophic diatom taxa that tolerate elevated concentration of organically bound $N_2$. But then all other forms are also present in low numbers which support the above view that the ecosystem has degraded from the natural or semi-natural conditions. This statement receives support from fairly even distribution of diatom community in $O_2$ requirement categories (Table 1).

Like the above parameters, the saprobity values show presence of forms that prefer higher BOD and low $O_2$ saturation; 28.6% β-mesosaprobous (2–4 mg/l BOD and 70–85% $O_2$ saturation), 13.6% oligosaprobous (<2 mg/l BOD and >85% $O_2$ saturated), 11.9% α-mesosaprobous, and 10.6% α-mesopolysaprobous representing 4–13 and 13–22 mg/l BOD and 25–70% and 10–25% $O_2$ saturation, respectively, and 3.0% polysaprobous diatoms (>22 mg/l BOD and <10% $O_2$ saturation). All these categories are reflected in Hoffmann and Lange-Bertalot values. The trophic

**Table 1** Ecological characteristics of Loktak Lake based on analysis using OMNIDIA software

| N° PREP | Date | | Basin | | | Imphal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 02/28/2008 | | River/Site | | | Loktak/KLNP | | | | | |
| **Van Dam 1994** | | | | | | | | | | | |
| | 1 | 2 | 3 | | 4 | 5 | 6 | 7 | Dominant | | |
| pH | 0.3 | 1.4 | 26.5 | | 46.1 | 6.0 | 0 | | 4 | Alkaliphilous | |
| Salinity | 6.2 | 62.6 | 5.6 | | 3.3 | | | | 2 | Fresh brackish | |
| $N_2$ uptake | 21.4 | 28.8 | 9.4 | | 3.5 | | | | 2 | $N_2$ autotrophic taxa tolerating elevated concentrations of organically bound nitrogen | |
| $O_2$ requirements | 14.9 | 24.0 | 14.1 | | 11.3 | 1.4 | | | 2 | Fairly high | |
| Saprobity | 13.6 | 28.5 | 11.9 | | 10.6 | 3.0 | | | 2 | β-mésosaprobic | |
| Trophic state | 3.0 | 12.3 | 3.1 | | 6.8 | 39.1 | 3.1 | 3.9 | 5 | Eutraphentic | |
| Moisture | 5.0 | 31.2 | 27.8 | | 2.6 | 0 | | | 2 | Mainly occurring in water sometimes on wet places | |
| **Lange-Bertalot 1979** | | | | | | | | | | | |
| | 11.8 | 6.6 | 8.0 | | 0.3 | 8.0 | 3.7 | | 1 | Most pollution tolerant | |
| **Hofmann 1994** | | | | | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Dominant |
| Trophic state | 34.3 | 1.6 | 9.2 | 0.3 | 5.7 | 12.1 | 32.3 | 0.9 | 3.5 | | 6 Tolerant |
| Saprobity | 35.0 | 7.2 | 9.1 | 22.8 | 1.6 | 6.5 | 0 | 6.0 | 0.11 | 11.7 | 3 Mesosaprobe |

status clearly indicates high share of eutraphentic forms (39.1% nearly double of natural waters). There is a reasonable presence of oligo-mesotraphentic forms. Other categories though low in share were consistent in presence; oligo-eutraphentic, mesotraphentic, and hyper-eutraphentic and oligotraphentic as observed in Hoffmann values. Moisture preferences showed that 31.2% taxa were mainly occurring in water bodies, sometimes on wet place, 27.8% taxa were occurring in water bodies, also rather regularly on wet and moist places, 5.0% taxa were never or very rarely occurring outside water bodies, and 2.6% taxa were occurring on wet and moist or temporarily dry places. Leclercq Index shows very high degradation in the lake. Probably the barrage prevents flushing of nutrients accumulated from decaying phumdis causing perturbations in the bio-geochemical cycles. There were 16.5% diatom taxa that indicated organic pollution while 15.33% indicated anthropogenic eutrophication, indicating low levels as indicated by green color (Fig. 1).

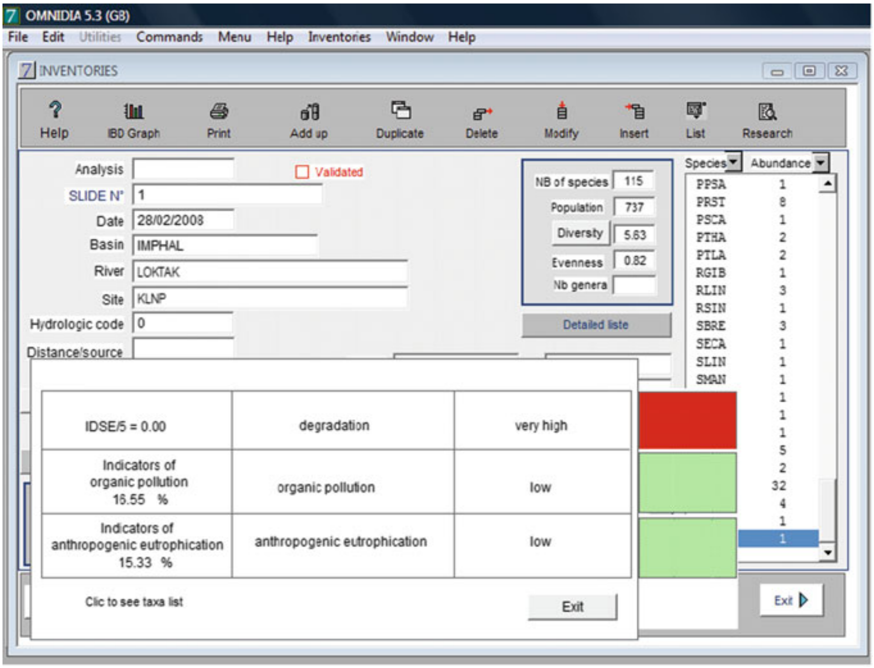



**Fig. 1** OMNIDIA software showing levels of degradation, organic pollution, and anthropogenic eutrophication in Loktak Lake

# 4 Conclusion

The freshwater Loktak Lake ecosystem exhibits perturbations in the nutrient regimes and hence the water chemistry. This is reflected in the flora (presence of salinity loving forms *A. styriaca* and *B. vitrea*) and the community (higher abundance of *G. parvulum* that prefers organically enriched waters). The Van Dam ecologic values also support this observation, as evident by the higher share of nitrogen autotrophic diatom taxa that tolerate elevated concentration of organically bound $N_2$, forms that prefer higher BOD, low $O_2$ and eutraphentic conditions. The Leclercq index shows low organic pollution, anthropogenic eutrophication and very high degradation. Lake restoration is the only solution to current state of the Loktak Lake ecosystem.

**Acknowledgements** The first author acknowledges academic institutional support from the Principal, Government P.G. College, Dakpathar, and the co-author is thankful to the Head, Department of Zoology & Biotechnology, H.N.B. Garhwal University, Srinagar, for extending all facilities during the present study.

# Appendix 1

Diatom flora of Loktak Lake

| **Pennales** | **C** |
|---|---|
| *Diatoma vulgaris* Bory morpho *producta* Gr. in VH | 4 |
| *Fragilaria rumpens* (Kützing) G.W.F. Carlson | 26 |
| *Tabellaria fenestrate* (Lyngbye) Kützing | 5 |
| *Ulnaria ulna* (Nitzsch) Compère | 1 |
| *U. u.* var. *aequalis* (Kützing) Aboal | 4 |
| *U. u.* var. *acus* (Kützing) Abol | 32 |
| *U. amphirhynchus* (Ehrenberg) Compere et Bukhtiyarova | 1 |
| *U. danica* (Kützing) Compere et Bukhtiyarova | 2 |
| *Achnanthes brevipes* Agardh | 1 |
| *Achnanthidium catenatum* (Bily& Mar.) Lange-Bertalot | 14 |
| *A. exigum* (Grunow) var. *heterovalvum* (Krasske) Czarnecki | 2 |
| *Achnanthes microcephala* (Kützing) Grunow | 1 |
| *A. minutissimum* (Kutzing) Czarnecki | 1 |
| *Cocconeis euglypta* Ehrenberg | 31 |
| *C. pediculus* Ehrenberg | 7 |
| *C. placentula* Ehrenberg | 40 |
| *Lemnicola hungarica* (Gr) Round & Basson | 1 |
| *Planothidium hauckianum* (Gr) Round & Bukhtiyarova | 2 |
| *P.lanceolatum* (Brebisson ex Kutzing) Lange-Bertalot | 2 |
| *P. rostratum* (Öestrup) Round & Bukhtiyarova | 8 |

(continued)

(continued)

| **Pennales** | **C** |
|---|---|
| *Rossithidium linearis* (W. Smith) Round & Bukhtiyarova | 3 |
| *Actinella guianensoides* Metzeltin & Lange-Bertalot | 1 |
| *Eunotia alpina* (Naegeli) Hustedt | 1 |
| *E. flexuosa* (Brebisson) Kützing | 1 |
| *E. pectinalis* (Dyllwyn) Rabenhorst | 1 |
| *E. monodon* Ehrenberg | 4 |
| *E. m.* var. *bidens* (Gregory) Hustedt | 1 |
| *Amphora libyca* Ehrenberg | 1 |
| *A. montana* Krasske | 2 |
| *A. pediculus* (Kützing) Grunow | 3 |
| *A. veneta* Kützing | 2 |
| *Amphipleura pellucida* Kützing | 1 |
| *Anomoeoneis styriaca* (Grunow) Hustedt | 1 |
| *Brachysira vitrea* (Grunow) Ross in Hartley | 40 |
| *Caloneis bacillum* (Grunow) Cleve | 1 |
| *Craticula accomoda* (Hustedt) D.G. Mann | 2 |
| *Craticula cuspidata* (Kützing) D.G. Mann | 1 |
| *Cymbella aspera* (Ehrenberg) H. Peragallo | 1 |
| *C. austriaca* Grunow | 1 |
| *C. excisa* Kützing | 10 |
| *C. gracilis* (Ehrenberg) Kützing | 1 |
| *C. hantzschiana* Krammer | 5 |
| *C. hustedtii* Krasske | 13 |
| *C. h.* var. *crassipunctata* Lange-Bertalot & Krammer | 7 |
| *C. mesiana* Cholnoky | 7 |
| *C. orientalis* Lee in Lee Gotoh & Chung | 1 |
| *C. perparva* Krammer | 1 |
| *C. parva* (W. Smith) Kirchner in Cohn | 1 |
| *C. pervarians* Krammer | 1 |
| *C. subleptoceros* Krammer | 11 |
| *C. subhelvetica* Krammer | 4 |
| *C. stigmaphora* Østrup | 5 |
| *C. tumida* (Brébisson) Van Heurck | 6 |
| *C. turgidula* Grunnow | 1 |
| *C. t.* var. *venezolana* Krammer | 1 |
| *Diadesmis confervacea* Kützing | 1 |
| *Diploneis elliptica* (Kützing) Cleve | 1 |
| *D. modica* Hustedt | 1 |
| *Encyonema minutum* (Hilse in Rabenhorst) D.G. Mann | 27 |
| *Epithemia sorex* Kützing | 3 |

(continued)

(continued)

| **Pennales** | **C** |
|---|---|
| *E. zebra* (Ehrenberg) Kützing | 10 |
| *Frustulia vulgaris* (Thwaite) De Toni | 2 |
| *Gomphonema affine* Kützing | 4 |
| *G. acuminatum* Ehrenberg | 18 |
| *G. neonasutum* Lange-Bertalot & Reichardt | 51 |
| *G. angustum* Agardh | 1 |
| *G. augur* Ehrenberg | 6 |
| *G. clevei* Fricke | 7 |
| *G. gracile* Ehrenberg | 2 |
| *G. olivaceum* (Hornemann) Brébisson | 1 |
| *G. parvulum* Kützing | 59 |
| *G. subtile* Ehrenberg | 1 |
| *G. truncatum* Ehrenberg | 1 |
| *Gyrosigma obtusatum* (Sullivan & Wormley) Boyer | 29 |
| *Hantzschia amphioxys* (Ehrenberg) Grunow | 5 |
| *Luticola goeppertiana* (Bleish in Rbenhorst) D.G. Mann | 2 |
| *Navicula capitatoradiata* Germain | 1 |
| *N. cryptocephala* Kützing | 10 |
| *N. cryptotenella* Lange-Bertalot | 9 |
| *N. krammerae* Lange-Bertalot | 1 |
| *N. upsaliensis* (Grunow) Peragallo | 1 |
| *N. phyllepta* Kützing | 20 |
| *N. radiosa* Kützing | 16 |
| *N. schroeteri* Meister | 16 |
| *N. rostellata* Kützing | 3 |
| *N. veneta* Kützing | 1 |
| *N. v.* var. *viridula* (Kützing) Ehrenberg | 4 |
| *N. v.* var. *v.* forma *linearis* (Hustedt) Kobayasi | 1 |
| *Neidium affine* (Ehrenberg) Piftzer | 1 |
| *N. ampliatum* (Ehrenberg) Krammer | 1 |
| *N. binodeforme* Krammer | 1 |
| *Nitzschia clausii* Hantzsch | 23 |
| *N. dissipata* (Kützing) Grunow | 1 |
| *N. dravellensis* Coste & Ricard | 1 |
| *N. frustulum* (Kützing) Grunow | 4 |
| *N. gracillis* Hantzsch | 2 |
| *N. hantzschiana* Rabenhorst | 12 |
| *N. obtusa* var.*scalpelliformis* Grunow | 1 |
| *N. palea* (Kützing) W. Smith | 20 |
| *Placoneis elliptica* (Hustedt) Ohtsuka | 1 |

(continued)

(continued)

| Pennales | C |
|---|---|
| *Pinnularia acrospheria* W. Smith | 1 |
| *P. braunii* (Grunow) Cleve | 1 |
| *P. subcapitata* Gregory | 1 |
| *Pleurosigma angulatum* (Quekett) W. Smith | 4 |
| *Reimeria sinuata* (Gregory) Kociolek & Stoermer | 1 |
| *Rhopalodia gibba* (Ehrenberg) O. Müller | 1 |
| *Sellaphora mantasoana* Metzeltin et Lange-Bertalot | 1 |
| *S. parapupula* Lange-Bertalot | 1 |
| *S. pupula* (Kützing) Mereschkowsky | 1 |
| *Stauroneis anceps* Ehrenberg | 1 |
| *S. phoenicenteron* (Nitzsch) Ehrenberg | 1 |
| *urirella capronii* Brebisson in Kitton | 3 |
| *S. linearis* W. Smith | 1 |
| **Centrales** | |
| *Cyclotella meneghiniana* Kützing | 8 |
| *Discostella stelligera* (Cleve at Grunow) Houk & Klee | 1 |

Acronym: C = Count

## References


1. LRIS: Catchment characterization of Loktak lake using remote sensing and GIS. Report published in Map Asia (2003)
2. Round, F.: Use of diatoms for monitoring rivers. In: Whitton, B., Rott, E., Friedrich, G. (eds.) Use of Algae for Monitoring Rivers, pp. 25–32. Proceedings of International Symposium, Institut fur Botanik, Universität of Innsbruck, Innsbruck Austria (1991)
3. Whitton, B., Rott, E., Friedrich, G. (eds.): Use of Algae for Monitoring Rivers, 193 pp. Institut fur Botanik, Universität of Innsbruck, Innsbruck Austria (1991)
4. Kelly, M.G., Whitton, B.A.: The Trophic diatom index: a new index for monitoring Eutrophication in Rivers. J. Appl. Phycol. 7, 433 (1995)
5. Whitton, B., Rott, E. (eds.): Use of algae for monitoring rivers II. In: Proceedings of the 2nd European Workshop, Innsbruck, 1995, 196 pp. Institut fur Botanik, University of Innsbruck, Innsbruck (1996)
6. Lowe, R.L., Pan, Y.: Benthic algal communities and biological monitors. In: Stevenson, R.J., Bothwell, M., Lowe, R.L. (eds.) Algal Ecology: Freshwater Benthic Ecosystems, pp. 705–39. Academic Press, San Diego, California, USA (1996)
7. Lobo, E.A., Callegaro, V.L.M., Hermany, G., Go’mez, N., Ector, L.: Review of the use of microalgae in South America for monitoring rivers, with special reference to diatoms. Vie Milieu-Life Environ. **54**, 105–114 (2004)
8. Poulíčková, A., Dokulil, M., Duchoslav, M.: Littoral diatom assemblages as bioindicators of lake trophic status: a case study from perialpine lakes in Austria. European J. Phycol. **39**, 143–152 (2004)

9. Csilla S.K., Buczko K., Hajnal E., Judit, P.: Epiphytic, littoral diatoms as bioindicators of shallow lake trophic status: trophic Diatom Index for Lakes (TDIL) developed in Hungary. Hydrobiologia, **589**, 141–154 (2007)
10. Juttner I., Chimonides P.J., Ormerod S.J.: Using diatoms as quality indicators for a newly-formed urban lake and its catchment. Environ. Monit. Assess. **162**, 47–65 (2009)
11. Szczepocka, S, Szczepocka E., Szulc B.: The use of benthic diatoms in estimating water quality of variously polluted rivers. Oceanol. Hydrobiol. Stud. **38**(1), 17–26 (2009)
12. Hustedt F., Jensen N.G.: The pennate diatom (a translation of Hustedt's Die kieselagen 2 Teil' with supplement by N G Jensen). Koeltz Scientific Books, Koenigstein (1985)
13. Sarode, P.T., Kamat N.D.: Freshwater diatoms of Maharashtra, 338 pp. Siakripa Prakashan Aurangabad, India (1984)
14. Krammer, K., Lange-Bertalot H.: Susswasser Flora von Mitteleurope, 2/1. Gutsav Fuscher Verlag, Stuttgart, New York (1986)
15. Lange Bertalot, H.: Iconographia Diatomologica, vol. 8. A. R. G. Gantner and Verlag K. G, FAL 94191 Ruggell. Koeltz Scientific Books, Koenigstein (1999)
16. Krammer, K.: Diatoms of Europe: Diatoms of European Inland waters and comparable habitats. In: Lange-Bertalot, H. (ed.). *The genus Cymbella*, vol. 3, 584 pp., 194 pl. A. R. G. Gantner and Verlag K. G, FAL 94191 Ruggell. Koeltz Scientific Books, Koenigstein (2002)
17. Lange Bertalot, H.: Iconographia Diatomologica, vol. 14. In: Gantner, A.R.G., Verlag, K.G. (eds.) Diatoms of North America (2005)
18. Kant, S., Vohra, S.: Algal flora of J & K State. J. Indian Bot. Soc. **78**, 51–64 (1999)
19. Khan, M.A.: Phycological studies in Kashmir I. In: Kumar, A. (ed.) Algal Biodiversity, pp. 69–93. APH Publishing Corporation, New Delhi (2000)
20. Gandhi, H.P.: Fresh water diatoms of central Gujarat with a review and some others, 313 pp. Bishen Pal Singh Mahendra Pal Singh, Dehradun (1998)
21. Verma, J. Nautiyal, P.: Floristic composition of the epilithic diatoms central highland region of Indian Subcontinent: Thalassiosiraceae, Fragilariaceae, Eunotiaceae and Achnanthaceaea. J. Indian Bot. Soc. **89**(3, 4), 397–400 (2010)
22. Karthick, B., Hamilton, P.B., Kociolek, J.P.: An illustrated guide to common diatoms of Peninsular India, 206 pp. Gubbi Labs, Gubbi (2013)
23. Kawecka, B.: Zonal distribution of algal communities in streams of the polish high Tatra Mts. Acta Hydrobiol. **13**, 393–414 (1971)
24. Kawecka, B.: Vertical distribution of algae communities in Maljovica stream (Rila-Bulgaria). Polskie Arch Hydrobiol. **22**, 371–420 (1974)
25. Ohtsuka, T.: Check list and illustration of diatoms in the Hii river. Diatom **18**, 23–56 (2002)
26. Iijima, T.: The diatoms in the River of Tenryu-gawa of Nagano Prefecture, Japan. Bull. Bot. Soc. Nagano **35**, 1–15 (2002)
27. Venkataramam, G.: A systematic account of some South Indian diatoms. Proc. Indian Acad. Sci. **10**, 293–368 (1939)
28. Krishna Murthy, V.: A contribution to the diatom flora of South India. J. Indian Bot. Soc. **33**, 354–381 (1954)
29. Suxena, M.R.: Algae from Kodaikanal Hill, South India. Bibliotheca Phycol. **66**, 43–99 (1983)
30. Verma, J., Nautiyal, P.: Lotic diatom diversity patterns in mountain chains (North India), 270 pp. Lambert Academic Publishing, Amazon Distribution GmbH, Leipzig (2011)
31. Xing, W., Binghui, Z., Lusan, L., Li, L.: Use of diatoms in River health assessment. Ann. Res. Rev. Biol. **4**(24), 4054–4074 (2014)
32. Nautiyal, P., Mishra, A.S.: Epilithic diatom assemblages in a mountain stream of the lesser Himalaya (India): longitudinal patterns. Int. J. Ecol. Environ. Sci. **39**(3), 171–185 (2013)

# Biogenic Synthesis of Silver Nanoparticles Using *Citrus Limon* Leaves and Its Structural Investigation

**Ravindra D. Kale and Priyanka Jagtap**

## 1 Introduction

In the recent years, researchers have shown enormous positive attention for metal nanoparticles. These nanoparticles have wide range of applications in various diverse fields like pharmaceuticals, textiles, agriculture, cosmetics. The prevalent nanoparticle synthesis methods pose hazardous risks to the environment. Hence, a green route for biosynthesis of nanoparticles using the reducing phytochemicals from plant sources is emerging as a reliable and environment-friendly method.

Silver nanoparticles are widely used in many industries because of their efficient antimicrobial property. They find applications in textile finishing and effluent treatment. [1]. Various leaf extracts have been reported to give stable *n* crystalline silver nanoparticles viz. geranium leaf extract, *Azadirachta indica*, fruit extract of *Embalica officinalis* [2], aloe vera, *capsicum annum* [3, 4], *Helianthus annus*, *Basellaalba*, *Oryza sativa*, *Saccharum officinarum*, *Sorghum bicolar*, *Zea mays* [5], fruit extract of *Carica papaya* [6], Persimmon and Magnolia plants [7], *Jatropha curcas* [8], Eucalyptus hybrid leaves [9] and Acalypha indica leaf extract [10].

The present research work is undertaken to synthesize nano-sized silver particles using *Citrus Limon* leaves. Response surface methodology was used for the optimization of the production parameters. The nanoparticles were analysed for morphology, particle size and crystallinity.

R. D. Kale (✉) · P. Jagtap
Department of Fibres and Textile Processing Technology,
Institute of Chemical Technology, Mumbai 400019, India
e-mail: rd.kale@ictmumbai.edu.in

P. Jagtap
e-mail: jagtappu92@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_2

# 2 The Experiment

## 2.1 Materials

Fresh, dark green leaves of *Citrus Limon* were collected from the campus of Institute of Chemical Technology, Mumbai. Silver nitrate $AgNO_3$ (Mol. Wt. 169.70 g) salt, sodium hydroxide, sulphuric acid, Glauber's salt and soda ash were purchased from S. D. Fine-Chem Ltd. (SDFCL, Mumbai). C. I. Reactive Blue 171 was kindly provided by Atul Industries Limited, Mumbai. The other reagents were obtained from the laboratory and were of analytical grade.

## 2.2 Methods

**Synthesis of Silver Nanoparticles**
100 ml of silver nitrate solution with 0.01 M was prepared in an Erlenmeyer flask using distilled water. Fresh *Citrus Limon* leaves which were harvested from the on-campus plants were thoroughly washed with distilled water, finely chopped and added to the salt solution. The solution was continuously stirred on a shaker bath machine (Rossari Labtech, Mumbai) at 70 rpm. To study the effect of temperature, pH and amount of the leaves used as reducing agent various experiments were carried out according to the Design of Experiment for two hours. To maintain the pH, sulphuric acid 0.1 N and sodium hydroxide 0.1 N solutions were used. The formation of nanoparticles was evident from the colour change of the solution. After complete reduction of the silver nitrate, the solution was filtered and stored in colloidal form for further analysis and application.

**Experimental Design for Optimization of Process Parameters**
In this study, the possible effect of parameters like temperature, pH and amount of the reducing agent on silver nanoparticles synthesis was analysed and optimized using the response surface methodology. A central composite design (CCD) was obtained for the three factors at their high and low levels, and the centre and axial points were replicated. The experimental design consisted of 20 experimental runs which included eight cube points, six central points and six axial points. After each experimental run, absorbance at the maximum wavelength was measured spectrophotometrically indicating synthesis of nanoparticles.

**Characterization of Silver Nanoparticles Synthesized Using Optimum Process Conditions**
UV–Visible spectral analysis was done (UV-1800 ENG 240 V, Shimadzu) in the wavelengths ranging from 200–800 nm with a resolution of 1 nm. Laser diffraction technique was used for particle size analysis in terms of particle size and particle size distribution (SALD 7500 nano, Shimadzu, Japan). Transmission electron microscopy was used to study the morphological characteristics (TEM Model 200

Supertwin STEM (Phillips make)). X-ray diffraction analysis for the crystalline nature, quality and crystallographic determination of the silver nanoparticles was carried out using X-ray diffractometer (Shimadzu XRD-6100). The infrared spectra of the reducing agent and the silver nanoparticles were recorded on FTIR instrument (FTIR 8400S, Shimadzu, Japan) in the range of 4000–400 $cm^{-1}$. The chemical composition of the biosynthesized nanoparticles was examined in the Na–U channel using EDAX (EDX-720, Shimadzu). The optical examination of the original *Citrus Limon* leaves and after synthesizing nanoparticles was done using Leica DM EP microscope attached with a camera system Leica DMC 2900.

**Decolourization of Textile Effluent with used *Citrus Limon* Leaves**

The nanoparticle-deposited leaves were used to decolourize the textile effluent. C.I. Reactive Blue 171 effluent stock solution of 0.1 gpl was prepared. The leaves were put in this solution, and the solution was continuously stirred on a magnetic stirrer for 60 min at room temperature. After 60 min, the absorbance of the solution was measured on UV–Vis spectrophotometer at λmax (620) nm and the percentage decolourization was calculated using Eq. 1.

$$\%\text{decolourization} = \frac{\text{Initial Concentration} - \text{Final Concentration}}{\text{Initial Concentration}} \times 100\ldots \quad (1)$$

# 3 Results and Discussion

## *3.1 ANOVA Analysis*

The results of the central composite design experimental runs are represented in Table 1. To calculate the optimal levels of the three process variables viz. temperature (A), pH (B) and amount of reducing agent (C), a second-order polynomial model was fit to determine the maximum nanoparticles synthesis and develop a relation between the response and the process variables. The maximum silver nanoparticles biosynthesis (absorbance 0.3725) was achieved in run six under the conditions of temperature 100 °C, pH 3 and 7.5 g of reducing agent.

$$\begin{aligned} \text{Absorbance} = & -0.40693 + 0.0189995 \times \boldsymbol{A} - 0.0049525 \times \boldsymbol{B} - 0.050922 \times \boldsymbol{C} \\ & + 0.00005.85 \times \boldsymbol{A} \times \boldsymbol{B} + 0.000264 \times \boldsymbol{A} \times \boldsymbol{C} - 0.00003 \times \boldsymbol{B} \\ & \times \boldsymbol{C} - 0.00012904 * \times (\boldsymbol{A})^\wedge 2 - 0.0001875 \times (\boldsymbol{B})^\wedge 2 \\ & + 0.00596 \times (\boldsymbol{C})^\wedge 2\ldots \end{aligned} \quad (2)$$

After applying multiple regression analysis, the determination coefficient value of $R^2 = 0.91138$ was obtained. The high $R^2$ value indicates good correlation between the predicted and the observed values. Hence in the present study,

**Table 1** CCD experimental run of trials with response for synthesis of silver nanoparticles using *Citrus Limon* leaves

| Run | Temperature (°C) | pH | Amount of reducing agent | Absorbance at 410 nm | |
|---|---|---|---|---|---|
| | | | | Experimental | Predicted |
| 1 | 75 | 5 | 5 | 0.31 | 0.27731 |
| 2 | 75 | 5 | 5 | 0.2708 | 0.27731 |
| 3 | 75 | 5 | 5 | 0.2296 | 0.27731 |
| 4 | 75 | 5 | 5 | 0.2793 | 0.27731 |
| 5 | 75 | 3 | 5 | 0.2973 | 0.28174 |
| 6 | 100 | 3 | 7.5 | 0.3725 | 0.354285 |
| 7 | 75 | 5 | 5 | 0.2592 | 0.27731 |
| 8 | 100 | 3 | 2.5 | 0.1677 | 0.179345 |
| 9 | 50 | 7 | 2.5 | 0.117 | 0.139485 |
| 10 | 100 | 5 | 5 | 0.2079 | 0.22806 |
| 11 | 75 | 5 | 5 | 0.2808 | 0.27731 |
| 12 | 75 | 5 | 7.5 | 0.3574 | 0.38538 |
| 13 | 50 | 7 | 7.5 | 0.2552 | 0.247825 |
| 14 | 75 | 7 | 5 | 0.2729 | 0.27138 |
| 15 | 100 | 7 | 2.5 | 0.1786 | 0.175135 |
| 16 | 100 | 7 | 7.5 | 0.3596 | 0.349475 |
| 17 | 50 | 3 | 2.5 | 0.141 | 0.155395 |
| 18 | 75 | 5 | 2.5 | 0.2888 | 0.24374 |
| 19 | 50 | 5 | 5 | 0.2025 | 0.16526 |
| 20 | 50 | 3 | 7.5 | 0.2566 | 0.264335 |

independent variables had 91.138% variability. Also, a highly significant model was fit which was indicated by the adjusted determination coefficient (Adj. $R^2_{abs}$ = 0.90401). ANOVA was employed to test the significance and adequacy of the model. F-values and p-values showed the significance of each coefficient which are listed in Table 2. The degree of significance shows that the linear and quadratic effects of A (temperature), B (pH) and C (amount of reducing agent) are significant, suggesting that the product production rate will be significantly altered with slight variation in these parameters. The interaction between studied variables and their optimal levels were determined using the response surface curves (shown in Fig. 1). This was done by fixing one of the variables at optimum value and allowing the others to be varied. Figure 1a shows that the interactive effect of the factors A and B is not significant on the synthesis of silver nanoparticles. The effect of pH is not very significant. Figure 1b shows that there is gradual increase of the silver nanoparticles biosynthesis with increasing the levels of temperature and the amount of reducing agent. The maximum silver nanoparticles yield was obtained at high temperatures. Figure 1c shows that higher levels of reducing agent amounts support high silver nanoparticles yield. Lower levels of pH and higher levels of amount of reducing agent lead to higher yields of the nanoparticles. The experimental and predicted results were in good agreement with accuracy of more than 95.08%,

**Table 2** Analysis of variance (ANOVA) for optimization of silver nanoparticles synthesis

| Source | Sum of squares | df | Mean square | *F*-value | p-value Prob > *F* | Confidence level |
|---|---|---|---|---|---|---|
| Model | 0.084162036 | 9 | 0.009351 | 9.359527 | 0.000833 | 99.9167 |
| A-Temperature | 0.0098596 | 1 | 0.00986 | 9.868235 | 0.010486 | 98.9514 |
| B-pH | 0.000268324 | 1 | 0.000268 | 0.268559 | 0.615572 | 38.4428 |
| C-Amount of reducing agent | 0.050154724 | 1 | 0.050155 | 50.19865 | 0.0000335 | 99.99665 |
| AB | 0.000068445 | 1 | 0.0000684 | 0.068505 | 0.798838 | 20.1162 |
| AC | 0.002178 | 1 | 0.002178 | 2.179907 | 0.170606 | 82.9394 |
| BC | 0.00000018 | 1 | 0.00000018 | 0.00018 | 0.989555 | 1.0445 |
| A^2 | 0.017887162 | 1 | 0.017887 | 17.90283 | 0.001741 | 99.8259 |
| B^2 | 0.00000154687 | 1 | 0.00000155 | 0.001548 | 0.969388 | 3.0612 |
| C^2 | 0.003815797 | 1 | 0.003816 | 3.819139 | 0.079187 | 92.0813 |

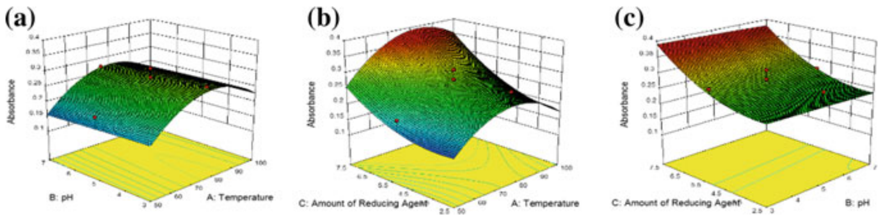



**Fig. 1** 3D response surface **a–c** showing the interactive effects of independent variables (temperature, pH and amount of reducing agent) on biosynthesis of silver nanoparticles using *Citrus Limon* leaves

thereby ensuring the validity of the model under the tested conditions. It was found that temperature of 95 °C, pH 3.2 and 7.5 g of reducing agent correspond to the optimal levels of the process variables for silver nanoparticles biosynthesis using *Citrus Limon* leaves.

## 3.2 *Characterization of Silver Nanoparticles*

The reduction of silver nitrate could be confirmed visually by observing the colour change of the solution, which changes colour from colourless to yellowish brown to reddish brown and finally to colloidal brown (Fig. 2a), indicating the formation of silver nanoparticles. The results are for biosynthesis of silver nanoparticles at 100 °C, pH 3 and with 7.5 g of reducing agent. It was observed that after 3 months of storage of the colloidal solution, the metal deposited on the inner surface of the storage container. This could be attributed to complete reduction of the metal into nanoparticles followed by agglomeration leading to conversion into metallic state.

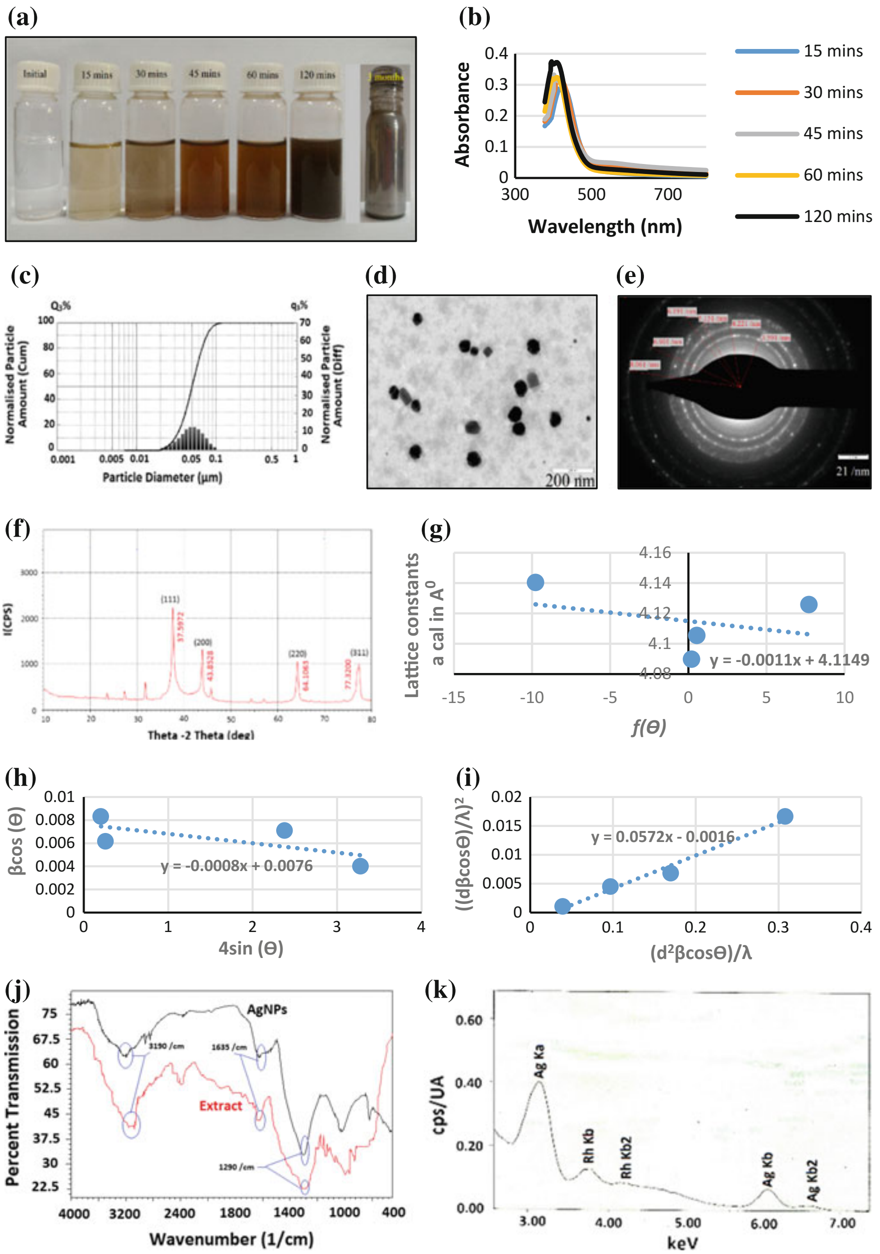



**Fig. 2** **a** optical observation of Ag nanoparticles **b** UV–Vis absorption spectrum **c** particle size of biosynthesized Ag nanoparticles **d** TEM image **e** SAED pattern **f** XRD pattern **g** Nelson–Riley plot **h** uniform deformation model (W–H) plot **i** size–strain plot **j** FTIR spectrum **k** EDX pattern

This form can find many applications such as silver-coated bottles for milk feeds for babies, storage of cosmetics. The dispersed colloidal silver can find many applications such as preparation of cosmetics, bath soaps, disinfectants, agricultural uses. Also, it can find many applications in textile to improve the functionality of the textile substrate such as to impart conductivity to the textile substrate, antibacterial effect, magnetic properties, optical properties. The nanoparticles in powdered form can be used for the decolourization of the textile effluents.

Figure 2b shows the UV–Vis absorption spectrum of Ag nanoparticles suspension synthesized using *Citrus Limon* leaves as a function of reaction time. As reported in the earlier studies [10], the presence of absorbance peak in the region of 420–440 nm proves the formation of Ag nanoparticles. The other process conditions were fixed as 100 °C temperature, pH 3 and 7.5 g of *Citrus Limon* leaves. It was observed that the λmax shifted from 425 to 422 nm with increasing reaction time from 15 to 30 min, and it centred at 422 nm for remaining samples.

Figure 2c shows the particle size distribution of the silver nanoparticles prepared by using *Citrus Limon* leaves. Silver nanoparticles with a mean particle size of 49 nm were obtained. The particle size analysis of the silver nanoparticles done by the laser diffraction technique shows median particle size of 49 nm, wherein 50% of the particles lie above 49 nm size and 50% of the particles lie below 49 nm size range. The modal particle size obtained by this analysis method was 56 nm, which represents the maximum value of the frequency distribution of the particles. 90% of the particles are below 76 nm size range, 50% of the particles are below 49 nm and 10% of the particles are below 30 nm range. The particles exhibit normal distribution with standard deviation of 0.153 nm which is significantly low. This shows the ability of the *Citrus Limon* leaves to act as a reducing agent in synthesizing Ag nanoparticles with narrow particle size distribution.

The morphology and size distribution of the synthesized silver nanoparticles were determined by TEM analysis. The TEM image in Fig. 2d shows that the particles were predominantly spherical with some particles of ellipsoidal shape. It also suggests that the particles ranged in size from 10 to 50 nm with an average diameter of 28 nm. The Ag particles were crystalline, as can be seen from the selected area electron diffraction (SAED) pattern, Fig. 2e recorded from one of the nanoparticles in the aggregate. SAED spots correspond to the different crystallographic planes of elemental silver.

Figure 2f shows the XRD pattern of Ag nanoparticles. Four distinct peaks are observed at 37.5972°, 43.8528°, 64.1063° and 77.32° with (111), (200), (220) and (311) Miller indices, respectively. These peaks correspond to Joint Committee on Powder Diffraction Standards (JCPDS), silver file No. 04-0783. It showed crystallinity of 36.69% which is also evident from the sharpness of the (111) peak. As compared to the diffraction angle of the bulk value ($2\Theta = 44.3$; JCPDS 04-0783), the (200) plane has modified marginally towards lower angle, leading to compressive stress in the various lattice crystals. Hence, these lead to dislocations of the crystals. The corrected lattice constant, average stress and dislocation density obtained were 0.41149 nm (Table 3; Fig. 2g), $0.795 \times 10^9$, $0.298 \times 10^{16}$ N/m$^2$, respectively. The peak narrowing is resulted from this residual stress which is

**Table 3** Structural parameters of biosynthesized Ag nanoparticles using *Citrus Limon* leaves

| Plane spacing $d$ (nm) | Crystallographic planes hkl | Bragg's diffraction angle 2Θ | Lattice constant $a_{cal}$ (nm) | Lattice constant $a_{corrected}$ (nm) |
|---|---|---|---|---|
| 0.239044 | 111 | 37.5972 | 0.4140364 | 0.41149 |
| 0.206285 | 200 | 43.8528 | 0.41257 | |
| 0.245146 | 220 | 64.1063 | 0.4105349 | |
| 0.123308 | 311 | 77.3200 | 0.4089664 | |

**Table 4** Particle size of Ag nanoparticle synthesized using *Citrus Limon* leaves calculated by different methods

| Crystallite size $D$ in nm | | | | |
|---|---|---|---|---|
| Debey–Scherrer formula | UDM method (W–H) plot | SSP plot | Laser diffraction method | TEM |
| 18.39 | 19.054 | 20.192 | 49 | 28 |

annotated from the UDM (Fig. 2h) and SSP (Fig. 2i) models [11]. The calculated crystallite size by the various methods was in good agreement with those obtained with the TEM and laser diffraction method (Table 4).

FTIR measurements helped in identifying the phytochemicals acting as reducing and capping agents. Figure 2j represents the FTIR spectrum of the colloidal silver nanoparticles and the leaf extract. It shows peaks at 3190, 2914, 2846, 1635, 1298, 1031 and 817 $cm^{-1}$.

The peak at 1635 $cm^{-1}$ is assigned to the amide I band of proteins released from the leaves which could possibly be the chlorophyll present in the leaves. During the degreening process, the chlorophyll is converted into number of tetrapyrroles which act as the reducing agent. The peaks 1290 and 1031 $cm^{-1}$ contribute to –CN stretching which could be possibly from amino acids or amines. It is well known that leaf extract contains large amounts of terpenoids, flavonoids, alkaloids and steroids. EDX spectroscopy analysis confirmed the presence of elemental silver by the signals (Fig. 2k) obtained in the range of 3–4 keV which is the typical absorption range of metallic silver nano-crystallites [10].

The microscopic images of the *Citrus Limon* leaves are shown in Fig. 3a, b. Because of the in situ extraction and synthesis of the nanoparticles, deposition of silver nanoparticles on the *Citrus Limon* leaves is observed. Textile effluents comprise of different dyes which make essential the use of prevailing techniques as well as to look for new techniques that can decolourize the dye mixtures. Use of metal nanoparticles for the decolourization process has been an effective way in the recent techniques employed. Efficient decolourization of the textile effluent has been observed with the use of Ni and Fe nanoparticles [12, 13]. In the present work, decolourization was attempted using nanoparticle-deposited leaves which showed decolourization efficiency of 91.07% (Fig. 3c). This could possibly be attributed to

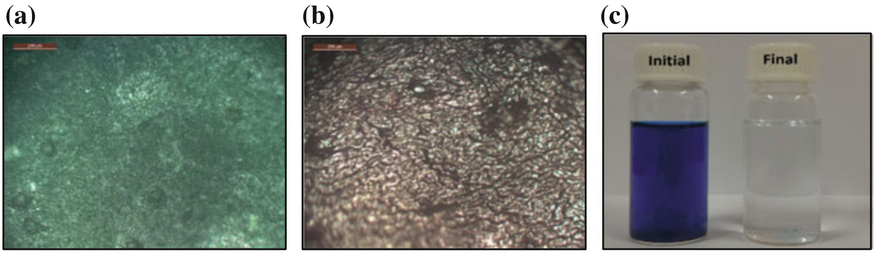



**Fig. 3** **a** microscopic images of *Citrus Limon* leaves **b** microscopic images of *Citrus Limon* leaves after use for synthesis of Ag nanoparticles **c** decolourization of C.I. Reactive Blue 171 using silver nanoparticle-deposited *Citrus Limon* leaves

the nanoparticles deposited on the leaves which help in breakdown of the dye molecules. Hence, these leaves can be used for the decolourization of the textile effluent.

## 4 Conclusion

In conclusion, we are introducing an efficient environment-friendly biological procedure to synthesize silver nanoparticles using Citrus Limon leaves. Significant model was fit for the metal salts using the response surface methodology of Design of Experiment, and all the process parameters play a vital role in the nanoparticle synthesis. The particle size results for the nanoparticles were in good agreement with the results obtained by W–H plot and SSP method. XRD study revealed significant crystallinity of the nanoparticles. Spherical- to elliptical-shaped nanoparticles were obtained. Hence, it can be concluded that *Citrus Limon* leaves can be used for the synthesis of the well-dispersed nanoparticles without agglomeration. Also, the nanoparticle-deposited Citrus Limon leaves can be used in the decolouration of textile effluent which showed decoration efficiency of 91.07%.

**Acknowledgements** Authors would like to acknowledge FIST–DST project, Govt. of India, and World Bank funded TEQIP-II for providing the machineries for this research project.

## References

1. Jiang, H., Manolache, S., Wong, A.C.L., Denes, F.S.: Plasma-enhanced deposition of silver nanoparticles onto polymer and metal surfaces for the generation of antimicrobial characteristics. J. Appl. Polym. Sci. **93**(3), 1411–1422 (2004)
2. Shankar, S.S., Rai, A., Ahmad, A., Sastry, M.: Rapid synthesis of Au, Ag, and bimetallic Au core—Ag shell nanoparticles using neem (*Azadirachta indica*) leaf broth. J. Colloid Interface Sci. **275**(2), 496–502 (2004a)

3. Chandran, S.P., Chaudhary, M., Pasricha, R., Ahmad, A., Sastry, M.: Synthesis of gold nanotriangles and silver nanoparticles using Aloe vera plant extract. Biotechnol. Prog. **22**(2), 577–583 (2006)
4. Li, S., Shen, Y. Xie., A. Yu, X., Qiu, L., Zhang, L., Zhang, Q.: Green synthesis of silver nanoparticles using capsicum annum L. extract. Green Chem. **9**(8), 852–858 (2007)
5. Leela, A., Vivekanandan, M.: Tapping the unexploited plant resources for the synthesis of silver nanoparticles. Afr. J. Biotechnol. **7**(17), 3162–3165 (2008)
6. Jain, N., Bhargava, A., Majumdar, S., Panwar, J.: Extracellular biosynthesis and characterization of silver nanoparticles using *Aspergillus flavus* NJP08: a mechanism prospective. Nanoscale **3**(2), 635–641 (2011)
7. Begum, N.A., Mondal, S., Basu, S., Laskar, R.A., Mandal, D.: Biogenic synthesis of Au and Ag nanoparticles using aqueous solution of black tea leaf extracts. Colloids Surf B **71**(1), 113–118 (2009)
8. Bar, H., Bhui, D.K., Sahoo, G.P., Sarkar, P., Pyne, S., Misra, A.: Green synthesis of silver nanoparticles using seed extract of Jatropha curcas. Colloids Surf A **348**(1), 212–216 (2009)
9. Dubey, M., Bhadauria, S., Kushwah, B.S.: Green synthesis of nanosilver particles from extract of Eucalyptus hybrida (Safeda) leaf. Dig. J. Nanomaterials Biostructures **4**(3), 537–543 (2009)
10. El-Naggar, N.E., Abdelwahed, N.A.M., Darwesh, O.M.M.: Fabrication of biogenic antimicrobial silver nanoparticles by streptomyces aegyptia NEAE 102 as eco-friendly nanofactory. J. Microbiol. Biotechnol. **24**(4), 453–464 (2014). http://dx.doi.org/10.4014/jmb.1310.10095
11. Prabhu, Y.T., Rao, K.V., Sai, V.S., Pavani, T.: A facile biosynthesis of copper nanoparticles: a micro-structural and antibacterial activity investigation. J. Saudi Chem. Soc. (2015). http://dx.doi.org/10.1016/j.jscs.2015.04.002
12. Kale, R., Kane, P.: Colour removal using nanoparticles. Text. Clothing Sustain. **2**(1), 1–7 (2016)
13. Kale, R., Kane, P., Phulaware, N.: Decolourization of C. I. reactive black 5 by PVP stabilized nickel nanoparticles. Int. J. Eng. Sci. Innovative Technol. **3**(2) (2014)

# Effectuation of Renewable Energy as an Effective Mitigation Approach Towards Climate Change

**Jaideep Saraswat, Varima Agarwal and Mainak Mukherjee**

## 1 Introduction

Energy has always been a part and parcel of human existence. The need of energy is never diminishing. Today, we require energy for manufacturing, mining and building, transportation, etc. Maximum energy obtained today is by combustion of fossil fuels. However, it comes with its own disadvantages. These are non-renewable energy sources which mean that they cannot be replenished at the same rate as they are consumed today. The reserve by production ratio of these fossil fuels is not enough to serve our coming generations. Furthermore, combustion of these fossil fuels release large amount of greenhouse gases in the atmosphere.

Greenhouse gases are those gases which are responsible for greenhouse effect. Greenhouse effect is a natural phenomenon in which the radiation coming from sun is initially absorbed by land and water masses. Later on, while cooling these masses emit infrared thermal radiations which are trapped by certain gases called greenhouse gases. This trapping of heat keeps our atmosphere warm enough for our survival. As per NASA, if there was no greenhouse effect, then the temperature of earth would have been 18 °C [1].

J. Saraswat · V. Agarwal
Renewable Energy Engineering, University of Petroleum & Energy Studies, Dehradun, India
e-mail: jaideepleo31@gmail.com

V. Agarwal
e-mail: varima1411@gmail.com

M. Mukherjee (✉)
Department of Electrical Power & Energy, University of Petroleum & Energy Studies, Dehradun, India
e-mail: mmukherjee@ddn.upes.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_3

Whenever we are talking about GHG emission, we tend to rely mostly on carbon dioxide. The reason lies in the fact that carbon dioxide gets accumulated in the biosphere, whereas gases like methane are transient greenhouse gases. They tend to breakdown after a certain passage of time.

The problem lies in the fact that there has been an increase in greenhouse effect in the last century. Since 1880, earth's temperature has increased by a factor of 1.7 °F [2]. This increase can be attributed to natural and human activities. Natural activities causing climate change are change in the earth's orbit, volcanic eruptions (500 million tonnes of $CO_2$ release every year), tectonic movement of plates, etc. However, these are the activities over which we have little or no control. Our matter of concern is human activities like combustion of fossil fuels for transportation, power generation and the increment of emission due to fossil burning directly impacts health in ways more than one. Additionally enhancing environmental degradation leading to stroms, droughts, photochemical smog, forest fires.

Renewable energy can provide a befitting solution to this problem. It is the energy obtained from natural sources which are abundant in the environment, i.e. wind, solar. It is called a clean energy as during its lifetime it releases a lesser or no amount of carbon emissions. Broad divisions of renewable energy are shown in Fig. 1.

India has committed in Intended Nationally Determined Contributions under COP 21 of United Nations Framework Convention on Climate Change, and it will reduce its greenhouse gas emissions by 33–35% by the year 2030 as compared to 2005 levels. This can only be realized when its energy-intensive sectors be it government or privately owned cut down their emission levels. Therefore, an understanding of their current scenario and futuristic approach will give us a clear idea about the numbers we will be able to realize.

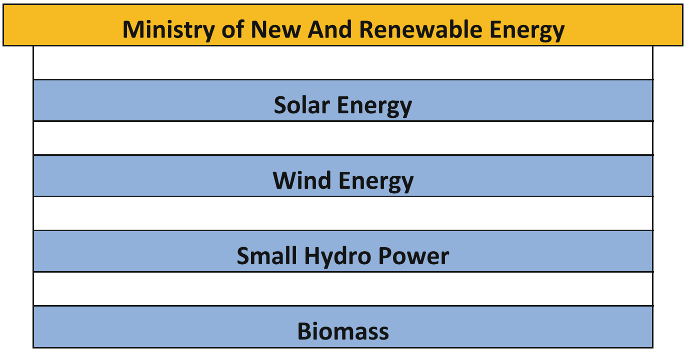



**Fig. 1** Areas under MNRE

## 2 Present Scenarios

Economic growth of any nation depends upon the incessant supply of energy to various sectors like agriculture, transport, commercial, industrial. Energy and economic growth follow a linear relationship.

India is an energy consumer nation rather than energy producer. Though India has about 7% of total world reserves of coal, it has a deficit of fossil fuels like natural gas, crude oil. The production rate of coal is not able to cope with the rate of consumption which has led to the import of coal from countries like Indonesia, Australia, and South Africa. By 2020, it is assumed that India will be importing about 92% of crude oil from countries like Russia and Saudi Arabia to meet its demand. India lacks infrastructural developments in the field of natural gas. India is strategically located in close proximity to countries like Iran, Russia, and Saudi Arabia having largest natural gas reserves in the world.

Currently, India faces ginormous hurdles in the path to meet its energy requirements. India's per capita energy consumption is 565 kg oil equivalent (kgoe) per year. World average energy consumption per capita is 1700 Kgoe per year. Table 1 lists the per capita energy consumption of various developed and developing countries. The fossil fuels have low reserve to production ratio as well which means in coming future we have to rely on alternate sources of energy.

The combustion of fossil fuels is leading to myriad problems and ultimately to climate change. Increased emission of greenhouse gases in atmosphere is a result of the above-mentioned activities. Out of all the sectors, energy sector in India is responsible for highest GHG emissions every year. This has led to an increase in average temperature of the earth as well as changes in the annual average rainfall.

Therefore a major switch to renewable energy is under consideration. Table 2 depicts current status of renewable energy in India.

**Table 1** Per capita energy consumption of selected countries

| S. No. | Country | Per capita energy consumption (kgoe per year) |
|---|---|---|
| 1 | Canada | 7379.6 |
| 2 | United States of America | 7164.5 |
| 3 | Saudi Arabia | 6167.9 |
| 4 | Russia | 4943.1 |
| 5 | France | 4030.5 |
| 6 | Germany | 4003.3 |
| 7 | China | 1806.8 |
| 8 | India | 565.6 |

**Table 2** Installed grid renewable power capacity of India as on 31 July 2016 [3]

| S. No. | Type | Current capacity (MW) | Current capacity (%) |
|---|---|---|---|
| 1 | Wind energy | 27441.15 | 61.3 |
| 2 | Solar energy | 8062 | 18 |
| 3 | Small hydro power | 4860.83 | 10.9 |
| 4 | Biomass | 4304.27 | 9.6 |
| 5 | Waste-to-power | 115.08 | 0.3 |

# 3 Sectorial Enforcements

See Table 3.

**Table 3** Current and future prospect of different sectors [4, 5]

| S. No. | Areas | Current scenario | Future | Impact |
|---|---|---|---|---|
| 1 | **Power—coal-based thermal power plant** | Usage of coal as fuel to generate heat | Integration of solar energy to the boiler to increase its efficiency | 1. Reduction in emission with usage of cleaner technology<br>2. Saving of fuel, i.e. coal by increasing the temperature of water fed into the boiler drum |
| 2 | **Railways** | Intensive usage of coal, diesel, and electricity | 1. Rooftop solar PV based to be introduced shortly<br>2. Solar energy-powered coaches<br>3. Installation of solar water heaters to meet the requirement<br>4. Biodiesel-based engines | 1. Able to meet 10% of energy needs via renewable energy by 2020<br>2. Lead to reduction in diesel consumption up to 90,000 l/year and $CO_2$ emission down by 200 tonnes |
| 3 | **Steel manufacturing plant** | 5% of total $CO_2$ emissions | 1. Increased use of non-pulverized coal<br>2. Using biomass for steel making | Saving of energy as well as fuel, i.e. metallurgical coal |
| 4 | **Cement manufacturing plant** | 1. Highly energy-intensive<br>2. Installed capacity—260 million tons as on 31st March 2010 | 1. Usage of alternative fuels like pet coal, biomass<br>2. Solar energy can be used for heating boiler feed water<br>3. Utilization of high-temperature heat to upgrade low carboniferous feedstock to produce high-quality synthetic gas | 1. Mitigation of $CO_2$ emissions<br>2. Development of sustainable technology |

## 4 Government Initiatives and Policies

Government of India has taken a plethora of initiatives to adapt as well as mitigate the climate change. Adaptation and mitigation though sound alike but are very different in their respective ways. Adaptation since being a localized effort implies changes undertaken by the local community to diminish the impact of climate change. Mitigation, on the other hand, being a globalized effort implies changes undertaken by a local community to sabotage the cause of climate change (Tables 4 and 5).

**Table 4** Government initiatives and policies [6, 7]

| S. No. | Initiatives/policies | Objective | Impact |
|---|---|---|---|
| 1 | Policy for repowering of the wind projects | To upgrade framework for repowering of wind projects | 1. Meeting energy demand<br>2. Less $CO_2$ emission |
| 2 | Generation-based incentives for grid interactive wind power project | Fabricated to finance loan to GBI claim payable to renewable energy developers | Ebullient participation of renewable energy developer |
| 3 | Generation-based incentives for solar rooftop PV and small power generation programme | Fabricated to finance loan to GBI claim payable to renewable energy developers | Ebullient participation of renewable energy developer |
| 4 | Jawaharlal Nehru National Solar Mission | To achieve 100 GW of solar power by 2022 | 1. Enhanced energy security<br>2. Less $CO_2$ emission in atmosphere |
| 5 | RE-INVEST—renewable energy investors meet and expo | To achieve target of 175 GW by 2022 | Attracting investors from around the globe to invest in renewable opportunities in India |
| 6 | International solar alliance | To increase solar energy utilization as well as application | Innovation of new technologies in the field of solar and enhanced coordination on a common platform |
| 7 | Eightfold increase in clean environment cess on coal—carbon tax | To encourage masses to opt for energy-efficient technology | Reduction in $CO_2$ emission in atmosphere |
| 8 | Increase in state-specific renewable purchase obligation | To establish India as a global leader in solar energy | 1. Energy security<br>2. Less $CO_2$ emission |

**Table 5** Emission from various sources [8]

| S. No. | Types | Tons $CO_2$ e/GWH | | |
|---|---|---|---|---|
| | | Mean | Low | High |
| 1 | Coal | 888 | 756 | 1310 |
| 2 | Oil | 733 | 547 | 935 |
| 3 | Natural gas | 499 | 362 | 891 |
| 4 | Biomass | 45 | 10 | 101 |
| 5 | Solar PV | 85 | 13 | 731 |
| 6 | Nuclear | 29 | 2 | 130 |
| 7 | Hydroelectric | 26 | 2 | 237 |
| 8 | Wind | 26 | 6 | 124 |

## 5 Discussion

Human activities, leading to anthropogenic emissions impacts the climate directly. These climatic changes in return impacts on human health advertently. Without understanding the causes of climate change, it is impossible to make accurate projection for future. This paper provides an overall analysis of highly energy-intensive sectors in India and their impact on the climate. Furthermore, it outlines government's initiatives and policies to curb the emissions released in the atmosphere and to meet its greenhouse gas reduction targets globally.

Presently, India is moving towards development at a myriad pace. There is rapid growth in economy and hence in the demand of energy and standard of living. It needs to set up more power plants and wider transport infrastructure to meet this increase in demand.

Coal-based thermal power plants are majorly responsible for emissions as compared to other power plants. Coal is used as a fuel to convert water into steam. Steam rotates the turbine which is linked to the generator, and the electricity is produced. The gases emitted after coal combustion are carbon dioxide, nitrogen dioxide, sulphur dioxide, etc. This emission of gases to the atmosphere is the major point of concern. Implementation of electrostatic precipitators, integration of solar energy with the boiler by providing raised temperature water to the boiler drum, and energy-efficient equipment will minimize the emissions to a satisfactory level.

Railways are the lifeline of India. It is impossible for a country to grow without expanding their transport infrastructure. With its expansion will come more demand of fossil fuels and more emissions in the atmosphere. Indian railways are taking major renewable steps to reduce their dependency on fossil fuels and to become more energy efficient. Renewable energy-powered stations, solar energy-powered coaches, and biomass-powered engines are a few of the steps Indian railways are adamant to implement in the near future.

Steel and cement manufacturing industries are highly energy-intensive industries. They are front runners of greenhouse gas emissions which is evident from their excessive dependence on fossil fuels. Their attempts to shift to renewable energy and energy-efficient technology will not only lessen carbon footprints in the atmosphere but also provide them energy security in the future.

Government initiatives and policies have given a huge boost to the above-mentioned sectors. The efforts are twofold. Firstly, it provides financial aid in the form of subsidies to all opting for renewable energy. Secondly, it has set up research and development centres across India for innovation in renewable energy and its applications. Apart from local initiatives, India has become a part of global programmes like international solar alliance. RE-INVEST is also an important event to showcase India's renewable energy potential and to invite investors from across the globe to invest in India.

Finally, the concept of comparison of life cycle for various forms of energy comes into picture. Hence, the definition of life cycle gains immense importance. Some include waste management and treatment in scope, while others do not. The data in the table are excluding the same. It is also evident that with the advancement in technology this proportion of emission from waste management will reduce.

## 6 Conclusion

India and many other countries have confirmed internationally for reduction in emissions of greenhouse gases. Similarly, India has to maintain the rate of economic growth. Hence, the problem posed in front of India is a dual problem comprising of energy growth and environmental conservation. India has to switch to renewable energy to address these problems simultaneously.

It is also evident that excessive greenhouse effect can destabilize the earth's climate. Reduction in emissions should be considered of highest priority to mitigate climate change. There is no single bullet solution to this problem. There is a portfolio of solutions that should be incorporated to achieve desired results.

## References

1. National Aeronautics and Space Association: Earth observatory. Available at: http://m.earthobservatory.nasa.gov/Features/GlobalWarming/page2.php
2. Adger, W.N., Huq, S., Brown, K., Conway, D., Hulme, M.: Adaptation to climate change in the developing world. Prog. Dev. Stud. **3**(3), 179–195 (2003)
3. Kumar, A., Kumar, K., Kaushik, N., Sharma, S., Mishra, S.: Renewable energy in India: current status and future potentials. Renew. Sustain. Energy Rev. **14**(8), 2434–2442 (2010)
4. Indian Power Industry's—Major challenges and future scope, published on 31 Jan 2013
5. Ghosh, S., PratimSengupta, P., Maity, B.: Evidence on the future prospects of Indian Thermal Power Sector in the perspective of depleting coal reserve. Glob. J. Bus. Res. **6**(1), 78–79 (2012)
6. Ministry of New and Renewable Energy: National Solar Mission. Available at: http://www.mnre.gov.in/solar-mission/jnnsm/introduction-2/

7. Ministry of New and Renewable Energy: Schemes of Solar Energy. Available at: https://india.gov.in/schemes-solar-energy-ministry-new-and-renewable-energy
8. Comparison of Lifecycle GHG Emission electricity generation sources. Available at: http://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/comparison_of_lifecycle.pdf

# Energy Efficiency Measures Across Key Sectors in India—An Approach Towards Climate Change

**Ajay Nahar, Anam Hasib, Gerry George and Mainak Mukherjee**

## 1 Introduction

Climate change, a grievous global environmental concern, is not a newly encountered phenomenon. In fact, in past few million years, Earth has had seven glacial advances and retreats. What makes the recent global climate change harmful are the anthropogenic causes [1] behind it, and effects of this global change in system dynamics are rise in temperature, ozone ($O_3$) layer depletion, acid rain, rise in sea level, draughts, and floods. Global warming, a significant part of global climate change, is caused by accumulation of green house gases in atmosphere, and it results in the increase in temperature of Earth's atmosphere. Methane and nitrous oxide concentrations, in atmosphere, are increasing due to agricultural activities. The concentration of carbon dioxide—one of the main green house gases—in atmosphere is stimulated by burning of conventional fuels and land use alteration. In 2013, activities involving fossil fuel combustion released 32190 million tonnes of carbon dioxide, on a global scale.

India, a developing country, has fifth largest electricity generation capacity, sixth largest energy consumption, and per capita energy consumption up to 1010 KWh. There is a continuous increase in energy demand, and it is met by renewable and non-renewable energy resources. With renewable sector contributing 28% and the rest coming under non-renewable power generation sector, in India, coal-based power generation comprises 61% of the total installed capacity, and it is responsible for huge amount of carbon dioxide emissions. COP-21 (Conference Of Parties)

A. Nahar · A. Hasib · G. George
Energy Systems, University of Petroleum & Energy Studies, Dehradun, India

M. Mukherjee (✉)
Department of Electrical Power & Energy (EPE), University of Petroleum & Energy Studies, Dehradun, India
e-mail: mmukherjee@ddn.upes.ac.in

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_4

report shows that, approximately, 1348 million tonnes of $CO_2$ (1.49MT $CO_2$/capita) has been emitted into atmosphere by Indian coal-based industries in 2013 [2].

Efforts to reduce carbon dioxide emissions have been muffled by growing population in India, which, as a result, increases the energy demand and hence leads to an increased burning of fossil fuels, deforestation, etc. [3]. Although renewable energy is a promising sector, the high cost involved and poor quality attained make it a secondary option, unlike cheap fossil fuels. This current helplessness calls for mitigation and conservational steps, and these steps can be applied to energy utilization.

Talking about mitigation, energy efficiency and energy conservation are climate change mitigation techniques. Energy efficiency ensures lesser consumption of energy for the same output [4]. By optimizing the system's behaviour and enabling it to consume less energy, energy efficiency techniques can be implemented at generation as well as at utilization level. Energy conservation refers to the reduction of energy consumption by reduced usage of energy services. Both energy efficiency techniques and energy conservation measures have significantly proved their ability to reduce carbon dioxide emissions. Moreover, mitigation includes usage of new energy-efficient and renewable technologies; protection of natural carbon sinks like forests and oceans, and if possible, then creating new sinks; and improvement of management practices and consumer behaviour [5].

In order to make existing energy consuming domains in India more productive and eco-friendly, some important steps should be brought under practise, and these include: identifying various organizations in India and categorizing them into large, medium, and small-scale industries; reviewing sustainability reports, Corporate Social Responsibility (CSR) reports, and annual reports; extensive search over various web portals which are available in public domain and assimilation of data relevant to climate change mitigation initiatives in a common database; and highlighting key initiatives (initiatives as per governmental schemes, international mechanisms, and certain commitments made by organization) taken on behalf of the organization.

Optimizing energy utilization is the go-to technique for reducing GHG emissions. There are numerous national (governmental and non-governmental schemes) and international projects which have been adopted in India for energy savings in industries, and they aim to reduce GHG emissions. Following is the description of energy efficiency techniques and energy conservation measures adopted by some Indian designated consumers and various industries.

## 2 Sectorial Enforcements

Table 1 summarizes various sectorial reforms that are aimed at reducing the emissions from these sectors.

**Table 1** Sector-wise climate change initiatives to reduce greenhouse emissions and control discharge of pollutants

| Key sectors | Climate change initiatives |
|---|---|
| Power | • Different environmental studies at various stations initiated on a weekly basis<br>• Usage of efficient low Nox burners mitigating lesser emissions to existing furnaces and boilers<br>• Implementation of ash dryers and disposals for proper waste management and disposal with transport facility<br>• Replacement of sodium vapour lamps with LED lamps emphasizing of lighting system, an integral part of energy audit<br>• Using VFDs for industrial pumps, ID/FD fans, and industrial blowers<br>• Electrostatic precipitators installation in power plants for enhanced emission control<br>• Improving combustion efficiency by ensuring full combustion and proper fuel mixture<br>• Sewage treatment plant for recycle and reduce dependency on water |
| Iron & steel | • Energy efficiency through slag heat recovery, blast furnace gas recycle<br>• Energy saving by insulation of furnace, hot charging<br>• Using of regenerative burners for lean gas at hot strip mill<br>• Energy-efficient techniques such as coke dry quenching, recovery of flue gas (waste heat) implemented<br>• Use of blast furnace gas (waste heat recovery) as replacement for fuel oil (FO)<br>• Using light diesel oil (LDO) compliments emission control<br>• Energy efficiency techniques by slag heat recovery for saving energy and reutilizing the heat<br>• Preventive maintenance and chalking out energy-saving plans to control activities like combustion and emission |
| Oil & gas | • Emphasizing on energy auditing, carbon and water foot printing<br>• Promoting carbon neutral events |
| Automobile | • Conversion of paint shop in workshops air supply unit(s) (ASU) and incinerator from propane to LNG<br>• Using LED lights replacing them with conventional tubes<br>• IGBC certified green building<br>• Ensuring proper part functioning and HVAC system efficiency<br>• Installation of vapour absorption machine (VAM) on gas engines for higher efficiency<br>• Emphasizes on replacing normal tubes with LED lightings as an energy-saving initiative<br>• Adopting techniques in installation of waste heat recovery for paint baking oven<br>• Development in electric traction technology enhancing energy-saving options |
| Cement | • Plan to achieve higher thermal substitution rate<br>• To increase the percentage share of renewable energy capacity up to 9%<br>• Waste heat recovery power generation units<br>• Energy conservations followed are close moving of cement mills, fuel mix optimization, and increase in AFR conserving fossil fuels |

(continued)

**Table 1** (continued)

| Key sectors | Climate change initiatives |
|---|---|
| Pharmaceuticals | • Energy conservation projects and current production without using hazardous dichloromethane, acetone, and acetonitrile<br>• Implementation of environmental policy (as part of ISO 14001) across all manufacturing site<br>• Waste reduction at source<br>• Water and energy audits<br>• Boiler fuel conversion from RFO to biomass-based briquettes for lesser emission<br>• Water and energy audits |
| Chemical | • Promotion of awareness in terms of environment impact<br>• Launching of large waterproofing group (LWG)<br>• Energy efficiency efforts in urea production plant, using of salt pans solid waste facility, Lupa bulkers usage<br>• Cogeneration plant for waste heat generation<br>• Water and chemical storage facilities waste heat recovery |
| Hospitality | • A total of 38% ITC power consumption is renewable based, with a target of 50% + in next 5 years<br>• All ITC hotels are LEED certified<br>• Specific hotels percentage of renewable energy usage was 6.91% of total energy use in 2013–14 |
| Heavy engineering | • Usage of recycled water from effluent treatment plant for maintenance of greenery in the plant<br>• Central Gauging Centre—replace present condenser pump with energy-efficient pump<br>• Improve AHU air delivery and replace with energy-efficient system at coil winding section in shops<br>• Improving operational efficiency of cranes by introduction of variable frequency drives in cranes<br>• Revamping of solid state induction heating unit in place of conventional motor–generator set in induction pressure welder machine |
| Construction | • Energy-efficient techniques followed are by providing insulation the external walls of building<br>• Ensuring reduction in energy consumption by implementing automatic switching off lights in unoccupied areas by deploying sensors<br>• Efforts for continuous improvement of the environment sustainability performance of end products by analyzing their life cycle (such as using energy-efficient lighting and HVAC systems, using feasible renewable energy sources, treatment and recycling of wastewater, harvesting rainwater)<br>• Certain ongoing construction projects are equipped with alternate sources of energy. Alternate sources are arranged by utilizing hybrid power systems comprising of wind mill and solar panels which are installed and integrated in the electrical distribution system to ensure that there is minimal wastage |
| Coal mining | • Installation of LV distribution lines with insulated wire to prevent hooking and thereby saving energy<br>• Overhead water tanks in residential/non-residential buildings fitted with float valves<br>• Researching ways to capture methane by adsorption techniques |

(continued)

**Table 1** (continued)

| Key sectors | Climate change initiatives |
|---|---|
| | • Ensuring availability of voltage to the loads/machineries for achieving better efficiency and rated output as well as prescribed life of the machineries without leading to much loss<br>• Adoption of enhanced ways like blast-less mining technology which helps in eliminating the dust generating operations like drilling, blasting, and crushing completely. Additionally, sprinkling of water at the same time can be carried out to avoid spreading of dust |
| Aluminium | • Few of the key energy efficiency techniques that can be followed are phasing out the old smelter and replacing that with environment-friendly point feeder prebaked technology<br>• Emission control by using state-of-art technology with the usage of dry scrubbing fume treatment plant ascertaining that emissions are kept well within averages<br>• Installation of variable frequency drives (VFD's) for speed control of FD/ID fans installed |

## 3 Discussion

Description given above is all about adoption of new energy-efficient techniques at energy generation as well as energy utilization level, in order to mitigate climate change. By implementing these methods, GHG emissions can be controlled to a large extent. Not only complex techniques, but also simple movements, like UJALA scheme for replacing CFL and incandescent bulbs with LED bulbs, provide a head start for energy efficiency project. Aforementioned scheme has helped in bringing down per capita carbon dioxide emissions to acceptable level.

Over the last few decades, thermal power plants have emerged as a lifeline for modern civilization. That being said, technically, a thermal power plant is highly inefficient, incurring huge amount of losses. Nonetheless, there are various opportunities to reduce such losses, and these include new technologies like integrated gasification combined cycle, waste heat recovery, power saving in auxiliaries by using VFDs, and optimization of part load operations [6–8]. This reduction in losses is environmentally important as it is accompanied by reduction in usage of fossil fuels and reduction in carbon dioxide emissions at generation stage itself. In power plants, preheating air by 22 °C can improve the efficiency by 1%. Usage of low NOX burners and complete combustion ensures less air pollution. Many production industries in India have implemented energy-saving techniques like efficient usage of electricity by power factor improvement and following Bureau of Energy Efficiency (BEE) guidelines to reduce transformer and auxiliary losses. Waste water treatment, solid waste-based power and heat generation, solar PV power, wind power are some key methods that have been adopted by various government and non-government organizations to reduce their energy and resource consumption. Indian government is promoting the introduction of renewable elements in power systems by providing subsidies at domestic as well as commercial levels. Renewable power utilization has become a revolutionary step to combat global warming. It helps to reduce GHGs emission and looks after the energy security of the country. Green building is an innovative concept which aims to reduce the energy consumption of a building while it is being constructed or in working phase [9]. Following certain codes while constructing a building or at later stages, the building gets rated accordingly by various national and international rating schemes. All these measures not only help in mitigating the effect of climate change but also assist a nation in achieving the aim of sustainable development.

## 4 Conclusion

Energy efficiency measures and the advent of renewable energy technologies are supposedly going to be predominant in the near future. The calculated risks have already started paying off with the mitigation efforts made by various sectors. Above complied data gives a snapshot of the various measures that are being taken by the key sectors in India individually classified under CSR initiatives or voluntary initiatives. With the advent of tremendous industrialization and proliferation of emission levels, India by all means promises to commit to the cause by inculcating mitigation and adaptation measures. Climate change as proved is largely anthropogenic hence requires efforts with contemplation.

## References


1. Liverman, D.: From uncertain to unequivocal. Environ. Sci. Policy Sustain. Dev. **49**(8), 28–32 (2007)
2. Chitre, S.P.: Climate change & India: Paris & Beyond. Available at: SSRN 2799605, (2016)
3. Paul, S., Bhattacharya, R.N.: $CO_2$ emission from energy use in India: a decomposition analysis. Energy Policy. **32**(5), 585–593 (2004)
4. Worrell, E., Bernstein, L., Roy, J., Price, L., Harnisch, J.: Industrial energy efficiency and climate change mitigation. Energy Effic. **2**(2), 109–123 (2009)
5. Change, I.C.: Mitigation of climate change. In: Contribution of working group III to the fourth assessment report of the Intergovernmental Panel on Climate Change 2007
6. Cheng, P.J.: Phillips Petroleum Company. Waste heat recovery. US Patent 4,245,693 (1981)
7. Brittian, L.W.: Variable frequency drives. Audel Electrical Trades Pocket Manual, pp. 79–87 (2012)
8. Jian, T.W., Novotny, D.W., Schmitz, N.L.: Characteristic induction motor slip values for variable voltage part load performance optimization. IEEE Trans. Power Appar. Syst. (United States). **102**(1) (1983)
9. Council, U.G.B.: Buildings and Climate Change Fact Sheet. Washington, DC (2007)

# Identification of Soil Digging Using Acoustic Pattern Recognition

**Preetam Suman, Ashwaray Raj, Pramila Choudhary and M. Radhakrishna**

## 1 Introduction

Many airborne acoustic signals are generated by events that take place around us in the forest and are of interest to us. Some of such events are as follows: a gunshot fired in forest or urban areas, cutting wood or felling trees in forests, call of a wild animals or chirping of a bird or moving vehicles or human beings in forests, digging ground by poachers to lay traps or bury the remains of animals killed. Often we are interested in identifying these events and the location of the events from the acoustic signals. Of these events, detection of digging activities and their location are important in other contexts as they indicate planting land mines or digging tunnel. We often employ guards and officials to observe these events, yet automation in identifying the type of the event and the location of the event are important for any fail-proof system. While looking for any of the above events, all the other events become the noise and we have to detect all the events in real time and without losing any of them.

This paper presents approaches that would identify the soil digging activity that is taking place in a forest and in noisy environment. The acoustic signals were generated by digging the soil with different digging implements (such as pickax,

P. Suman (✉) · A. Raj · P. Choudhary · M. Radhakrishna
Indian Institute of Information Technology, Allahabad, India
e-mail: preetam.suman@gmail.com

A. Raj
e-mail: ashwarayraj@gmail.com

P. Choudhary
e-mail: pramilachoudhary8@gmail.com

M. Radhakrishna
e-mail: mkrishna@iiita.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_5

spades, shovels, and hoes). The acoustic signals were collected by digging the clay, sand, gravel soils with pickaxes and hoes.

Several techniques were suggested for training the system to recognize the digging. Some of the useful approaches are as follows: ANN [1], decision tree [2], envelogram [3], spectrogram quantization method [4], and Mel-frequency cepstrum coefficients [5]. There is considerable literature available on these learning techniques.

Nakadai et al. [6] presented footstep detection on floor. Footstep sound is groundborne sound of low frequency. Authors have used time domain, spectral, cepstral, and geometrical features for classification using support vector machine (SVM) [7].

Dorantes-Méndez [8] proposed a model "Time-Variant Autoregressive (TVAR)" that can be used for the training and testing of the multichannel lung signals that were collected with sampling rate of 10 kHz. The samples were analyzed using TVAR model. This model able to provide fine and coarse crackles presence with number efficiently, even when the crackles overlaps. The paper also presented a technique to remove substantial noise so that lung crackles could be heard.

Ahlstrom et al. [9] presented detection of 3rd heart sound (normally heard in heart failure patients—is it a strong or weak signal). The 3rd heart sound is difficult to listen because of its very low amplitude signal. The author presents recurrence time-statistic-based algorithm to detect 3rd heart sound. Author has analyzed signals from 10 children. The efficiency of the algorithm is 98%, but it has higher rate of false positives.

Sen and Kahya [10] presented a device used for the data acquisition and transient detection. The device consists of 14 microphones with one airflow system, fifteen channel amplifiers, and a filter. The device was directly connected with computer. The storage SD card was also attached with the computer. The algorithm is based on signal separating into frequency bands by decomposition of wavelet; the relevant bands enhance the transients after applying a nonlinear energy with extracting the coefficients; these coefficients are above then a threshold. The algorithm was developed [10] on MATLAB and LabVIEW.

The signals for soil digging have been collected and analyzed (described in following sections) for the development of soil digging detection algorithm. The paper has the sections as follows: Sect. 2 presents experimental setup and data collection of signals. Section 3 describes the analysis and feature identification of signals. Section 4 presents feature identification and description of features. Section 5 presents proposed algorithm design. Section 6 presents results and conclusion.

## 2 System Overview

The prototype model (Fig. 1) consists of acoustic signal acquisition unit uses a microphone sensor, acoustic signal acquisition and signal conditioning unit, processing unit, and transmission unit.

**Acoustic signal acquisition and signal conditioning unit**: It consists of microphone, signal conditioning, and storing unit.

**Microphone**: It is used to collect acoustic signals from environment. The sensitivity of the microphone used is −60 to +60 dB. This microphone is able to sense acoustic signal for digging up to 50 m distance.

**Signal Conditioning**: Maximum frequency of soil digging signal was found to be 5 kHz. A low-pass filter with 5 kHz cutoff frequency is used to filter higher frequencies. After filtering out high-frequency signals, the acoustic signals are amplified with amplifier gain of 600.

The amplified signal is converted into digital form to store in buffer using 12-bit analog–digital converter. To record the signal, the 10 kHz sampling rate was used. The recorded signal is stored in the memory.

Two buffers were used to store the signal. Concept of double buffer is explained in Chap. 6.

**Processor unit**: Processor unit is responsible for decision making and recognizing the event. The 12-bit low-power ARM processor has been used for decision making. The processor is programmed with digging detection algorithm. It extracts the features from the signal and compares it with event signature.

**Transmission Unit**: Once algorithm detects the event, it activates the transmitter to send event information to the base station through wireless communication. Between ADC and buffers, we need a control unit, and the “buffer-full” controls the active buffer and buffer and processor interaction too.

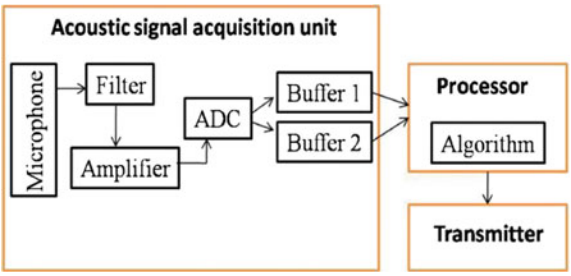



**Fig. 1** Sample collection from digging detection system

## 3 Experimental Setup

Experimental setup for digging sample collection is shown in Fig. 2. The airborne acoustic signals that are generated while digging the ground have been recorded by digging the soil. Pickax and hoe were used for soil digging. The signals were recorded from distances of 5, 10, 15, 20 (in meters) simultaneously from the place of digging. To make the algorithm robust, signals were recorded in different soil conditions. Four variations have been used: wet soil, hard soil, wet soil with gravels, and hard soil with gravels, sandy bed, etc.

## 4 Analysis of Signals

A total of 120 signals have been collected for analysis and testing. Signals are divided into two parts: First 80 signals were used for analysis and training of system, and remaining 40 signals (not present in training set) are used for testing of the algorithms. Figure 3a–f shows waveform and spectrogram of acoustic signals of digging. The high amplitude shows the strikes on ground. Each single strike has been extracted from recorded signal.

## 5 Parameter Calculation

After analysis of time and frequency domain with 80 acoustic with the help of MATLAB and the literature survey, 10 parameters were identified which are helpful to recognize the soil digging event. The description of parameters is as follows:

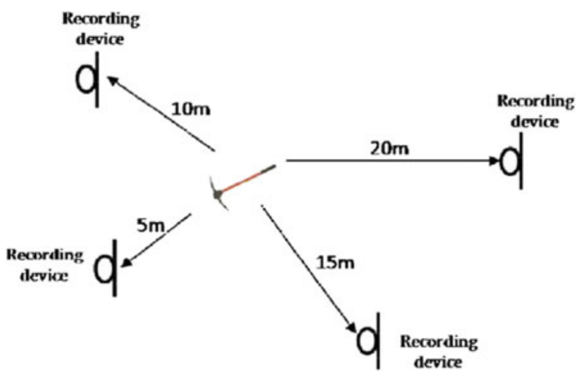



**Fig. 2** Experimental setup for digging

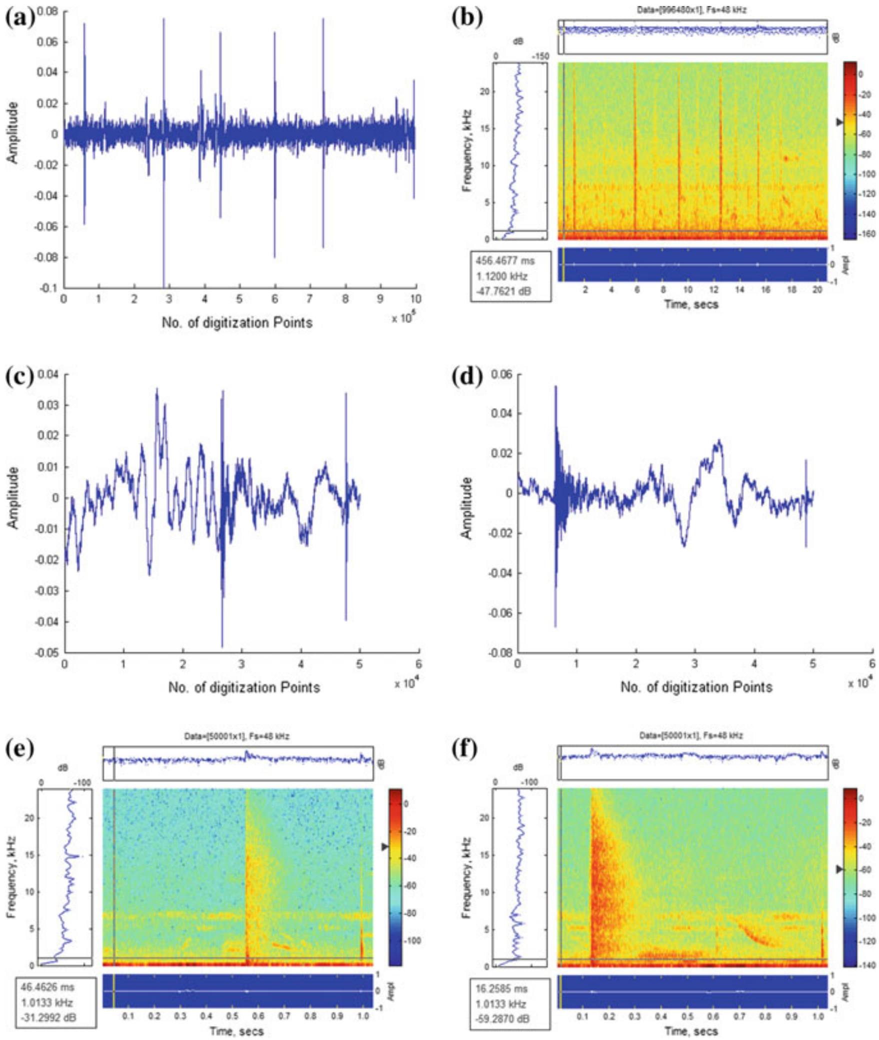



**Fig. 3** **a** Waveform of entire signal, **b** spectrogram of entire signal, **c** waveform of single strike by pickax, **d** waveform of single strike by hoe, **e** spectrogram of single strike by pickax, **f** spectrogram of single strike by hoe

| S. No. | Parameter | Description |
|---|---|---|
| *Temporal features* | | |
| 1 | Min peak | It is the minimum amplitude of signal per frame. It is used to define lower threshold boundary of signals |
| 2 | Max peak | It is the maximum amplitude of signal per frame. It is used to define upper threshold boundary of signals |
| 3 | Zero-crossing rate (ZCR) | When the zero crossings occur that gives the frequency content of a signal. When the amplitude crosses zero value in a time interval that supervised by the ZCR $Z_t = \frac{1}{2}\sum_{n=1}^{N} \lvert sign(x[n]) - sign(x[n-1])\rvert$ |
| 4 | Root-mean-square (RMS) | RMS value is measure of global energy of the signal. It indicates loudness/intensity of signal $\boldsymbol{x_{rms}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} \boldsymbol{x_i^2}}$ |
| 5 | Standard deviation | The dispersion of the set of data from its mean measured by it $\sigma = \sqrt{\left\{\left(\frac{1}{N}\right)\sum_{i=1}^{N}(xi-\mu)^2\right\}}$ |
| *Spectral features* | | |
| 6 | Spectral centroid | Magnitude spectrum of the STFT gives the center of gravity $C_t = \frac{\sum_{n=1}^{N} n \cdot \lvert M_t[n]\rvert^2}{\sum_{n=1}^{N} \lvert M_t[n]\rvert^2}$ where magnitude $M_t[n]$ at frame t and frequency n of the Fourier transform |
| 7 | Spectral roll-off | Below 85% concentrated of magnitude distribution indicated by $R_t$ $\sum_{n=1}^{R_t} M_t[n] = 0.85 \times \sum_{n=1}^{N} M_t[n]$ |
| 8 | Spectral flux | The magnitude of successive spectral distributions Squared difference between the normalized magnitudes of successive spectral distributions $F_t = \sum_{n=1}^{N}(N_t[n] - N_{t-1}[n])^2$ |
| 9 | Spectral crest factor | Peak amplitude and RMS energy of a waveform calculated by $\frac{\max_{n \in B_k}\{M_t[n]\}}{\frac{\sum_{n=1}^{N} M_t[n]}{N_k}}$ |
| 10 | Spectral entropy | Shannon entropy offers a general description of the input *X* and indicates in particular whether it contains predominant peaks or not $H(x) = -\sum_{i=1}^{N} p(x_i)\log_2 p(x_i)$ |

## 6 Algorithms for Soil Digging Detection

There are many machine learning algorithms that are developed for pattern recognition. In this paper, three approaches are used for identification of soil digging event.

(a) **Approach 1: K Means Clustering [11]**

With the help of K means the data set is classified into number of clusters. The main idea behind this is to define k centroid for each cluster and elect a new optimized cluster through iteration. The process of K means clustering is follows:

The flowchart for this approach is as follows:

Step 1: Initialize the number of cluster centers selected by the user by randomly selecting them from the training set.

Step 2: Classify the entire training set. For each pattern $X_i$ in the training set, find the nearest cluster center C* and classify $X_i$ as a member of C*.

Step 3: For each cluster, recompute its center by finding the mean of the cluster:

$$M_k = \frac{1}{N_k} \cdot \sum_{j=1}^{N_k} X_{jk}$$

where $M_k$ is the new mean, $N_k$ is the number of training patterns in cluster k, and $X_{jk}$ is the k-th pattern belonging to cluster.

Step 4: If the number of cluster centers is less than the number specified, split each cluster center into two clusters by finding the input dimension with the highest deviation:

$$\sigma_i = \sum_{j=1}^{N_k} (X_{ij} - M_{ij})^2$$

The i-th dimension ($X_{ij}$) of the j-th pattern in cluster k, the i-th dimension ($M_{ij}$) of the cluster center in cluster k, and $N_k$ represent the number of training patterns.

Step 5: Store the k cluster centers.

**Testing**: For each pattern X, associate X with the cluster Y closest to X using the Euclidean distance:

$$\boldsymbol{Dist}(\boldsymbol{X},\boldsymbol{Y}) = \sqrt{\sum_{\boldsymbol{i}=1}^{\boldsymbol{m}} (\boldsymbol{X_i} - \boldsymbol{Y_i})^2}$$

(b) **Algorithm 2: Linear Discriminant Analysis (LDA) [12]**

LDA is an approach that is used for pattern recognition and machine learning to calculate linear combination that characterizes the classes of events. This combination may be used as linear or, more commonly, for dimensionality reduction before classification.

The steps of this approach are as follows:

1. Compute the *d*-dimensional mean vectors $m_i$, (i = 1, 2, 3… n) for the different classes in the dataset.
2. Calculation of the scatter matrices (for outer- and inner-class scatter matrices).
   a. Within-class scatter matrix ($S_W$) is computed by the following equation:
   b. $S_w = \sum_{i=1}^{c} S_i$ Where $S_i = \sum_{x \in D_i}^{c} (x - m_i)(x - m_i)^T$ and $m_i$ is the mean vector

$$m_i = \frac{1}{n_i} \sum_{x \in D_i}^{n} x_k$$

   c. Outer (between)-class scatter matrix:

Outer-class scatter matrix ($S_B$) computation:

$$S_B = \sum_{i=1}^{c} N_i(m_i - m)\,(m_i - m)^T$$

where m represents overall mean, and $m_i$ and $N_i$ denote the sample mean and sizes of the respective classes.

3. For the scatter matrix, compute the eigenvectors (**e1, e2, …, ed**) and eigenvalues (**λ1, λ2, …, λd**).
4. To form a matrix, sort the eigenvectors by falling eigenvalues and select **k** eigenvectors by increasing eigenvectors, **W** with $d \times k$ dimension. Every column has an eigenvector.
5. By using eigenvector matrix (W), transform the samples into the new subspace. This can be shown by the equation $\boldsymbol{Y} = \boldsymbol{X} \times \boldsymbol{W}$. $\boldsymbol{X}$ is a matrix with dimension of $n \times d$; the $i^{th}$ row equals to $i^{th}$ sample. n x k is the dimension of transformed matrix ***Y****; new subspace projected by the n samples*.

**Testing**:

6. Testing of this approach is done using Euclidian distance of feature vectors. The Euclidian distance is distance between two points. If p and q are two points, then Euclidean distance between p and q is:

$$d(p,q) = \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2}$$

(c) **Approach 3: Proposed Distance-Based Approach**

The proposed approach is based on the difference between the parameters. The 11 parameters were stored in master database, and a minimum difference has been calculated for matching. When new signal arrives, algorithm calculates the parameters of signal and calculates the difference between the parameters stored in master database. The pseudocode for algorithm is as follows:

```
If (signal_amp > x)
{
Processing start
Calculation of parameter
}
// matching with database
```

**Loop: till length of matrices**

```
If (parameter 1 of database – parameter 1 of frame 1 < y)
count_1 = count_1 + 1;
If (parameter 2 of database – parameter 2 of frame 1 < y)
count_2 = count_2 + 1;

If (parameter n of database – parameter n of frame 1 < y)
count_n = count_n + 1;
```

**Calculation of percentage**

```
If (percentage of matching > 75)
Event detected
```

**Table 1** Efficiency of algorithms

| | K means clustering (%) | LDA (%) | Proposed algorithm (%) |
|---|---|---|---|
| Soil digging detection | 83 | 87 | 93 |
| False-positive recognition | 15 | 14 | 5 |
| False-negative recognition | 17 | 13 | 7 |

## 7 Result

The algorithms were tested in open ground with the help of microphone sensor and laptop by digging the ground using pickax. All three approaches are tested one by one. The efficiency of algorithms is shown in Table 1. The algorithms are also tested with the acoustic signals of tree cutting and hammering on wood.

## 8 Conclusion

This paper presents an algorithm for soil digging detection. Acoustic signal for soil digging has been recorded in different soils and soil conditions, such as wet soil, hard soil, wet soil with gravels, and hard soil with gravel. The tools used for digging are pickax and hoe. Signals are analyzed with time and frequency domain. Eleven parameters were calculated for each signal. Three approaches were used for event detection. The third approach is distance-based approach, and its efficiency is 93%, with a 5% of false positive and 7% of false negative.

**Acknowledgements** Without the support of officials and staff of IIIT-Allahabad, this work cannot be completed. They always allowing us to dig-up the ground and perform experiments. Thank you very much all the officials and Staff of IIIT-Allahabad.

## References

1. Hebden, J.E., Torry, J.N.: Neural network and conventional classifiers to distinguish between first and second heart sounds. In: IEE Colloquium on Artificial Intelligence Methods for Biomedical Data Processing, pp. 3/1–3/6, 26 Apr 1996
2. Stasis, A.C., Loukis, E.N., Pavlopoulos, S.A., Koutsouris, D.: Using decision tree algorithms as a basis for a heart sound diagnosis decision support system. In: 4th International IEEE EMBS Special Topic Conference on Information Technology Applications in Biomedicine, pp. 354–357, 24–26 Apr 2003
3. Liang, H., Lukkarinen, S., Hartimo, I.: Heart sound segmentation algorithm based on heart sound envelogram. Comput. Cardiol. 105–108 (1997)
4. Liang, H., Lukkarinen, S., Hartimo, I.: A boundary modification method for heart sound segmentation algorithm. Comput. Cardiol. 593–595 (1998)

5. Kumar, D., Carvalho, P., Antunes, M., Gil, P., Henriques, J., Eugenio, L.: A new algorithm for detection of S1 and S2 heart sounds. In: IEEE International Conference on Acoustics, Speech and Signal Processing, vol. 2, (2006)
6. Nakadai, K., Fujii, Y., Sugano, S.: Footstep detection and classification using distributed microphones. In: 14th International Workshop on Image Analysis for Multimedia Interactive Services (WIAMIS), pp. 1–4, 3–5 July 2013
7. Burges C.J.C.: A tutorial on support vector machines for pattern recognition. Data Min. Knowl. Discov. 2, 121–167, (1998). Available at: http://research.microsoft.com/pubs/67119/svmtutorial.pdf. Last accessed on 02 Jun 2105
8. Dorantes-Mendez, G., Charleston-Villalobos, S., Gonzalez-Camarena, R., Chi-Lem, G., Carrillo, J.G., Aljama-Corrales, T.: Crackles detection using a time-variant autoregressive model. In: Engineering in Medicine and Biology Society (EMBS), 30th Annual International Conference of the IEEE, pp. 1894–1897, 20–25 Aug 2008
9. Ahlstrom, C., Hult, P., Ask, P.: Detection of the 3rd heart sound using recurrence time statistics. In: IEEE International Conference on Acoustics, Speech and Signal Processing, vol. 2, 14–19 May 2006
10. Sen, I., Kahya, Y.P.: A multi-channel device for respiratory sound data acquisition and transient detection. In: Engineering in Medicine and Biology Society, IEEE-EMBS 2005. 27th Annual International Conference of the, pp. 6658–6661, 17–18 Jan 2006
11. Xie, J., Jiang, S.: A simple and fast algorithm for global k-means clustering. In: Second International Workshop on Education Technology and Computer Science (ETCS), vol. 2, pp. 36–40, 6–7 Mar 2010
12. Chu, D., Liao, L., Ng, M.K., Wang, X.: Incremental linear discriminant analysis: a fast algorithm and comparisons. Neural Netw. Learn. Syst. IEEE Trans. **26**(11), 2716–2735 (2015)

# Environmental Implications of Rice and Wheat Stubble Burning in North-Western States of India

**Jabrinder Singh, Naveen Singhal, Shailey Singhal, Madhu Sharma, Shilpi Agarwal and Shefali Arora**

## 1 Introduction

India is an agrarian nation with diverse farming practices according to agro-climatic zones. The paddy and wheat system (PWS) is the extensively practiced farming systems in north-western states of India and generates a huge amount of agricultural wastes in the form of straw and stubbles. The practice is widespread throughout the plains of Haryana, Punjab, Rajasthan and western Uttar Pradesh. Farming system residues or the stubbles are the biomass of crop remains at fields after reaping the profitable constituents, i.e. kernel. The farming dregs generated include mainly the cereal straws, stubbles, woody stems, cotton stalk and leave, etc. A large amount of husk and other biomass is also generated after farm yield processing in the agro-industries. The agricultural residue mainly leaves and stubbles is utilized as animal fodder, roofing and shedding of homes, cattle shed, domestic usage fuel and small-scale industries raw material and fuel. Still, a bulky part of the stubbles and straw is not employed and remains in the agricultural farms. The dumping of huge quantity of farm yield remains is a far-reaching trouble for the farmers.

The IARI (Indian Agricultural Research Institute), New Delhi, estimates that maximum residue is generated by cereal crops, i.e. 352 Mt, out of this, 34 and 22% are contributed by paddy and wheat, respectively [1]. In situ burning of crop residue

J. Singh (✉) · N. Singhal
Department of Chemistry, DIT University, Dehradun 248001, Uttarakhand, India
e-mail: drjabrinder.singh@dituniversity.edu.in

S. Singhal · S. Agarwal · S. Arora
Department of Chemistry, University of Petroleum & Energy Studies (UPES), Dehradun 248007, Uttarakhand, India

M. Sharma
Department of Electrical Engineering, University of Petroleum & Energy Studies (UPES), Dehradun 248007, Uttarakhand, India
e-mail: jschahar@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*, Springer Transactions in Civil and Environmental Engineering, https://doi.org/10.1007/978-981-10-7122-5_6

is adopted to clear the agricultural field promptly and allocate tillage practices for sowing of next crop [2]. These river plains famous for its extensive agriculture are equally defamed for burning of rice and wheat straw and stubbles by peasants after the reaping season. Stubble burning is the planned blazing of the straw and stubble that stay behind after harvesting of wheat, paddy, cotton or any other crop. This incident is spread universal and also a significant cause of poor air quality throughout the globe [3]. Globally, forest fires are the biggest cause of the blaze discharges due to its heavy carbon content, and agricultural residue flaming is the subsequent biggest one, contributing approximately 2020 Tg (1/4th part of total biomass burned) [4].

Farm residues blazing emits a high magnitude of air pollutants like $N_2O$, $CO_2$, $CH_4$, CO, $NH_3$, $SO_2$, Hydrocarbons, VOCs and suspended particulate matter at a diverse pace which is observed in any grassland or forest fire because of separate composition of the farm residues and burning forms [5, 6]. These air pollutants cause adverse impacts on human health. They can cause chronic obstructive pulmonary diseases (COPD), pneumoconiosis, pulmonary tuberculosis, bronchitis, skin diseases, eye irritation, cataract, corneal opacity and blindness. The cases of road accidents also enhance during the period of stubble burning.

In India, National Green Tribunal (NGT) forbids the tradition of straw and stubble flaming in highly polluted city New Delhi as well as its adjacent four states (Haryana, Rajasthan, Punjab and Uttar Pradesh). Due to the mounting crisis combined with crop dregs burning in these states, numerous initiatives for its appropriate management have been approached. Government organizations and research centres are encouraging alternate utilization of straw and stubbles in lieu of blazing such as utilize farm dregs as animal fodder; utilization of stubbles in electricity generation; employment for mushroom farming, for quilt substance in cattle shed; utilization as bio-lubricant; paper and pulp production; biogas generation and in situ amalgamation in soil [7].

Further, in last two three decades, many conversion processes were developed to produce alternate biofuels under different forms (pellets, logs, briquettes) from crop residues in order to be used in household boilers, stoves and even in some plants for producing heat and electricity at a wide scale. In this paper, an attempt has been made to discuss the implications of stubble burning in north-western states of India and their mitigation methods.

## 2 The Generation and Burning of Crop Stubble

After harvesting of grain, i.e. economic part of agricultural practice, the biomass left in the field is the residual biomass. Every year, a huge amount of farm residues are produced, in the form of leaves/tops, straws, stubbles, stem, etc. [2]. Table 1 depicts the amount of crop residue generated studied by different authors. The table illustrates that there is large disparity in farm remains generation among various states of the country. Cereal crop dregs production was maximum in the

Uttar Pradesh (72 Mt) chased by Punjab (45.6 Mt), West Bengal (37.3 Mt), Andhra Pradesh (33 Mt) and Haryana (24.7 Mt). Cereal crop residues are generated maximum by paddy (53%) followed by wheat (33%) [8]. According to some studies, agricultural remains production was 253 Mt in 2010 [9].

According to an estimate, paddy straw production was 22,289 Gg in excess in India annually and out of which, 13,915 Gg is burnt in situ. Haryana and Punjab, the two states alone share 48% of the entire amount and burn the same in farms. Further, it was studied that about 40 million tonnes of farm yield waste every year is produced in Punjab alone. Table 1 describes the total extent of agriculture remains generated in India by various authors. Cereal plants produce the largest amount of 352 Mt residues, in which 34 and 22% is contributed by paddy and wheat, respectively. In India, the excess amount of residues (balance residue after domestic utilization) of cereal crops amounts to 82 Mt are usually fired in the agricultural farm, in which rice and wheat contribute 44 and 24.5 Mt, respectively [1]. We can see plumes of smoke rising from the fields which by the end of October or sooner becomes a thick blanket in the air over Haryana, Punjab and western UP extending up to the national capital [14]. It is the season for paddy stubble burning in this region. According to another study, in India, 84 Tg of crop remains is burnt annually [15].

Various methods have been chosen for disposal of paddy stubbles and straw as mentioned in different studies (Tables 2 and 3). Figures 1 and 2 illustrate the burning of straw in agricultural fields by farmers.

**Table 1** Status of crop stubble produced in India as stated by various authors

| Sr. no | References | The quantity of crop remains produced in India per year |
|---|---|---|
| 1 | Garg [10] | 133,138 Gg |
| 2 | Mandal et al. [11] | 350 million tonnes |
| 3 | Gupta et al. [12] | $347 \times 10^6$ tonnes (2000) |
| 4 | Agarwal et al. [13] | 184,902 Gg |

*Source* Kumar et al. [7]

**Table 2** Rice straw disposal pattern

| S. no. | References | Usage pattern of farm yield residue of rice |
|---|---|---|
| 1 | Sarkar et al. [16] | 75% Mechanized reaped and totally burnt (100%). |
| 2 | Sidhu and Beri [17] | In situ burning (paddy—81% and wheat—48%), animal fodder (paddy—7% and wheat—45%), rope making (paddy—4% and wheat—0%), soil incorporation (paddy—1% and wheat—1%), miscellaneous (paddy—7% and wheat—7%) |
| 3 | Badarinath et al. [18] | Three fourth or 75% of straw and stubbles are burnt in situ |
| 4 | Venkataraman et al. [19] | 30–40% straw is burnt (IGP) |
| Average | | In rice, 75% remains is burnt |

**Table 3** Utilization of straw and stubbles by the farmers of Punjab

| Sr. no | Pattern of end usage | Percentage of entire paddy stubble generated | Percentage of entire wheat stubble generated |
|---|---|---|---|
| 1 | Animal feed | 7 | 45 |
| 2 | Soil amalgamation | 1 | 1 |
| 3 | Burning | 81 | 47 |
| 4 | Rope production | 4 | 0 |
| 5 | Miscellaneous | 7 | 7 |

*Source* Govt. of Punjab [20]

**Fig. 1** In situ stubble burning after harvesting of crop

## 3 Effects of Stubble Burning on Environment

According to a study, emission of NOx, $CH_4$, SPM, CO and $CO_2$ was 0.1, 0.6, 1.2, 4.1 and 91 Tg/year, respectively, as a result of crop residue burning in India [21]. Some scientists have calculated that there is an emission of 4.86 Mt of carbon dioxide equivalents of greenhouse gases, 3.4 Mt of carbon monoxide and 0.14 Mt of nitrogen oxides by burning of 63 Mt of crop residue [9]. Another study concluded that 1 tonne of agriculture residue burning releases SPM (3 kg), CO (60 kg), $CO_2$ (1460 kg), fly ash (199 kg) and $SO_2$ (2 kg) [12]. According to National Remote Sensing Agency, paddy burning in Punjab alone released CO (261 Gg) and NOx (19.8 Gg) and several other gases to the atmosphere. In India, there is an emission of 144,719 Mg of total suspended particulate matter by virtue of in situ burning of paddy stubbles.

**Fig. 2** Farmer keeps on straw burning despite of ban by authorities

The above emissions have several atmospheric, biospheric and ecological implications. Since the R–W cropping system is cultivated on a large scale (about 9.6 million ha in India), pollutants from agricultural residue burning are very significant. These high amounts of residues from the R–W agro-ecosystems when burnt form an important source of GHGs, in the Indian region. Considering these implications, agriculture residue burning is one of the major areas, where GHG mitigation options can be focused upon [18].

Stubble and straw flaming also burn the nutrients present in the farm residues besides causing a huge pollution. The total quantity of carbon, 80–90% nitrogen, 25% of phosphorus, 20% of potassium and 50% of sulphur present in various crop remains is vanished in the harmful gaseous forms and particulate matter, causing the air pollution [22]. The blazing of rice straw and stubbles cause huge soil nutrient loss (organic carbon: 3.85 million tonnes; nitrogen: 59,000 tonnes; phosphorus: 20,000 tonnes and potassium: 34,000 tonnes) besides severely affecting the ambient air quality as stated officially. As a result, various hazardous gases are also added to the atmosphere. These gaseous discharges can create human health hazards, especially asthma, persistent bronchus problem and dwindling pulmonary capacity. Blazing of farm yield remains also increases ozone concentration in lower atmosphere [7]. Some researchers stated that farm residue burning elevated the temperature of soil up to 42.2 °C (up to one cm depth) which adversely affects soil ecology. Due to the same, about 23–73% of nitrogen in various forms is vanished and the beneficial microbial population also declined (2.5 cm depth of soil). The residue burning increases the temperature of the soil to a high extent which results in changes in the C-N equilibrium hastily in the upper 3 inches soil. The carbon is vanished to atmosphere in the form of $CO_2$, and nitrogen is translated to nitrate. Due to this process, approximately 824,000 tonnes of NPK is lost from the soil [12].

The studies discussed above indicate that ablazing of the farm residues (in situ) at enormous level is critically detrimental to the environment. Furthermore, in situ crop residual flaming also declines population of soil microorganisms and burns the multipurpose tree species in agricultural fields. It also causes off-site health hazard impacts such as cough, emphysema, asthma, bronchitis, eye irritation, corneal opacity and skin diseases. Small respiratory particles can also intensify persistent cardiac and pulmonary ailments and furthermore related with untimely deaths in people previously suffering from these illnesses. The black dust produced during residue flaming also results in reduced vision which hampers traffic movements and raised road side accidents [7].

According to a study, detrimental compounds like polyhalogenated organic compounds (PCDDs), peroxy aceyl nitrate (PAN) polyaromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCBs) and polychlorinated dibenzofurans (PCDFs) referred commonly as dioxins are emitted by open burning of farm residue. These atmospheric pollutants may have noxious properties and are carcinogenic in nature. Flaming of crop straw and stubble has severe negative impacts on health. Pregnant women and infants are more prone to dangerous consequences due to pollutants released by stubble flaming. Respiratory suspended particulate matter of very small size ($PM_{2.5}$) inhalation prompts asthma and can even worsen signs of respiratory attack [8].

## 4 Management of Crop Stubble

Due to ever growing predicaments linked with crop residue flaming in the north-western states of India, several proposals and techniques have been developed for its appropriate handling in the past years by different agencies.

Soil incorporation is a broadly documented strategy for enhancing organic carbon (OC) sequestration and enhancing soil health and crop yield. In a study conducted on maize–wheat cropping system, the best remedy is high straw return for domestic animal fodder, but more suitable practices, such as wheat and maize straw mulching in soil, increase crop yield and soil carbon sequestration, eventually led to establishment of a sustainable cropping system [23].

Flawed use of residue and in situ burning of straws not only generates threat to environment by producing large quantity of greenhouse gas (GHG) emission, but also led to lose of a vital by product from farming practices. Straw and stubbles can be employed in biofuel generation and can be a source of additional monetary benefit and justified utilization of waste. It will also meet the demand of clean and green energy to ever increasing power demand in India [24].

## 4.1 On Farm Soil Mulching and Compost Production

The farm residue has a range of optional values; however, cultivators prefer burning of stubbles as an easy mode for disposal of residue. After mechanized harvesting, farmers can opt for in situ incorporation of the crop residue in soil. According to a study, the best substitute for flaming of paddy residue is amalgamation of stubbles in soil on the field site [17]. Some scientists reported that the paddy residue incorporation in soil three weeks before cultivating considerably increase wheat yield on clay loam soils. It will also increase organic carbon in soil by 14–29% [25]. In contrary, if the paddy residue is amalgamated instantaneously before sowing the wheat in rabi, then the crop production is reduced due to arrest of inert nitrogen which adversely cause nitrogen deficit [25]. As per some studies, amongst the various alternatives to burning of stubbles, incorporation of farm yield residues into the soil in R–W systems seems to be the best strategy, instead of residue burning [26]. Different studies indicated that one of the best methods to reduce this menace is incorporation of straw into soil which eventually enhances soil fertility.

## 4.2 Alternate Methods of Crop Residue Management

Some of the alternative utilization of crop stubbles may be animal fodder; fuel material in heat generated power plants; utilization in mushroom farming, for cattle shed preparation; for extraction of bio-lubes; paper and pulp manufacturing and biogas generation can be incorporated to avoid drawbacks of stubble and straw burning. Some alternate utilization includes amalgamation of wheat and paddy straw in soil to produce mulch, various energy technologies and thermal power generation [2]. Power and paper industries are now approaching to farmers for rice, mustard, cotton and wheat straw and stubbles. Further, the stubble compost consists approximately 2% of $N_2$, 1.5% of P and 1.4–1.6% of K which improve crop yield by 4–9% [26].

The crop residue material can also be used for bio-compost formation. These methods are adopted traditionally also in various farming practices. Several researchers suggested that alternate energy resources can be generated from this biomass of agricultural sector. The milestone step to prevent this threat is to set up alcohol refineries to take out sustainable bio-energy from this farm yield residue by employing various models. Biogas plants can also be employed for disposal of crop residue such as straw and stubble.

## 5 Conclusion

Burning of farm residues, i.e. straw and stubbles from paddy–wheat farming systems of Punjab, Rajasthan, Haryana and Uttar Pradesh at a large scale is an issue of grave concern which results in greenhouse gases emission besides causing problems of atmospheric pollution, health risks and thrashing nutrients from soil. It becomes need of the hour to authenticate the emission calculations experimentally and the allied ambiguity. The farm yield residues can be exploited to various productive methods such as compost formation, in situ assimilation in soil, bio-energy generation, and this is possible only if straw and stubbles are gathered and handled properly.

Regardless various austere legislations and compliance steps implemented by the Government of India and different state authorities, this malignant practice of in situ stubble burning continuously adds woes to the ambient air quality and health problems of the area and turn out to be an issue of grave concern even for various transportation modes. Effective execution of statutory policy verdicts to curb this threat is required with periodic to continuous monitoring and improvement. According to MoEFCC, prohibition of stubble burning by states of Haryana, Punjab, Uttar Pradesh and Rajasthan has outcome with 38.93 and 20.3% reduction in stubble burning in Punjab and Haryana, respectively.

Programmes related to awareness and incentives must be launched for the farming communities. They must be well conscious regarding the harmful consequences of crop straw and stubble flaming and significance of alternate uses such as incorporation of farm remains in soil, for sustaining agricultural efficiency.

## References

1. IARI: Crop residues management with conservation agriculture: potential, constraints and policy needs. Indian Agricultural Research Institute, New Delhi, pp. 7–32, (2012)
2. Jain, N., Bhatia, A., Pathak, H.: Emission of air pollutants from crop residue burning in India. Aerosol Air Qual. Res. **14**, 422–430 (2014)
3. Yang, S., He, H., Lu, S., Chen, D., Zhu, J.: Quantification of crop residue burning in the field and its influence on ambient air quality in Suqian. China. Atmos. Environ. **42**, 1961–1969 (2008)
4. Chang, D., Song, Y.: Estimates of biomass burning emissions in tropical Asia based on satellite—derived data. Atmos. Chem. Phys. **10**, 2335–2351 (2010)
5. Zhang, H., Hu, D., Chen, J., Ye, X., Wang, S.X., Hao, J., Wang, L., Zhang, R., Zhisheng, A.: Particle size distribution and polycyclic aromatic hydrocarbons emissions from agricultural crop residue burning. Environ. Sci. Technol. **45**, 5477–5482 (2011)
6. Mittal, S.K., Susheel, K., Singh, N., Agarwal, R., Awasthi, A., Gupta, P.K.: Ambient air quality during wheat and rice crop stubble burning episodes in Patiala. Atmos. Environ. **43**, 238–244 (2009)
7. Kumar, P., Kumar, S., Joshi, L.: Socioeconomic and Environmental Implications of Agricultural Residue Burning. Springer Briefs in Environmental Science (2015)

8. Gadde, B., Christoph, M.C., Wassmann, R.: Rice straw as a renewable energy source in India, Thailand, and the Philippines: Overall potential and limitations for energy contribution and greenhouse gas mitigation. Biomass Bioenerg. **33**, 1532–1546 (2009)
9. Sahai, S., Sharma, C., Singh, S.K., Gupta, P.K.: Assessment of trace gases, carbon and nitrogen emissions from field burning of agricultural residues in India. Nutr. Cycling Agroecosyst. **89**, 143–157 (2011)
10. Garg, S.C.: Traces gases emission from field burning of crop residues. Indian J Air Pollut. Control **8**(1), 76–86 (2008)
11. Mandal, K.G., Misra, A.K., Hati, K.M., Bandyopadhyay, K.K., Ghosh, P.K., Mohanty, M.: Rice residue management options and effects on soil properties and crop productivity. Food Agric. Environ. **2**, 224–231 (2004)
12. Gupta, P.K., Sahai, S., Singh, N., Dixit, C.K., Singh, D.P., Sharma, C.: Residue burning in rice-wheat cropping system: Causes and implications. Curr. Sci. **87**(12), 1713–1715 (2004)
13. Agarwal, S., Trivedi, R.C., Sengupta, B.: Air pollution due to burning of agricultural residue. Indian J. Air Pollut. Control **8**(1), 51–59 (2008)
14. Sandhu, K.: Fields on Fire: Burning Paddy Straw. The Indian Express, 10 October 2016, Kurukshetra, India. (2016)
15. Streets, D.G., et al.: An inventory of gaseous and primary aerosol emissions in Asia in the year 2000. J. Geophys. Res. **108**, 8809 (2003)
16. Sarkar, A., Yadav, R. L., Gangwar, B., Bhatia, P. C.: Crop Residues in India: Project Directorate for Cropping System Research Modipuram, India (1999)
17. Sidhu, B.S., Beri, V.: Experience with managing rice residues in intensive rice-wheat cropping system in Punjab. In: Abrol, I.P., Gupta, R.K., Malik, R.K. (eds.) Conservation Agriculture: Status and Prospects, pp. 55–63. Centre for Advancement of Sustainable Agriculture, National Agriculture Science Centre, New Delhi (2005)
18. Badarinath, K.V.S., Kiranchand, T.R., Krishna Prasad, V.: Agriculture crop residue burning in ht Indo-Gangetic Plains—A study using IRS-P6 AWiFS satellite data. Curr. Sci. **91**(8), 1085–1089 (2006)
19. Venkataraman, C., Habib, G., Kadamba, D., Shrivastava, M., Leon, J.F., Crouzille, B., Boucher, O., Streets, D.G.: Emissions from open biomass burning in India: Integrating the inventory approach with high-resolution moderate resolution imaging spectro-radiometer (MODIS) active-fire and land cover data. Glob. Biogeochem. Cyc. **20**(2), 1–12 (2006)
20. Government of Punjab: State of Environment. Punjab State Council of Science and Technology, Chandigarh, India, (2007)
21. Yevich, R., Logan, J.A.: An assessment of biofuels use and burning of agricultural waste in the developing world. Global Biogeochem. Cycles **17** (2003)
22. Lefroy, R.D., Chaitep, W., Blair, G.J.: Release of sulphur from rice residue under flooded and non-flooded soil conditions. Aust. J. Agric. Res. **45**, 657–667 (1994)
23. Li, S., Li, Y., Li, X., Tian, X., Zhao, A., Wang, S., Shi, J.: Effect of straw management on carbon sequestration and grain production in a maize–wheat cropping system in Anthrosol of the Guanzhong Plain. Soil Tillage Res. **157**, 43–51 (2016)
24. Singh, R., Srivastava, M., Shukla, A.: Environmental sustainability of bioethanol production from rice straw in India: A review. Renew. Sustain. Energy Rev. **54**, 202–216 (2016)
25. Singh, Y., Singh, D., Tripathi, R. P.: Crop Residue Management in Rice-Wheat Cropping System. In: Abstracts of Poster Sessions 2nd International Crop Science Congress, p. 43. National Academy of Agricultural Sciences New Delhi, India. (1996)
26. Sood, J.: Not a waste until wasted. Down to Earth. Available http://www.downtoearth.org.in/content/not-waste-until-wasted (2013). Accessed on 15 Sept 2016

# Treatment of Dairy Farm Effluent Using Recirculating Constructed Wetland Units

**Deepa Minakshi, Pradeep Kumar Sharma, Anju Rani, Piyush Malaviya and Narveer**

## 1 Introduction

Dairy farms generally discharge large volumes of nutrient-rich wastewater which has high potential of polluting nearby environment. Most often, these medium strength wastewaters are either used for irrigating agricultural fields but sometimes treated using trickling filters, activated sludge system, anaerobic digesters, etc., which are expensive to afford [1]. Thus, due to high operation and maintenance cost, dairy farm owners usually show no/least interest in practicing these treatment methods.

Constructed wetlands (CWs) are artificial engineered systems designed and constructed for using natural processes along with use of macrophytes and microbial activities in treatment processes [2]. The CW technology is simple and cost-effective in design and operation. The common designs include horizontal CW,

D. Minakshi · P. K. Sharma (✉)
Department of Environmental Science, Graphic Era University, Dehradun, Uttarakhand, India
e-mail: pradeep2910@gmail.com

D. Minakshi
e-mail: meenu.indian06@gmail.com

A. Rani
Department of Biotechnology, Graphic Era University, Dehradun, Uttarakhand, India
e-mail: anju.teotia@gmail.com

P. Malaviya
Department of Environmental Science, University of Jammu, Jammu & Kashmir, India
e-mail: piyushmalaviya@jammuuniversity.in

Narveer
DBT Project, Graphic Era University, Dehradun, Uttarakhand, India

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*, Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_7

vertical CW, and hybrid CW systems [3]. While designing CW system parameters which need to be considered include selection of appropriate filter material, flow characteristics of wastewater, loading rate, bed depth, and selection of suitable plants [4]. These parameters show combined effect on removal of pollutants from dairy wastewater and thus on the performance of a CW system.

In this research work, vertical subsurface flow CW system filled with 20 mm gravels has been used for treating dairy farm washings. In vertical system, wastewater is dosed vertically on the surface of the filter medium and allowed to percolate slowly into the bed from top surface to the bottom. During its percolation, several physicochemical and biological processes occur which are responsible for removing pollutants from dairy wastewater. Microbial biofilms associated with the substrates and the macrophytes, and their roots have very important role in this process [5]. This paper deals with the study of a recirculating VFCW system constructed for treating dairy wastewater. According to previous studies, recirculation is highly effective in removing TSS and BOD and also shows good nitrification even at low temperatures [6–9]. Recirculation results in addition of oxygen for aerobic microbial activities into wastewater and is repeatedly pumped and redistributed so that there is maximum removal of pollutants. Arias et al. [10] observed that recycling improves the rate of denitrification and overall performance of the CW system. The objective of this research work is to determine the rate of removal of pollutants from dairy wastewater using vertical system CW operated at different recirculation rates required for maximum removal of pollutants from wastewater.

## 2 Materials and Methods

### *2.1 Study Site*

This research work has been carried out in a vertical flow CW system having an area of 4 $m^2$ per bed constructed near the dairy farm located at Graphic Era University, Dehradun. The vertical system consisting of three beds, CW1–CW3, was filled with 20 mm gravels as filter materials and planted with common reed *Phragmites australis*. This plant has ability to capture nutrients from wastewater and thus plays a vital role in treatment process.

### *2.2 Dosing and Sampling*

Approximately 220 L of dairy wastewater was dosed into first bed of CW1, CW2, and CW3 and allowed to stand for 24 h. After 24 h, the water was drained out and further dosed in second bed of CW1, CW2, and CW3 for HRT of 20 min and then samples were collected from the outlet points of all three CW beds. Further treated

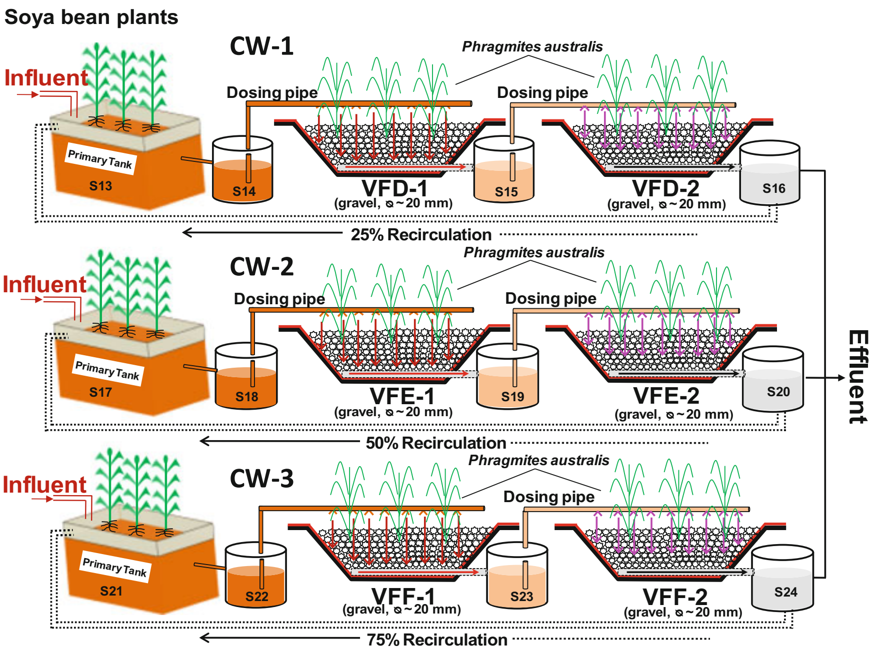



**Fig. 1** Design of vertical subsurface constructed wetland system

water from the collecting tanks was recirculated back to their respective recirculation tanks located before first bed of CW units. Recirculation tanks contained soybean floating bed prepared using bamboo stick and PVC pipes (Fig. 1). Recirculation pattern was followed as: 25% in CW1, 50% in CW2, and 75% in CW3, respectively. Similar dosing pattern was followed in all CW units, and samples were collected.

## *2.3 Laboratory Experiments*

Physical parameters such as pH, temperature, ORP, EC, TDS, salinity were recorded in the field during sampling using multiparameter system (Hach SensION + MM150) and DO was measured using DO meter of model no. DRB 200 (Hach) in the field during sampling. Other parameters such as TSS, BOD, COD, total nitrogen (TN), $NH_4$-N, $NO_3$-N, and total phosphorous (TP) were analyzed in the laboratory by using standard methods of analysis [11] and Hach manual.

The efficiency of each CW unit for each parameter was calculated using the following formula:

$$\text{Removal Rate}(\%) = (\text{Inlet Load} - \text{Outlet Load}) * 100/\text{Inlet Load} \tag{1}$$

$$\text{Purification rate}(\%) = (C_\text{i} - C_\text{o}) * 100/C_\text{i} \tag{2}$$

where $C_\text{i}$ = Inlet concentration (mg $L^{-1}$); $C_\text{o}$ = Outlet concentration (mg $L^{-1}$)

$$\text{Load}\left(\text{gm}^{-2}\text{day}^{-1}\right) = [\text{Wastewater volume dosed (L)} \times \text{conc.}\left(\text{mgL}^{-1}\right)/1000]/\text{area of CW unit}\left(\text{m}^2\right) \tag{3}$$

## 3 Results and Discussion

In all CW units, arrangement for partial recirculation of treated water from collecting tanks to inlet tank was done to determine appropriate recirculation rate for achieving maximum removal of pollutants. All the three CW units showed a remarkable decrease in average concentrations of pollutants such as BOD, COD, TP, $NH_4$-N, $NO_3$-N, and TN.

### *3.1 Effect of Recirculation on BOD, COD, and TP*

BOD mainly reflects the amount of organic matter present in wastewater. It is removed in form of suspended solids which settle over filter media surface and also by microbial activity which occurs due to microbial biofilms formed around the filter media. Vertical flow CW system shows good removal of BOD as per several previous studies [12]. In this study, BOD in influent ranged between 176.0 and 619.0 mg $L^{-1}$ during the entire study period. Average BOD concentration in influent was recorded as 323.3 ± 139.3 mg $L^{-1}$. Average BOD concentration at the outlets ranged from 81.0 to 40.0 mg $L^{-1}$ in all the CW units. After recirculation, BOD concentrations were further decreased and recorded between 28.0 and 20.0 mg $L^{-1}$ at final outlets. Maximum decrease of 73.3 ± 33.5 mg $L^{-1}$ in BOD concentration was observed in CW3 with 75% recirculation rate. BOD purification rates of all the CW units fluctuated between 50.0 and 92.0% during the entire study period. Average BOD purification rates varied between 73.0 and 74.0% in all the units before recirculation. After recirculation, all units showed good removal of BOD between 81.0 and 87.0% while CW3 unit with 75% recirculation rate was found to be most appropriate in achieving maximum BOD removal of 87.0%. Average BOD load in the influent was recorded as 17.8 ± 7.7 g $m^{-2}$ $day^{-1}$ while in the effluents, the average load decreased and was recorded between 4.5 ± 1.9 and 4.0 ± 1.8 g $m^{-2}$ $day^{-1}$ before recirculation. After recirculation, BOD load in the effluents was further decreased and was found to be in the range of 3.2 ± 1.5–2.2 ± 0.9 g $m^{-2}$ $day^{-1}$ (Fig. 2).

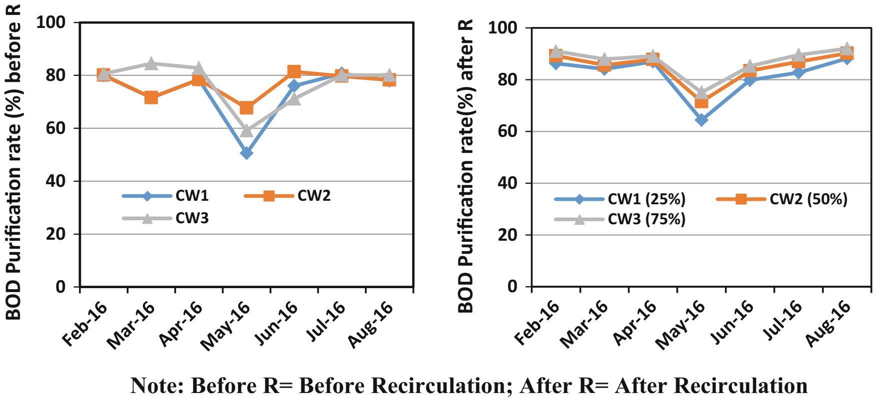



**Fig. 2** Effect of recirculation on BOD purification rate in CW1, CW2, and CW3 units

COD load in dairy influent was recorded between 14.5 and 56.0 g $m^{-2}$ $day^{-1}$. Average load in influent was found as 27.4 ± 13.3 g $m^{-2}$ $day^{-1}$ while average load in effluents was recorded between 6.5 and 5.9 g $m^{-2}$ $day^{-1}$ before recirculation. COD is mainly removed by combination of physical and microbial processes where physical process contributes about 50–70% while microbial process about 20–50% removal. Inside the wetland bed, gravel media allows accumulation of large number of microbes which are entirely responsible for catalyzing chemical reactions [13]. After recirculation, load decreased from 4.9 to 3.4 g $m^{-2}$ $day^{-1}$ and minimum COD load was observed in CW3 unit with 75% recirculation rate. During this study, the average COD purification rate was found between 74.0 and 77.0% in CW units before recirculation while after recirculation, average purification rate was recorded between 81.0 and 87.0% at the outlets. Maximum removal of 91.0 ± 5.5% was observed in CW3 unit with 75% recirculation arrangement.

TP concentration in dairy influent was observed to occur between 16.0 and 50.0 mg $L^{-1}$ while treated water showed TP concentration between 3.4 and 31.4 mg $L^{-1}$ before recirculation. Average concentration in effluents was observed between 16.8 and 14.8 mg $L^{-1}$ before recirculation while after recirculation, there was a remarkable decrease in TP concentration, i.e., between 7.3 and 5.5 mg $L^{-1}$. Minimum concentration was recorded in CW3 unit with 75% recirculation rate. Precipitation, adsorption, complexation reaction, and plant uptake are the processes that are responsible for phosphorous [14]. In a similar study, there was a sharp decrease in TP concentration in the influent. Average TP purification rate was ranged between 55.4 and 63.0% before recirculation while purification rate increased after recirculation in all CW units, i.e., recorded between 81.0 and 85.0%. Maximum removal of phosphorous was recorded at 75% recirculation in CW3 unit. In a similar study carried out by [15], TP removal was recorded as 41.8, 60 and 67.3% for recirculation ratio of 1:1, 1:2, and 1:3, respectively in subsurface VFCW.

### 3.2 Effect of Recirculation on $NO_3$-N, $NH_4$-N, and TN

In dairy wastewater, nitrogen occurs organic and inorganic forms and removal of these forms takes place by nitrification–denitrification reactions, plant absorption, and ammonium nitrogen volatilization [16]. Plant uptake is a very important process responsible for nitrogen removal as they directly uptakes the contaminants into their root structure, through a process called as phytodegradation [17]. Microbial activities play very important role in the inorganic nitrogen removal. Microorganisms in wetland capture soil and store nutrients and are more crucial in organic pollutant removal. The bacteria utilizes the carbon found in organic matter as an energy source and transforms it to carbon dioxide under aerobic conditions while into methane when the conditions are anaerobic [18]. Average $NO_3$-N concentration was recorded as 2.9 ± 2.1 mg $L^{-1}$. Maximum increase in $NO_3$-N concentration was 17.4 ± 2.3 1 mg $L^{-1}$ was in CW3 unit with 75% recirculation arrangement. Dairy influent showed $NH_4$-N concentration between 38.4 and 76.0 mg $L^{-1}$, whereas average concentration of $NH_4$-N in influent was recorded as 68.9 ± 13.5 mg $L^{-1}$. There was a significant decrease in $NH_4$-N concentration during the study period. Treated effluents showed an average $NH_4$-N concentration between 32.0 and 24.0 mg $L^{-1}$ in the outlets before recirculation. Minimum concentration was recorded in CW3 unit with 75% recirculation rate. Average $NH_4$-N purification rate varied between 53.0 and 65.0% in all the units before recirculation whereas after recirculation the purification rate ranged between 66.0 and 83.0% in all units. Among all the three units, maximum purification was recorded in CW3 unit with 75% recirculation rate (Fig. 3).

Average total nitrogen (TN) concentration in dairy influent was recorded between 64.0 and 127.0 mg $L^{-1}$. Before recirculation, the concentration of TN in effluents was observed between 22.0 and 83.0 mg $L^{-1}$, whereas after recirculation, TN concentration showed a considerable decrease in all CW units. Part of TN in the influent is removed by plant uptake and microorganisms and some amount is lost through adsorption, volatilization, and denitrification. [19]. Denitrification occurs in anoxic areas of VF bed [20]. Average concentration of TN in treated water ranged

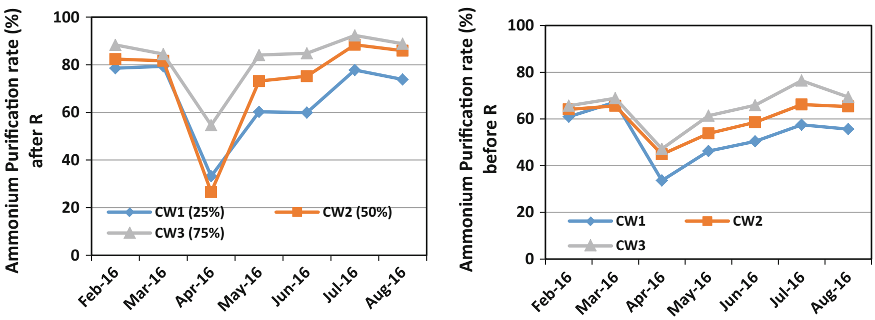



Fig. 3 Effect of recirculation on ammonium purification rate in CW1, CW2, CW3 units

between 55.0 and 40.0 mg $L^{-1}$ before recirculation and after recirculation the concentration further decreased to 43.0–24.0 mg $L^{-1}$. Minimum concentration was recorded in CW3 with 75% recirculation arrangement. All CW units showed good TN purification efficiency during the entire assessment period. Average purification rate was recorded in the range of 53.0–65.0% in all the three CW units before recirculation while after recirculation, the purification rate was achieved between 64.0 and 80.3%. Maximum removal of TN was recorded in CW3 at 75% recirculation rate. In a similar study, it was observed that in a recirculating VFCW system, nitrification process is responsible for decreasing ammonium nitrogen from 80 to 4.9 mg $L^{-1}$ and TN from 93 to 19.1 mg $L^{-1}$ and the final concentration of nitrate was recorded as 14.2 mg $L^{-1}$ [21] (Fig. 4).

### 3.3 Oxygen Transfer Rate (OTR)

OTR determines the amount of atmospheric oxygen essential for aerobic degradation of organic matter and for nitrification of $NH_4$-N. OTR can be calculated using following equation:

$$\begin{aligned} \mathrm{OTR}\left(\mathrm{g\ O_2 m^{-2} d^{-1}}\right) = \mathrm{Flow\ rate}\ [(\mathrm{BOD_{in}} - \mathrm{BOD_{out}}) \\ + 4.3(\mathrm{NH_4} - \mathrm{N_{in}} - \mathrm{NH_4} - \mathrm{N_{out}})/\mathrm{Bed\ Area} \end{aligned} \quad (4)$$

In a previous study, it was observed that OTR values ranged between 16.0 and 32.0 g $O_2$ $m^{-2}$ $d^{-1}$ in different CW systems utilized in treating dairy wastewater [22]. In the present study, OTR value fluctuated from 40.0 to 77.0 g $O_2$ $m^{-2}$ $d^{-1}$ in all CW units before recirculation while average OTR was recorded in the range of 52.0–62.0 g $O_2$ $m^{-2}$ $d^{-1}$ before recirculation. But after recirculation, there was a significant increase in OTR value of finally treated water and observed between 86.0 and 163.0 g $O_2$ $m^{-2}$ $d^{-1}$ in all CW units and average OTR values of these

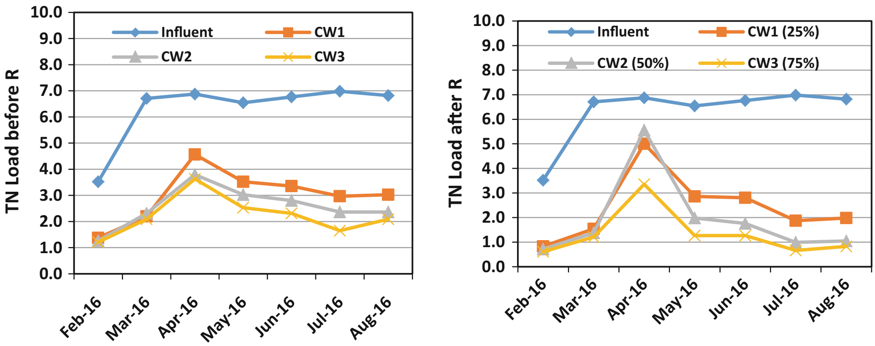



**Fig. 4** Effect of recirculation on TN load in CW1, CW2, and CW3 units

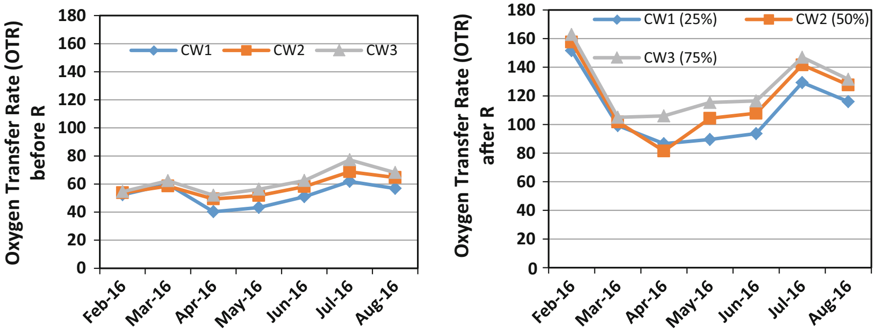



**Fig. 5** Effect of recirculation on oxygen transfer rate in CW1, CW2, and CW3 units

units were in the range of 109.0–126.0 g $O_2$ $m^{-2}$ $d^{-1}$. OTR depends on factors such as influent load fluctuations (BOD, $NH_4$-N load), hydraulic loading rates. [23] (Fig. 5).

## 4 Conclusion

All the three CW units showed good efficiency for pollutant removal at all the three recirculation rates, i.e., 25, 50, and 75%. Mechanisms such as nitrification, denitrification, plant root absorption, microbial activities are some of the important processes responsible for purification of wastewater. It has been observed that in this study, the roots of the plant (*Phragmites australis*) showed excessive branching inside the bed which resulted in better aeration. Thus, there was efficient organic matter degradation. This paper discusses the significance of effluent recirculation because recirculation leads to addition of oxygen for aerobic microbial activities that can be transferred into wastewater and is repeatedly pumped and redistributed so that there is maximum removal of pollutants. This operation has shown benefits to the treatment by enhancing interactions between pollutants in wastewater and microorganisms attached to the roots of plants and surface of gravels. On the basis of the present research work, maximum removal of pollutants was achieved by CW unit with 75% recirculation arrangement. Thus, it can be concluded that a CW system filled with 20 mm gravel and 75% recirculation arrangement can be used efficiently for achieving better removal of pollutants from dairy wastewater.

**Acknowledgements** This project was funded by Department of Biotechnology, Ministry of Science and Technology, Govt. of India under sanction no. 102/IFD/SAN/5429/2013–2014 on 19/03/2014. Authors wish to express deepest gratitude toward DBT for providing funds for carrying out experimental works and Graphic Era University, Dehradun, for financial assistance for construction of wetland units and infrastructure facilities.

## References


1. Munavalli, G.R., Saler, P.S.: Treatment of dairy wastewater by water hyacinth. Water Sci. Technol. **59**(4), 713–722 (2009)
2. Brix, H., Schierup, H.-H.: The use of macrophytes in water pollution control. Ambio **18**, 100–107 (1989)
3. Imfeld, G., Braeckevelt, M., Kuschk, P., Richnow, H.H.: Monitoring and assessing processes of organic chemicals removal in constructed wetlands. Chemosphere **74**, 349–362 (2009)
4. Stefanakis, A.I., Akratos, C.S., Tsihrintzis, V.A.: Effect of wastewater step-feeding on removal efficiency of pilot-scale horizontal subsurface flow constructed wetlands. Ecol. Eng. **37**, 431–443 (2011)
5. Hiley, P.D.: The reality of sewage treatment using wetlands. Water Sci. Technol. **32**(3), 329–338 (1995)
6. Brix, H., Arias, C.A., Johansen, N.H.: BOD and nitrogen removal from municipal wastewater in an experimental two stage vertical flow constructed wetland system with recycling. In: Proceedings of the Eighth International Conference on Wetland Systems for Water Pollution Control, Arusha, Tanzania, pp. 400–410. 16–19 Sept (2002)
7. Brix, H., Arias, C.A., Johansen, N.H.: Experiments in a two-stage constructed wetland system: nitrification capacity and effects of recycling on nitrogen removal. In: Vymazal, J. (ed.) Wetlands—Nutrients, Metals and Mass Cycling, pp. 237–258. Backhuys Publishers, Leiden, The Netherlands (2003)
8. Marti, E., Arias, C.A., Brix, H., Johansen, N.H.: Recycling of treated effluents enhances reduction of total nitrogen in vertical flow constructed wetlands. Publicationes Instituti Geographici Universitatis Tartuensis **94**, 150–155 (2003)
9. Arias, C.A., Brix, H., Marti, E.: Recycling of treated effluents enhances removal of total nitrogen in vertical flow constructed wetlands. J. Environ. Sci. Health A Toxic/Hazard. Subst. Environ. Eng. **40**(6–7), 1431–1443 (2005)
10. Arias, C.A., Brix, H., Johansen, N.H.: Phosphorous removal from municipal wastewater in an experimental two-stage vertical flow constructed wetland system. Water Sci. Technol. **48**(5), 51–58 (2003)
11. American Public Health Association. Standard Methods for the examination of Water & Wastewater. (1999)
12. Cooper, P.: The performance of vertical flow constructed wetland systems with special reference to the significance of oxygen transfer and hydraulic loading rate. In: Proceedings of the Ninth International Conference on Wetland Systems for Water Pollution Control, pp. 153–160. Avignon, France (2004)
13. Lee, C.-Y., Lee, C.-C., Lee, F.-Y., Tseng, S.-K., Liao, C.-J.: Performance of subsurface flow constructed wetland taking pretreated swine effluent under heavy loads. Bioresour. Technol. **92**, 173–179 (2004)
14. Watson, J., Reed, S., Kadlec, R., Knight, R., Whitehouse, A.: Performance expectations and loading rates for constructed wetlands. In: Hammer, D.A. (ed.) Constructed Wetlands for Wastewater Treatment. Municipal, Industrial and Agricultural, pp. 319–358. Lewis publishers, Chelsea, Michigan (1989)
15. Lavrova, S., Koumanova, B.: Applied Bioremediation—Active and Passive Approaches. Nutrients and organic matter removal in a vertical-flow constructed wetland dx.doi.org/10.5772/56245 (2013)
16. Wang, Xia: Progress on the nitrogen removal mechanism in surface flow constructed wetland. Electr. Power Environmen. Prot. **23**(2), 47 (2007)
17. Interstate Technology & Regulatory Council Technical & Regulatory Guidance for Constructed Treatment Wetlands. United States Environmental Protection Agency (2003)
18. DeBusk, W.F.: Wastewater Treatment Wetlands: Contaminant Removal Processes. Soil and Water Science Department, University of Florida. SL155 (1999)

19. Vymazal, J., Kropfelova, L.: Wastewater treatment in constructed wetlands with horizontal sub-surface flow. Springer, Netherlands (2008)
20. Cooper, P.F., McBarnet, W., O'Donnell, D., MacMahon, A., Houston, L., Brian, M.: The treatment of run-off from a fertilizer factory for nitrification, denitrification and P removal by constructed wetlands: a demonstration study. Water Sci. Technol. **61**(2), 355–363 (2010)
21. Garcia-Perez, A., Grant, B., Harrison, M.: Water quality effluent from a recirculating vertical flow Constructed Wetland. Small Flow Q. **7**(4), 34–38 (2006)
22. Kato, K., Inoue, T., Ietsugu, H., Koba, T., Sasaki, H., Miyaji, N., Kitagawa, K., Sharma, P.K., Nagasawa, T.: Performance of six multi-stage hybrid wetland systems for treating high-content wastewater in the cold climate of Hokkaido, Japan. Ecol. Eng. **51**, 256–263 (2013)
23. Sharma, P.K., Takashi, I., Kato, K., Ietsusgu, H., Tomita, K., Nagasawa, T.: Effects of load fluctuations on treatment potential of a hybrid sub-surface flow constructed wetland treating milking parlor wastewater. Ecol. Eng. **57**, 216–225 (2013)

# Diatom Flora in Natural and Regulated Stretch of River Tons and Yamuna: Determining the Impacts of Hydropower Projects on the River Ecosystem

**Swati Sharma, Rachna Nautiyal and Prakash Nautiyal**

## 1 Introduction

Through hydro-technical regulation, the water of montane streams and rivers can be utilized to produce electricity but at the same time, these regulating projects interfere, disturb and fragment the lotic ecosystem. The flow regulated by the creation of a barrage/dam is an important factor to affect the biota, their diversity and the communities in rivers. Natural environmental conditions and habitat in the stream are always upset by the hydro-technical development which altered the biocoenosis whose value is sometime unique in biological sense. The current state of knowledge indicates that the impact of dams on ecosystems depends on the scale of development; however, it is mostly negative, intricate, and intellectually deep [1, 2]. There is much literature on the effects of dams and other regulating structures [3–9]. Variations in diatom community due to dam have received attention [10–13] but changes in the flora due to dams in the Himalayan Rivers are scarcely known. Hence, a study was designed to determine the variations in diatom flora with respect to natural upstream stretch and the regulated stretch consisting of impounded area and downstream stretch of the dam of rivers Tons and Yamuna.

**Electronic supplementary material** The online version of this chapter (doi:10.1007/978-981-10-7122-5_8) contains supplementary material, which is available to authorized users.

S. Sharma (✉) · R. Nautiyal
RUSA, Higher Education, Govt. of Uttarakhand, Dehradun, India
e-mail: swatisharma9381@gmail.com

P. Nautiyal
Department of Zoology & Biotechnology, H.N.B. Garhwal University,
Srinagar 246174, Uttarakhand, India



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_8

## 2 Materials and Methods

The present investigations were carried out to determine the impacts of the Hydropower projects (HPP) on the River Yamuna and its tributary the Tons. The Koti dam regulates the river Tons while the Dakpathar Barrage regulates the Yamuna after confluence with the Tons. Koti dam diverts water to the Chibro Power House (240 MW) which is then returned to the Tons River before being fed to the Khodri Power House (120 MW) which ultimately flows into the pondage area of Dakpathar Barrage on the river Yamuna. The Dakpathar Barrage serves to divert the water into the East Yamuna Canal for hydroelectric power production at the Dhakrani and Dhalipur Power Plants, located at 10 and 14 km, respectively, from Dakpathar. The dominant substratum was cobble and pebble at T1, cemented wall at both the regulated sections of each river T2 and Y2, sandy with small cobble and pebble at T3, rock and boulder were dominant substratum at T4 and the upstream section of Yamuna Y1 and boulder and pebble were dominant at Y3.

Geographical coordinates of sampling locations varied for Tons from 30° 38′ 40.67″ to 30° 31′ 46.95″N, 77° 47′ 09.67″ to 77° 49′ 29.96″E and 740 to 472 m asl and for the Yamuna from 30° 30′ 42.2″ to 30° 26′ 40.57″N; 77° 50′ 01.06″ to 77° 40′ 42.75″E and 469 to 400 m asl (Fig. 1).

## 3 Results

The unregulated and regulated part of the rivers Tons and Yamuna harbors 116 species from 24 genera and 144 from 28 genera, respectively; ninety-six (96) taxa from 21 genera were observed at T1, 59 taxa from 18 genera at T2, 63 taxa from 15 genera, and 69 taxa from 15 genera at T3 and T4, respectively. For Yamuna, 65 of 15 genera at Y1, 30 of 12 at Y2, and maximum at Y3 141 of 26 genera (Fig. 2). The number of taxa was observed to vary and decline from T1 to T4 but increased at Y1 to Y3. The flora differed among the stations as only 42 taxa from 14 genera were common to all four locations of river Tons and 26 taxa from 10 genera to the locations of river Yamuna. Seventeen (17) taxa for river Tons and 39 taxa for river Yamuna were totally absent in the regulated impounded section (T2, Y2) of each river (Appendices 1 and 2).[1]

Some species restricted to T1 and were not observed at T2, T3, and T4. Additional species were observed at T2 or T3 or T4, some of which were common to these three sites. Four genera *Denticula, Hantzschia, Hippodonta*, and *Adlafia* were present only at T1. *Cymbopleura* (T1, T3), *Gyrosigma, and Cyclotella* were present at 2 locations (both at T1, T2). *Didymosphenia* and *Melosira* were restricted to T2, and *Craticula* was present only at T4. For river Tons, thirty (30) taxa present only u/s of dam were totally absent at T2, 3 and 4. These included 5 taxa each for

[1]Not for print only for online viewing.

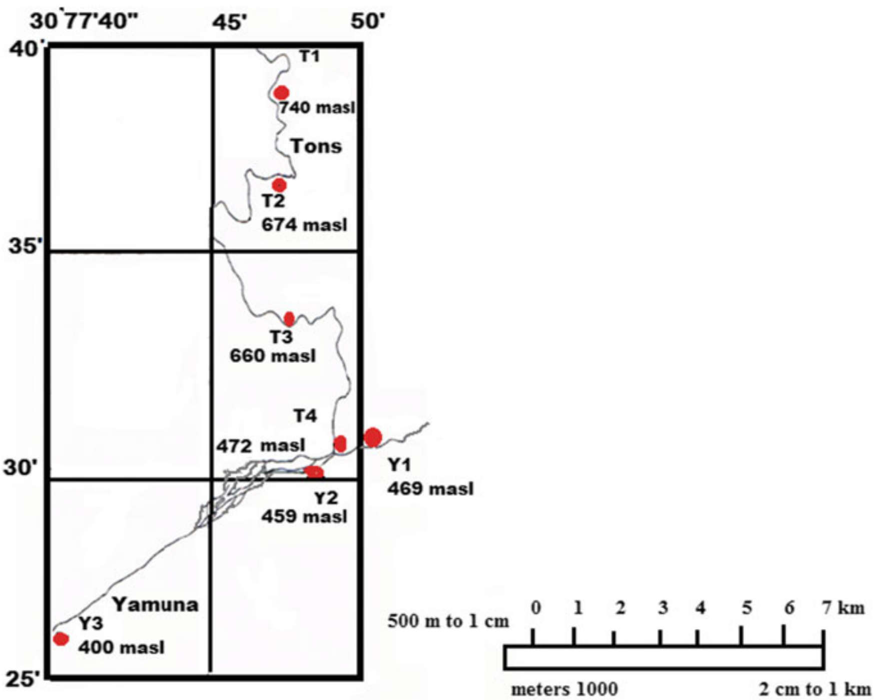



**Fig. 1** Samplings locations of river Tons and river Yamuna

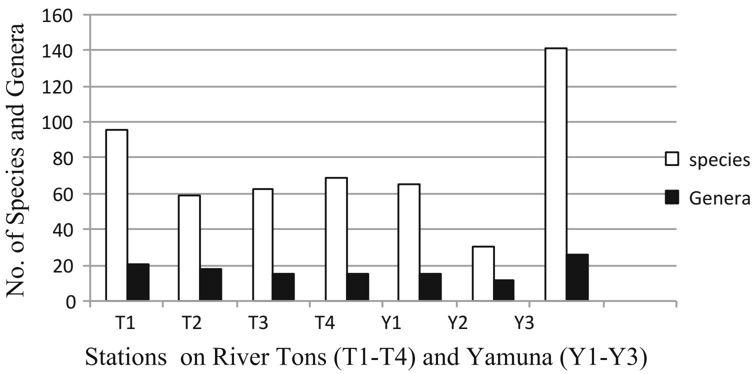



**Fig. 2** Number of species and genera of all locations of river Tons and river Yamuna

*Gomphonema* and *Nitzschia*, 4 for *Navicula*, 3 for *Cymbella* 2 each for *Achnanthidium*, *Denticula,* and *Cymbopleura* while 1 each for *Fragilaria*, *Achnanthes*, *Cocconeis*, *Hantzschia*, *Hippodonata*, *Adlafia*, and *Planothidium*. Different from these 30 species, another 17 taxa showed discontinuous distribution since they were found at T1, disappeared at T2 but reappeared at T3 and T4. These belonged primarily to *Cymbella* (8 taxa) followed by *Achnanthidium* (5), *Navicula* (3), and *Cocconeis* (1) (Appendix 1).[2]

Nineteen (19) taxa along with 2 new genera were recorded at T2 and downstream of dam (T3, 4). Among these species, the maximum (7) additional species were found at T4 followed by T2 (5) and T3 (3), respectively. Four (4) species were recorded at all the two sites below the dam *Synedra nana* (Meister), *Cymbella reichardtii* (Krammer), *Cymbella leptoceros* (Ehrenberg) Kützing, and *Gomphonema pseudotenellum* (Lange-Bertalot). All the above species recorded either at dam or d/s of dam and were absent at T1. The following 8 taxa were present at u/s of dam, at dam and D/s of dam either in continuation at T3 or in discontinuation at T4; *Fragilaria construens* forma *venter* (Ehrenberg) Hustedt, *Planothidium fragilarioides* (J.B. Petersen) Round & Bukhtiyarova, *Achnanthidium exilis* (Kützing), *Cymbella turgidula* var. *bengalensis* (Krammer), *Gyrosigma accuminatum* (Kützing) Rabenhorst, *Navicula gregaria* (Donkin), *Sellaphora parapupula* Lange-Bertalot, *Cyclotella meneghiniana* (Kützing). The genera *Didymosphenia* and *Melosira* occurred only at T2.

For river Yamuna, 39 diatom taxa that occurred at upstream unregulated section (Y1) disappeared at impounded section and again appeared at downstream section Y3. These taxa mostly belong to genera *Cymbella* (8), *Achnanthidium, Navicula* (7 for each), and *Achnanthes*, *Nitzschia* (5 for each). Seventy-nine (79) additional taxa were recorded at Y2 and Y3 not observed at Y1. Among them, 75 species were recorded only at Y3 included maximum 9 taxa for *Nitzschia* and *Achnanthes* followed by *Cymbella* and *Navicula* 8 for each, 7 for *Gomphonema*, 5 for *Achnanthidium*, 3 for *Synedra*, 2 each for *Fragilaria*, *Eunotia*, *Planothidium*, *Cocconeis*, *Cymbopleura*, *Pinnularia*, *Sellaphora*, *Surirella,* and *Melosira* while 1 each for *Diatoma*, *Amphora*, *Encyonopsis*, *Craticula*, *Luticola*, *Opephora*, *Stauroneis,* and *Cyclotella*. Some genera *Amphora*, *Encyonopsis*, *Craticula*, *Luticola*, *Opephora*, *Stauroneis*, *Eunotia*, *Cymbopleura*, *Pinnularia,* and *Surirella* were also restricted to Y3. Three (3) species *Encyonema minutum* (Hilse in Rabh) Mann, *Fragilaria capucina var. vaucheriae* (Kützing) Lange-Bertalot, *and Rossithidium lineare* (W. Smith) Round & Bukhtiyarova were found only at Y2 and only one diatom taxa *Nitzschia hantzschiana* was common to Y2 and Y3 (Appendix 2).[3]

## 4 Discussion

There have been extensive studies of algal assemblages in large temperate zone rivers of Europe and North America [14] regulated systems in arid and semiarid zone rivers [15, 16] with less research on large unregulated rivers. Diatom

[2]Not for print only for online viewing.

[3]Not for print online for online viewing.

communities have been modified by the barriers that hold or divert the flow and that mainstream reservoirs do change the quality and composition of the aquatic flora [17, 18]. Changes occur in diatom communities and benthic diatom densities due to river regulation of the Ganga in the foothills between Rishikesh and Hardwar [11, 19]. Differences occur in the periphytic diatoms between regulated and unregulated sites in the Hawkesbury River–Nepean River system in Australia.

The present study examines the impact of river regulation on the diatom flora of mountain rivers, Tons and Yamuna. The impact has been studied by comparing the unregulated stretch of the rivers at T1, Y1, much U/s of the dam site at T2, Y2 and the regulated locations (T3, T4, and Y3) considerably D/s of the dam. Thus, changes in the flora have been examined in a stretch of 28 km of Tons and 25 km of Yamuna. The study revealed a general decline in the diatom flora of the river Tons from unregulated (T1) to regulated (T2, T3, T4) stretch. A noticeable decline occurred from T1 (96 species from 21 genera) to T2 (59 from 18 genera) as the dam ceases the flow and inundation above the dam creates a deep column of water that obliterates suitable habitats created by a combination of substrate, shallow to moderate depth, and swift current velocities. The regulated river sections (T3, T4) that sustain shallow water except for few deeper pools gain some flora (63 from 15 genera, and 69 from 15 genera at T3 and T4, respectively) attributed to seepage and small tributaries that augment flow in the main channel. In river Yamuna, the number of genera and species declines from Y1 to Y2 due to impoundment (65 from 15 genera at Y1 and 30 species from 12 genera at Y2). However, the richness nearly doubles downstream of the barrage at Y3 (141 species of 26 genera). The difference may be due to the fact that barrage causes shallow and frequently fluctuating water column.

Some diatom taxa were sensitive to change in flow among them 30 diatom taxa (type 1) occurred only at unregulated section of Tons T1, as they were absent at all d/s stations. These seem to be true riverine forms found only in natural river courses and are hence sensitive forms. Their presence at T1 only suggests that they cannot tolerate habitat modification and hence fail to appear not only at the highly modified dam site T2 but also at partially modified/impacted T3 and T4, where the river is regulated. However, type-2 sensitive taxa were occurred only at regulated section of each river, 19 for Tons (T2–T4) and 75 for Yamuna (Y3) attributed to new habitats by combination of substrate and flow. Also, the river course changes at T3 and T4 in respect of T1 and T2 as the river approaches the mouth zone and in the case of barrage, the embankment is sloping and stony wall and is more prone to disturbances due to shallow condition along with the fact that a lot of human activity that becomes a source of eutrophication.

Besides, there were some taxa (8 taxa) present at T1, at dam (3) either in continuation at T3 (4) or in discontinuation at T4 (1). This is more likely due to habitat preferences. Since the morphometric and substrate conditions are similar at T1 and T2, the latter though modified, the taxa found at both locations were absent either at T3 or T4, where habitats modify and change due to difference in substrate conditions rather than flow conditions.

The river regulation did not altogether change the floral elements. Thus, some of the taxa were common at all stations. Among the 116 taxa observed from T1 to T4 and 144 taxa from Y1 to Y3, only 42 and 26 diatom taxa were common to these stations, respectively, implying substantial loss of flora. It is noteworthy that the taxa present at unregulated stretch occurred at highly modified dam site or regulated section. Their continuous presence at all stations indicates that they are highly tolerant to flow variation and capable of growing on wide-ranging substrate conditions including the artificial substrate (dam) and variable flow conditions (torrential to stagnant) due to dam at T2 and Y2 which holds back most of the flow. It must also be noted that riverine habitats are lost at impounded section and modified at T3 and T4 and Y3 as flow is restricted to a small part of the channel exposing most of the substrate and hence the habitats. seventeen (17) taxa for river Tons and 39 taxa for Yamuna were moderately tolerant showed discontinuous distribution by virtue of their absence at T2 and Y2 only. It appears that flow is important for these taxa and they can inhabit modified habitats provided the water flows, implying sensitivity to flow. Also, these are taxa that tolerate some modification but cannot withstand inundation.

*Encyonema lacustre* (C. Agardh) Pantocsek, *Diatoma vulgare* (Bory) and *C. tumida* (Brébisson) Van Heurck recorded [8] in the unregulated section only in contrast to dominance of *A. minutissima* (Kützing) Czarnecki in both, regulated and unregulated sections of the Ganga in foothills. *Amphora granulata* (Gregory) are typical of the regulated rivers of the Murray–Darling basin today compared with *Cyclotella stelligera* (Cleve & Grunow) Van Heurck before regulation, when it was oligotrophic [20]. In present study, *Cyclotella meneghiniana* (Kützing) was found at both at unregulated and impounded regulated site, but not in the d/s regulated section. *C. meneghiniana* was absent 25.7 km below the Cow Green Dam but became frequent at 78.8 km attributed to inocula received from Lunedale Reservoirs [21]. *Achnanthidium minutissimum* (Kützing) Czarnecki, *Cocconeis pediculus* (Schumann) Cleve, *Cocconeis placentula* (Ehrenberg), and *N. cryptocephala* (Kützing) various species were observed in regulated Durance [22]. These species were present in the unregulated as well as regulated stretch d/s of the dam in the Tons. However, *C. leptoceros*observed in the regulated Durance was present only in the regulated d/s section of the Tons.

## 5 Conclusion

For electricity generation, the rivers in mountain are considered most cost-effective because the mountains are natural embankments on both sides of the river and only one barrier across the flow of the river can help to store or divert the water.

The dam on the Tons River caused a general decline in the number of genera and species in the downstream regulated section in respect of the reference location (T1) upstream of the dam. The decline was higher in the impounded zone T2 as compared with upstream and downstream stations of the river. Due to the barrage on

Yamuna, the species decreased at regulated section Y2 but increased at downstream of barrage Y3. After T2 and Y2, the water releases in a carefully controlled manner and the flow of river was obstructed by capturing high river flows as a consequence of this water control, river flows below dams (T3, T4, Y3) commonly bear little resemblance to their historical variability due to this the diatom flora has changed at T3, T4, and Y3.

**Acknowledgements** First two authors acknowledge the academic support extended by the Principal, Government PG College, Dakpathar, Vikasnagar. Other authors acknowledge institutional support.

## References

1. Graf, W.L.: Dam nation a geographic census of American dams and their large-scale hydrologic impacts. J. Water Resour. Res. **4**, 1305–1311 (1999)
2. Adams, W.: Downstream impacts of dams. World Commission on Dams. (2000). http://www.dams.org/docs/kbase/contrib/soc195pdf
3. Walker, K.F.: Regulated streams in Australia the Murray-Darling system. In: Ward, J.V., Standford, J.A. (eds.) The Ecology of Regulated Rivers. 143–163. Plenum Press, New York (1979)
4. Ward, J.V., Stanford, J.A.: The Ecology of Regulated Streams. Plenum Press, New York (1995–1979)
5. Petts, G.E.: Impounded Rivers Perspectives for Ecological Management, p. 322. Wiley, Chichester England (1984)
6. Walker, K.F.: A review of the ecological effects of river regulation in Australia. J. Hydrobiol. **125**, 111–129 (1985)
7. Thomas, M.C., Walker, K.F.: Channel changes related to low-level weirs on the River Murray South Australia. In: Carking, P.A., Petts, G.E. (eds.) Lowland Floodplain Rivers Geomorphological Perspectives, pp. 236–249. Wiley, Chichester, England (1992)
8. Growns, I., Growns, J.: Ecological effects of flow regulation on macroinvertebrate and periphytic diatom assemblages in the Hawkesbury-Nepean River Australia. J. Regul. River **17**, 275–293 (2001)
9. Vallania, A.E., Corigliano, M.C.: The effect of regulation caused by a dam on the distribution of the functional feeding groups of the benthos in the sub basin of the Grand River (Sanluis, Argentina). J. Environ. Monit. Assess. **124**, 201–209 (2007)
10. Ross, E., Rushforth, S.R.: The effect of new reservoir on the attached diatom communities in Huntington Creek Utah USA. J. Hydrobiol. **68**, 157–165 (1980)
11. Badoni, K., Nautiyal, R., Bhatt, J.P., Kishor, B., Nautiyal, P.: Variations in epilithic diatom community structure due to river valley projects on the Ganga between Rishikesh and Hardwar. Proc. Indian Nat. Sci. Acad. B. **63**, 527–540 (1997)
12. Martina, L.C., Principe, R., Gari, N.: Effect of a dam on epilithic algal communities of a mountain stream before-after dam construction comparison. J. Limnol. **72**(1), 79–94 (2013)
13. Li, Y.R., King, O.D., Shorter, J., Gitler, A.D.: Stres granules as crucibles of ALS pathogenesis the Rock efeller. J. cell Biol. **20**(3), 361–372 (2013) (University press)
14. Wehr, J.D., Descy, J.P.: Use of phytoplankton in large river management. J. Phycol. **34**, 741–749 (1998)
15. Bertrand, J., Mars, A., Boyle, C., Bove, F., YearginAllsopp, M., Decoufle, P.: Prevalence of autism in a United States population. The Brick Township New Jersey investigation. Pediatrics **108**, 1155–1161 (2001)

16. Blinn, D.W., Shannon, J.P., Benenati, P.L., Wilson, K.P.: Algal ecology in tail water stream communities The Colorado River below Glen Canyon Dam Arizon. J. phyco. **l34**, 734–740 (1998)
17. Holmes, N.H.T., Whitton, B.A.: Phytoplankton of four rivers the Tyne, Wear, Tees and Swale. Hydrobiologia **5**, 257–289 (1981)
18. Lowe, R.L.: Phytobenthic ecology and regulated streams. J. In: Ward, J.V., Stanford, J.A. (eds.) The Ecology of Regulated Streams, pp. 25–34. Plenum Press, New York (1979)
19. Nautiyal, P., Nautiyal, R., Rawat, V.S., Bhatt, J.P., Kishor, B.: Variations in density of diatoms (phytobenthos) in impounded section of river Ganga. J. In: Grover, I.S., Thukral, A. K. (eds.) Environment & Development. pp. 237–239. Scientific Publishers Jodhpur, India (1997)
20. Gell, P., Little, F.: Water Quality History of Murrumbidgee River Floodplain Wetlands. A Report for the Murrumbidgee Catchment Management Authority, Land & Water Australia (2007)
21. Whitton, B.A., Crisp, D.T.: Tees. In: Whitton, B.A. (ed.) The Ecology of European Rivers, pp. 145–178. Blackwell Science Publication, Oxford (1984)
22. Comte, K., Cazaubon, A.: Structural variations of epiphytic diatom communities on three macrophytes in a regulated river (Durance) in South-East of France. Ann. J. Limnol. **38**, 297–305 (2002)

# Safety and Occupational Health Hazards of Agricultural Workers Handling Pesticides: A Case Study

**Dev Kumari and Siby John**

## 1 Introduction

Insecticides, fungicides and herbicides used to kill/control pests such as insects, fungi and weeds are commonly called as agrochemicals, and according to WHO, all these chemicals are designated under the broad classification of pesticides [1]. As these chemicals are extensively used in agricultural activities in India, the agricultural workers handling these chemicals possess a fair occupational health hazard [2]. India is the largest producer of pesticides in Asia and ranks 12th worldwide for the application of pesticides [3]. Although application of agrochemicals leads to the enhancement of crops production, it deteriorates the environment and affects human health [4]. According to International Labour Organization (ILO), 14% of all occupational injuries among the agricultural labourers were due to exposure to pesticides [5]. Many of the pesticides have harmful impact on human being either as acute or chronic toxicity [6]. High frequency of APP was reported during the spray on the crops [7]. The acute health problems such as red eye, insomnia, excessive tearing were common symptoms of APP [8]. Acute health effects during the mixing pesticides and refilling the spraying tanks were reported among female cotton growers/workers [9]. Several researchers have established the importance of knowledge, awareness and practice in such occupational hazards [10–14].

Kinnaur, Himachal Pradesh, India (31.6510° N, 78.4752° E), is a major apple-growing area which uses pesticides extensively to support the commercial agriculture. No study from this area to find out health hazards of the agricultural workers has been reported. Hence, an attempt has been made to study the safety and

D. Kumari
Environmental Engineeing, PEC University of Technology, Chandigarh, India

S. John (✉)
Department of Civil Engineering, PEC University of Technology, Chandigarh, India
e-mail: johnsiby1@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_9

health hazards among the agricultural workers in apple farms of Kinnaur district of Himachal Pradesh (India).

## 2 Methodology

Survey and interview through structured questionnaire were used to collect data. Randomly selected eight villages of Kinnaur district of Himachal Pradesh, viz. Sangla, Rakcham, Kamroo, Sungra, Nichar, Kangos, Lutuksa and Bhabanagar, formed the universe of the study. Data has been collected through questionnaire developed based on the standard protocol field surveys of exposure to pesticides [15]. Questionnaire was translated into vernacular language and read out to the respondents. Sample size was calculated by single population proportion formula as given in Eq. 1. Accordingly, a sample size of 96 (81 males and 15 females) was used in the study.

$$n = \frac{\left[Z_{\frac{\alpha}{2}}\right]^2 p(1-p)}{d^2} \tag{1}$$

where $n$ = Size of population, $Z_{(\alpha/2)}$ = Dependability coefficient (95% confidence level) = 1.96, $p$ = Assuming that 50% of the farmers had low level of perception on the hazard of pesticides, $d$ = Assumed marginal error 10%.

Bivariate analysis was done to find out the factor associated with pesticide poisoning by using statistical tool, IBM SPSS Statistica 20.

## 3 Results and Discussion

### 3.1 Pesticide Information

Table 1 lists the pesticides reported to be commonly used in the study area with their corresponding WHO Hazard classification index. Table 2 provides a hazard intensity definition of the WHO Hazard classification index [16]. In general, the fungicides (73%) application dominated over insecticides (27%). It was also observed that the extremely toxic pesticides like methyl parathion were being used in the study area whereas it is banned in many countries [17].

### 3.2 Safety Practices

Table 3 shows the results of the safety practices followed by the famers/workers in mixing and storage of pesticides. In general, 56% stored the pesticides inside the

**Table 1** Pesticides used and hazard classification index

| Brand name | Chemical name | Category of pesticide | WHO Hazard classification | Frequency (*n*) | Percentage (%) |
|---|---|---|---|---|---|
| Bavistin | Carbendazim | Fungicide | III | 31 | 37 |
| Captan | Captan | Fungicide | III | 13 | 16 |
| Metacid | Methyl parathion | Insecticide | Ia | 9 | 11 |
| Dodine | Dodine | Fungicide | II | 10 | 12 |
| Mancozeb | Mancozeb | Fungicide | U | 16 | 19 |
| Antracol | Propineb | Fungicide | U | 15 | 18 |
| Ethion | Ethion | Insecticide | II | 7 | 8 |
| Ziram | Ziram | Fungicide | II | 7 | 8 |
| Chlorpyrifos | Chlorpyrifos | Insecticide | II | 13 | 16 |
| Marshal | Carbosulfan | Insecticide | II | 8 | 10 |
| Score | Difenoconazole | Fungicide | II | 13 | 16 |
| Roko | Thiophanate methyl | Fungicide | U | 8 | 10 |

**Table 2** WHO Hazard classification index [16]

| Ia | Extremely hazardous |
|---|---|
| Ib | Highly hazardous |
| II | Moderately hazardous |
| III | Slightly hazardous |
| U | Unlikely to present acute hazard in normal use |
| FM | Fumigant, not classified |
| O | Obsolete as pesticide, not classified |

**Table 3** Safety practices among farmers

| *Mixing of pesticides* | |
|---|---|
| Variable | *n* (%) |
| Using sticks | 46 (53) |
| Using hands | 13 (15) |
| Others (machines) | 27 (31) |
| *Pesticide storage* | |
| In house | 54 (65) |
| Outside houses | 30 (36) |

house, and 13% used direct hands for mixing of pesticides which were obviously unsafe practices. Table 4 shows the disposal pattern of pesticide containers. More than 25% of the respondents still follow unsafe practices of disposal of the pesticide containers.

**Table 4** Disposal of pesticide container after use

| Variables | Disposal of pesticide container | | | | | |
|---|---|---|---|---|---|---|
| | Left in the farm | Sell to scrap dealer | Use in household purposes | Burning | Burning | Other |
| *N* (%) | 12 (14) | 4 (4.8) | 4 (4.8) | 54 (65) | 9 (10.8) | 0 (0) |

## 3.3 Awareness of Pesticides Spray

Only 24% has taken the formal training of pesticide spray. About 59% persons showed awareness of WHO colour code on the pesticide container, but very few people had knowledge of codes on the container. Out of four signs, 18% respondents identified the red colour sign and 36% hazard sign. Nobody could interpret the yellow and green colours on pesticide containers. Table 5 shows the results in respect of the knowledge of symbols and colour coding on pesticide containers.

**Table 5** WHO colour code on pesticide containers

| WHO colour code | Seen the code on containers *n* (%) | Know the meaning *n* (%) |
|---|---|---|
|   Red | 49 (59) | 15 (18) |
|   Yellow | 11 (13) | 0 (0) |
|   Blue | 17 (20) | 0 (0) |
|   Green | 36 (43) | 5 (6) |

### 3.4 Hygiene and Protection Practices

Out of the total respondents, 92% washed hands after application of pesticide, 96% changed the clothes after the application of pesticides, 62% ate at the workplace, and 83% drank water at the workplace. In case of protection practices, 58% protect their body during the spray. Table 6 shows the number of population taking different protection practices during pesticide spray.

Regarding perception related to pesticides, all the respondents knew that pesticides were poisonous, 92% of the respondents understood that the pesticides could cause health effects, 88% of the respondents were aware that the pesticide poisoning could result in death and 16% of the respondents believed that the used pesticide containers could be safely reused.

### 3.5 Health Effects

Table 7 shows the detailed acute pesticide poisoning among the farmers during and after the spray of pesticide of study area. Chronic health problems among the farmers were mostly asthma and hypertension. Most of the people were suffering from acute health problems like eye burning, red eye, dizziness, burning of nose, itchy skin, dryness and headache during the pesticide spray.

### 3.6 Bivariant Analysis

Most of the population were facing the problem of APP. APP was considered as the outcome variable. Bivariate analysis was done to find out the factors associated such as age, hours of work, years of work, awareness and mixing of pesticides with APP by using statistical tool IBM SPSS Statistica 20. Value of $p$ less than 0.05 is considered to be significant. Results showed that age and years of spray do not effect on APP. Duration of work, lack of awareness and mixing pattern are found to have significant effect on APP (Table 8).

**Table 6** Protection practices among farmers

| Articles | Hat | Gloves | Mask | Glasses | Full sleeve | Boots | Others |
|---|---|---|---|---|---|---|---|
| Frequency ($n$) | 39 | 47 | 51 | 35 | 44 | 48 | 0 |
| % | 50 | 57 | 61 | 42 | 53 | 58 | 0 |

**Table 7** Acute pesticide poisoning

| Effects | *n* (frequency) | % |
|---|---|---|
| Eye burning | 64 | 67 |
| Excessive tearing | 53 | 55 |
| Burning of nose | 27 | 28 |
| Red eyes | 81 | 84 |
| Dizziness | 47 | 49 |
| Loss of consciousness | 0 | 0 |
| Headache | 35 | 36 |
| Vomiting | 5 | 5 |
| Cough | 15 | 16 |
| Chest pain | 15 | 16 |
| Itchy skin | 76 | 79 |
| Dryness | 51 | 53 |
| Diarrhoea | 0 | 0 |
| Stomach cramps | 0 | 0 |
| Exhaust | 15 | 16 |

**Table 8** Factor affecting on acute pesticide poisoning

| Factors | No. of persons | APP | *p* |
|---|---|---|---|
| *Age* | | | |
| <25 | 4 | 1 | 0.348 |
| 25–50 | 51 | 21 | |
| >50 | 37 | 28 | |
| *Years of working* | | | |
| <10 | 21 | 16 | 0.897 |
| 10–20 | 30 | 20 | |
| 20–40 | 32 | 15 | |
| *Education* | | | |
| <5th | 16 | 13 | 0.034 |
| 5th–7th | 7 | 5 | |
| 7th–10th | 32 | 20 | |
| >10th | 41 | 35 | |
| *Hours of spray* | | | |
| >8 | 19 | 15 | 0.045 |
| 8–4 | 52 | 40 | |
| <4 | 12 | 7 | |
| *Mixing of pesticides* | | | |
| Using sticks | 46 | 35 | 0.015 |
| Using hands | 13 | 8 | |
| Others (machines) | 27 | 20 | |

(continued)

**Table 8** (continued)

| Factors | No. of persons | APP | *p* |
|---|---|---|---|
| *Learning of spray of pesticides* | | | |
| Own experience | 15 | 7 | 0.063 |
| Pesticide sellers | 13 | 11 | |
| Agriculture officers | 51 | 34 | |
| Media | 2 | 1 | |
| Others | 2 | 1 | |

## 4 Conclusions

It could be concluded that fungicide spray is more common than insecticide spray in apple orchards. The extremely hazardous pesticides like methyl parathion are being used by farmers. Most of the population store pesticides in the house premises. Operational practices like mixing technique are unsafe, and very few have taken formal training of pesticide spray. Majority of the population do not identify hazard signs on containers. Most of the population is facing the acute health problems during and after spray. Hours of spray and mixing technique have significant effect on APP.

## References

1. Available on http://www/who.int/topic/pesticide/en/
2. Chitra, G.A., Muraleedharan, V.R., Swaminathan, T., Veeraraghavan, D.: Use of pesticides and its impact on human health: a case of farmers in South Asia. Madras Int. J. Occup. Environ. Health **12**, 228–233 (2006)
3. Bhardwaj, T., Sharma, J.P.: Impact of pesticides application in agricultural industries: an Indian scenario. Int. J. Agric. Food Sci. Technol. **4**, 817–822 (2013)
4. Patil, D.A., Katti, R.J.: Modern agriculture, pesticides and human health: a case of agriculture labours of western Maharastra. J. Rural Dev. **31**, 305–318 (2012)
5. Geneva: International Labour Organization: ILO. Wage workers in agriculture: Conditions of employment and work; sectoral activities programme. Report for discussion at the tripartite meeting on improving conditions of employment and work of agricultural wage workers in the context of economic restructuring (1996)
6. U.S Environmental Protection Agency: Pesticides health and safety. Human health issues. Available from: http://www.epa.gov/pesticides/health/human.htm (2012)
7. Lekei, E.E., Ngowi, A.V., London, L.: Farmers knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health **14**, 1–13 (2014). Research Article
8. Jensen, H.K., Konradsen, F., Jors, E., Petersen, J.H., Dalsgaard, A.: Pesticide use and self-reported symptoms of acute pesticide poisoning among aquatic farmers in Phnom Penh, Cambodia. J Toxicol, Research Article, 2010. Available from: http://dx.doi.org/10.1155/2011/639814
9. Mancini, F., Ariena, H.C., Bruggen, V., Janice, L.S.: Acute pesticide poisoning among female and male cotton growers in India. Int. J. Occup. Health **11**, 221–232 (2005)

10. Pasiani, J.O., Torres, P., Silva, J.R., Diniz, B.Z., Cadlas, E.D.: Knowledge, attitudes, practices and biomonitoring of farmers and residents Exposed to pesticides in Brazil. Int. J. Environ. Res. Public Health **9**, 3051–3068 (2012)
11. Tandi, T.E., Wook, C.J., Shendeh, T.T., Eko, E.A., Afoh, C.O.: Small-scale tomato cultivators', perception on pesticides usage and practices in Buea Cameroon. Health **6**, 2945–2958 (2014)
12. Neupane, R.R.K., Wantamutte, A.S., Banjade, B., Kushwaha, N., Neupane, R.: Practice of pesticides use among the farmers of Kangrali village in Belgaum—a cross-sectional study. Int. J. Interdisc. Multi. Stud. **1**, 202–207 (2014)
13. Sam, K.G., Andrade, H.H., Pradhan, A., Sones, S.J., Sudhakar, C.: Effectiveness of on educational program to promote pesticide safety among pesticide handlers of south India. Int. Arch. Occup. Environ. Heath **81**, 787–795 (2008)
14. Banerjee, I., Tripathi, S.K., Roy, A.S., Sengupta, P.: Pesticide use pattern among farmers in a rural district of West Bengal, India. J. Nat. Sci. Biol. Med. **5**, 313–316 (2014)
15. World Health Organization: Field surveys of exposed to pesticides standard protocol. Pesticide development and safe use unit, Geneva .VBC/82.1
16. WHO: Guidelines to classification: the WHO recommended classification of pesticides by hazards, (2009)
17. FAO Corporation document repository: Decision guidance methyl parathion. Agriculture and consumer protection, June 1997

# Step Towards E-Waste Management (STEM)

**Meenal Arora, Madhu Sharma and Debajyoti Bose**

## 1 Introduction

Electronic industry is amongst the fastest and the largest growing industry [1]. The decrease in prices of the products along with technological developments has boosted demand for new technology consumer products in the country [2]. When these products reach end of their lifespan and are no more useful to the consumer, they form e-waste. Thus, growth of e-waste is directly related to the GDP of the country [3]. E-waste generation can be a business opportunity, but due to lack of awareness and technology, it is proving to be a burden on the society. From all the waste collected, the e-waste can be distinguished physically as well as chemically from the other waste such as municipal and industrial waste. According to reports today, 8% of municipal waste is already constituted by waste electrical and electronic equipment's (WEEE) and is growing at a rate of 3–5% annually [4].

E-waste is defined as "All waste from electronic and electrical appliances which have reached their end-of-life period or are no longer fit for their original intended use and are destined for recovery, recycling or disposal" [5]. Another way of defining E-waste is "All types of electrical and electronic equipment (EEE), and its parts that have been discarded by the owner as waste without the intention of re-use" [6]. According to WEEE, e-waste can be classified into electronic as well as non-electronic goods. Electronic goods comprise of computers, facsimile machine,

M. Arora (✉) · M. Sharma · D. Bose
Department of Electrical, Power & Energy, University of Petroleum & Energy Studies, PO Bidholi via Prem Nagar, Dehradun 248007, Uttarakhand, India
e-mail: marora@ddn.upes.ac.in

M. Sharma
e-mail: madhusharma@ddn.upes.ac.in

D. Bose
e-mail: dbose@ddn.upes.ac.in

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*, Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_10

photocopier, radio, video recorder and DVD player, whereas non-electronic goods comprise of ovens and refrigerators.

## 2 Global Scenario of E-Waste

According to a UN report, India ranks fifth as biggest producer of e-waste in the world, around 1.7 million tonnes (Mt) of e-waste was discarded in 2014. While North America and Europe are the largest producers of e-waste in world, Asian countries are also catching up as generators of e-waste. In China, around 73.9 million computers were sold along with 56.6 million televisions and 0.25 billion mobile phones, in 2011. Forecasts say that in just two years, i.e. by 2017, the total e-waste generated globally will be around 50 million tonnes, i.e. an increase of 21% [7, 8].

## 3 Composition of E-Waste

E-waste generated is a mixture of valuable as well as toxic materials, and depending on upon its constituents it can be segregated into hazardous and non-hazardous waste [9], which can be further classified into non-ferrous and ferrous metals, wood, glass, printed circuit boards and various other items [10]. The hazardous waste comprises of flame retardants, Hg, Sb, Pb, Cd, Ni along with polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) which are harmful to the environment [3] whereas the non-hazardous waste includes steel plastics and

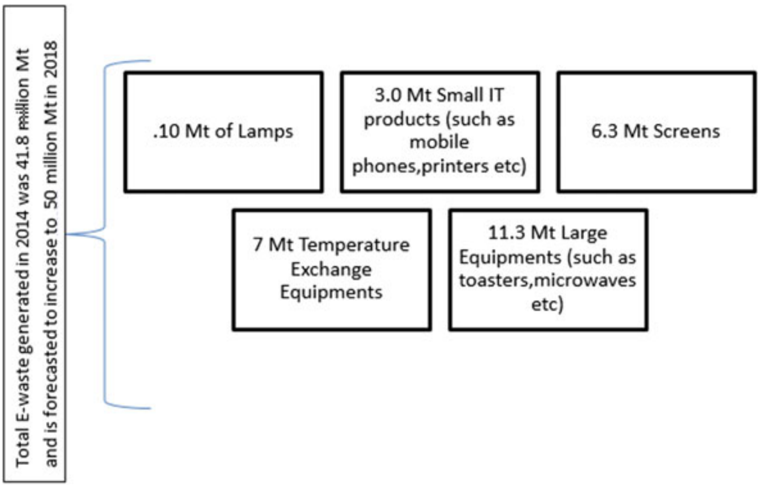



**Fig. 1** Quantity of e-waste generated for different category of products [8]

iron. There are also some valuable materials comprising of gold, silver, platinum group as well as Cu. E-waste products have different composition, and also depending on the area, different quantity of waste is generated which can be seen below (Fig. 1).

# 4 Legal Framework for E-Waste

For management of E-waste, there are laws, policies and regulation related to it. EPR and take back of the product form a part of these regulations in major countries. Various policies, law and regulations in India are:

1. The Environment Protection Act 1986
2. The Hazardous Waste (Management and Handling) Rules 1989 as amended in 2003 and 2008
3. National Environmental Policy 2008
4. E-Waste Management Rules 2016
5. Hazardous and Other Wastes (Management and Transboundary Movement) Rules 2015.

## *4.1 The Basel Convention*

Since 2002, The Basel Convention has started to address the issues of e-waste which include, amongst others

6. Management of waste in environmentally sound manner;
7. Prevention of illegal export of waste to developing countries and;
8. Better management of e-waste building capacity around the globe.

**Managing E-Waste**: For proper managing of e-waste there is a need for proper estimation of the e-waste generated from each house, each locality, each region and each country. The data available are either outdated or not from the authentic. Comparison of it also becomes impossible due to different scope of product in each area [8]. Different e-waste is generated in rural as well as urban areas. Hence their management will also differ which includes processes such as take back system and other being its disposal. Lack of awareness of people about recycling of e-waste results in majority of e-waste, ending up in incinerators, landfills or in ill-equipped recycling facilities. The waste is dumped in areas where rag-pickers or *kabadi-wallahs* disassemble the units and collect and sell whatever material is of value, and the remaining product is simply discarded as waste, creating immense problems [7].

Challenges faced globally during take back are that not all the electrical and electronic products are covered as the amount of product collected is low or the there is no existing regulation for a particular product [8] or the non-availability of recycling technologies.

Recycling of e-waste involves disassembling and recovering the material from the used electronic products. There is a need of turning the e-waste into an opportunity which will not only create jobs but also reduce the burden on the environment. Data available for e-waste collected in 2014 shows that only 16% was recycled, i.e. 6.5 Mt was recycled meeting the quality standards.

Harmful effects of underdeveloped recycling technologies are upon the workers who work in e-waste processing facilities through inhalation and skin contact and upon the community through dust and smoke. Hence, there is a need of safe and highest quality of technologies for recycling [3].

**Extended Producer Responsibility**: Extending of producer's responsibility towards the consumer after the product has completed its life cycle is known as extended producer responsibility (EPR) [11]. It is an environmental policy approach. This policy is identified by the shifting responsibility of the product partially or fully upstream, i.e. towards the producers [12]. It requires providing incentives to the consumers when the product is taken back and ensuring its proper disposal. If the consumer becomes aware of their right, it will not only help to reduce the burden on the environment but also force the producers to take account environmental considerations while designing their products.

## 5 Growth of Solar Industry

There is an ambitious aim for installation of solar power in India by 2022. A rapid reduction in tariff along with increased awareness of renewable energy has increased the demand for installation of solar panels. India is set to become the fourth largest in solar market around the world in 2016, with projected capacity addition of 5.4 gigawatt (GW). It will be overtaking countries like UK, France and Germany. It already has an installed utility-scale solar and rooftop capacity of 6.6 GW and 740 megawatt (MW), respectively [13]. Every year the capacity of solar plants being commissioned is increasing. China recently announced the world's biggest solar farm with the capacity of 2 GW and 6 million panels [14]. Despite having several environmental and climate benefits, PV generation has some environmental as well as social challenges that need attention. It requires proper management along with proper planning.

As on 31 August 2016, the collective installed capacity of grid-connected solar power is 8083 MW (8 GW), with Rajasthan having the highest installed capacity of 1294.6 MW and Tamil Nadu having 1267.4 MW with Gujarat having a capacity of 1123.4 MW [15] (Fig. 2).

The lifespan for solar panels is 20 years, thus in the coming years, a huge amount of solar panel waste will be generated when the panels will reach end of their life. The PV panel waste is estimated to be between 4.5–7.5 million till 2050 depending upon the early and regular loss scenario [11]. Till now there is no

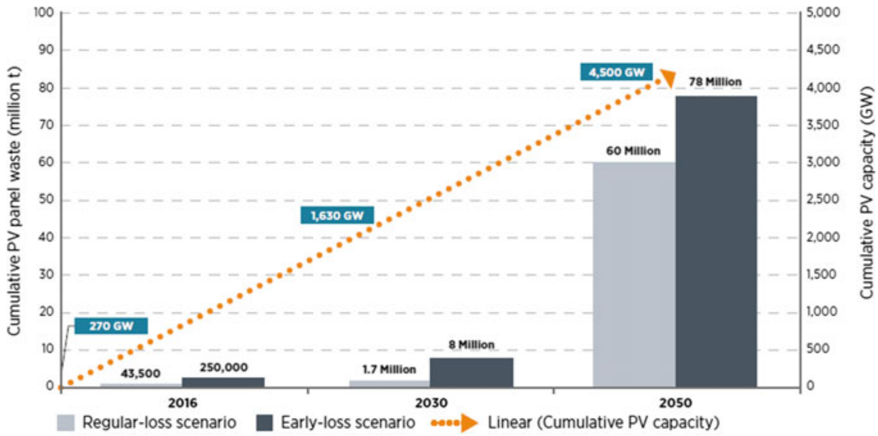



**Fig. 2** Overview of global PV panel waste projection for the year 2016–50 [11]

established technology for processing of solar waste. Recycling of solar panels will help in recovering the materials used in construction and reusing it again thus reducing the cost of new solar panels.

If not disposed properly, the hazardous content of electronic materials poses a threat to human health and environment and can leach substances such as lead into soil as well as groundwater. Most of these can be reused, restored or recycled in an environment-friendly manner, so that harm caused to the ecosystem is reduced.

## 6 The Way Forward

The development of technology along with it awareness has increased the electronic consumer in the industry. The renewable policies have supported the deployment of solar energy. The end-of-life management of electronic goods as well as solar PV panels is still an area which requires research. Hence, R&D, along with proper education and training will be required to managing e-waste. There lies huge gap between existence of policies and their implementation and enforcement. Scope of the take back policies should be well defined. The manufactures should offer incentives in lieu of take back, and the e-waste programme should be subsidized. With implementation of right policies in place, the new industries with developed technology that recycle and recover the usable materials from used components as well as old solar PV panels will not only create considerable economic value but will also be a critical element in the transition of world towards a future with sustainable energy.

## References


1. Herat, S., Agamuthu, P.: E-waste: a problem or an opportunity? Review of issues, challenges and solutions in Asian countries. Waste Manag. Res. (2012)
2. Consumer Electronics in India, 73 p, September 2016
3. Robinson, B.H.: E-waste: an assessment of global production and environmental impacts. Sci. Total Environ. 183–191 (2009)
4. Nair, S.: E-waste in India: Mumbai leads, followed by Delhi and Bangalore. 09 Jul 2015. [Online] Available: http://tech.firstpost.com/news-analysis/e-waste-in-india-mumbai-leads-followed-by-delhi-and-bangalore-273476.html
5. Monica, S.: E-waste management and Swach Bharat Abhiyan-a study. Int. J. Eng. Manag. Sci. **7**, 229–232 (2016)
6. Adrian, S., Choi, S, Gossart, C., Kuehr, R., Mars, C., McCann, D., Perry, J., Phippen, W., Pollet, K., Reyes, L., Seager, D., Shefveland, M., Vandendaelen, A., Vött, U., Wellum, R.: One global definition of e-waste (2014)
7. Gandhi, D.: India, a victim of e-waste crime, The Hindu, May 2015
8. Baldé, C.P., Wang, F., Kuehr, R., Huisman, J.: The global e-waste monitor—2014: Quantities, flows and resources. United 152 Nations University, Institute for the Advanced Study of Sustainability, Bonn (2015)
9. Agnihotri, V.K.: E-waste in India. Research unit (LARRDIS), Rajya Sabha Secretariat, New Delhi, June 2011
10. Gupta, M.: Guidelined for environmentally sound management of E-waste. Ministry of Environment and Forests, CPCB
11. Wecken, S., Health, G., Wade, A.: End of life management (Solar photovoltaics Panels). International Renewable Energy Agency (IRENA) and the International Energy Agency Photovoltaic Power Systems (IEA-PVPS) (2016)
12. Atasu, A., Van Wassenhove, L.N.: An operations perspective on product takeback legislation for e-waste: theory, practice and research need (2011), [Online] Available: www.prism.gatech.edu/~aatasu3/index_files/AV11.pdf
13. Aggarwal, M.: India will become fourth largest solar market in 2016: report. Live mint, Friday April (2016)
14. Puiu, T.: China will build the world's biggest solar farm: 6 million panels amounting to 2GW, stretched over 7,000 city blocks. ZME Science, [Online] Available: http://www.zmescience.com/science/news-science/china-world-biggest-solar-farm/
15. Ministry of New and Renewable Energy, http://mnre.gov.in/file-manager/UserFiles/grid-connected-solar-power-project-installed-capacity.pdf

# Computational Approach Towards the Identification of Allergenic Protein in Orphan Crops

**Devvret, Arpit Chauhan, Kumud Pant and Neema Tufchi**

## 1 Introduction

"Orphan crops" are the food crop that are grown at large level but used only by local communities. They are also used as a livestock grain and also considered as important crops to a specific region. Although they are grown at large level, they are not a part of main crops that are traded internationally such as rice and wheat [1]. In the developing countries, these are grown as staple crops that play important role in food security, have a high nutritional value, help in income generation to the poor farmers and are well-suited to socio-economic and agro-ecological conditions [2]. These crops are also known as underutilized crops, neglected crops [3], minor crops [1] and crops for the future [4]. They are widely classified under root crops, legumes, fruits and vegetable and cereals [5]. Some of these orphan crops have been reported to have allergenic properties. Allergenic protein has the ability to induce allergic response in the individual with low immunity. The complex interaction between the allergenic protein and the immune system causes allergic response like mild erythema, rhinitis, anaphylactic shock. Due to the complex interaction, they are particularly challenging to predict [6]. Several servers, tools and applications

Devvret and Arpit Chauhan—are equally contributed to this chapter.

Devvret (✉) · A. Chauhan · K. Pant · N. Tufchi
Department of Biotechnology, Graphic Era University, Dehradun, Uttarakhand, India
e-mail: devvret@gmail.com

A. Chauhan
e-mail: arpit12191@gmail.com

K. Pant
e-mail: pant.kumud@gmail.com

N. Tufchi
e-mail: neematufchi@gmail.com

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_11

were developed for the prediction of allergenic protein. In the study, we have selected three major orphan crops that have nutritional as well as economic importance. For allergen prediction, six software was used for the prediction of allergen present in these crops on the basis of the protein sequence.

### *1.1 Explanation of Orphan Crops Used in the Study*

In this study, three orphan crops Finger millet (*Eleusine coracana*), Tef (*Eragrostis tef*) and Bambara groundnut (*Vigna subterranea*) were selected for the prediction of the allergenic proteins. The description about these orphan crops is given below (Table 1).

**Finger millet [*Eleusine coracana*]** is also known as ragi or mandua. It is one of the world's oldest crops, and for years, it has been an important ingredient of the indian food culture. It is rich in starch and contains easy digestive protein that makes it superior to wheat. Being highly nutritious crop, it contains starch, calcium, iron and amino acids, which are mostly absent or present in a very low percentage in diets of the people under poverty line. The seed of finger millet contains valuable amino acid called methionine. This crop is mostly used in Africa for the production of the fermented products such as beer, alcoholic and non-alcoholic beverages. These are mostly grown and consumed in "Karnataka", "Rajasthan", "Andhra Pradesh", "Maharashtra", "Garhwal", etc. [7].

**Tef [*Eragrostis tef*]** is a C4 crop which is essentially grown cereal crop in Ethiopia. The seeds of tef can be stored easily without losing viability under local storage environment, since it is not attacked by storage pests [8]. Tef flour is used

**Table 1** Following three plants were taken for the allergen prediction

| Common name | Botanical name | Genus | Type of crop | Country or region of importance | Important trait | Family | Ref. |
|---|---|---|---|---|---|---|---|
| Finger millet | *Eleusine coracana* | *Eleusine* | Cereal | Africa and Asia | Rich in iron, protein; low in glycaemic | Poaceae or gramineae | [5] |
| Tef | *Eragrostis tef* | *Eragrostis* | Cereal | Ethiopia | Tolerant to abiotic stresses; free of gluten | Poaceae | [6] |
| Barbara groundnut | *Vigna subterranea* | *Vigna* | Legume | North Africa | Rich in protein, drought tolerant | Fabaceae | [10] |

for making fermented pancake, sour bread, alcoholic drink and porridge. With high nutritional value it has 9.6% of protein, 2.0% of fat, 2.9% of ash and 73.0% of carbohydrate content. Amino acid content is same as of Egg proteins. The level of micronutrient and macronutrient seems to be higher than that of sorghum, wheat and barley [9].

**Bambara groundnut [*Vigna subterranea*]** is yearly cultivated Fabaceae family legume crop. Origin of this crop is North Africa. It is a very popular crop because it can be grown in any types of soil and also gives better yield in very poor soil. Its seed contains high amount of proteins and also contains carbohydrate, fats and oil. Because of its highly nutritious value, it can be used as a complete food for the human [10] (Figs. 1, 2 and 3).

## *1.2 Importance of Orphan Crops*

These are the underutilized, very nutritious crop and have the capability to provide many nutrients and are beneficial for health, in comparison with other major crops. It combats with the "hidden hunger" which is caused by micronutrient (vitamin and minerals). These crops does not require the high maintenance for their cultivation such as pesticides, organic and inorganic fertilizers, but they are resistant towards the harmful diseases and pests. These minor crops should be grown in the extreme soil and in the climatic condition. Orphan crops are important source of income and empowerment, particularly for the women who are the main growers of these crops;

**Fig. 1** Finger millet or Ragi [7]

**Fig. 2** Tef [8]

**Fig. 3** *Vigna subterranean* [10]

especially in the geographical areas where they are grown [11]. The First International Conference on Orphan Crops was held from 19 to 21 September 2007, in Bern, Switzerland [12].

In the past decades, it has been observed that per capita grain output as well as grain consumption is having a sharp decline in the economy as a whole. A deep agricultural depression and rise in unemployment has shifted the economy towards the wealthy society. Due to poverty, a fraction of population has to face famishment. This condition gives rise to food crisis. In the duration 1980–85, per capita world cereal output was 335 kg/year that declined to 310 kg/year in the period of 2000–05. It has been seen that developing countries, like China and India which have contributed 30% of total world cereal output, had also faced food crisis during this period. Even the developed countries that contribute to the 40% of the worlds cereal output showed only 18.6% of rise in cereal output within the same duration. There is an increase of 1.3% in annual growth rate which is insufficient to feed their own population [13]. These orphan crops carry some proteins that cause allergies in few people. That is why we have studied approximately all proteins present in the Finger millet (Eleusine coracana), Tef (*Eragrostis tef*) and Bambara groundnut (*Vigna subterranean*) for the prediction of allergenic protein.

## *1.3 Bioinformatics in the Orphan Crop*

Bioinformatics is an interdisciplinary field that develops and improves upon methods for storing, retrieving, organizing and analysing biological data. A major activity in bioinformatics is to develop software tools to generate useful biological knowledge [14]. Here in this study, we have used six different software for prediction of allergenic proteins in the orphan crop. Each of the software is based on different algorithm that is why the confidence score was calculated to get an accuracy of the result. Table 2 contains the details about the information of orphan crops present in the database.

**Table 2** Information contents for various orphan crops present in Bioinformatics database

| Orphan crops | EST | GSS | Gene | Genome | Protein | Nucleotide |
|---|---|---|---|---|---|---|
| *Eulisine corcana* | 1934 | 1 | 0 | 0 | 418 | 947 |
| *Eragrostis tef* | 3608 | 40 | 0 | 1 | 176 | 847 |
| *Vigna subterranea* | 0 | 0 | 0 | 0 | 195 | 265 |

# 2 Materials and Methods

## 2.1 Retrieval of Protein Sequence

The information availability about the orphan crops in the secondary databases of NCBI was listed in Table 2. The protein sequences of orphan crops were retrieved in FASTA format from *National centre for biotechnology information* (NCBI), a composite database that have several integrated databases and tools. *Search terms were "Eleusine coracana", "Eragrostis tef" and "Vigna subterranea"*. These sequences were then used for the prediction of allergens (Table 3).

## 2.2 Allergen Prediction

The allergens in the major neglected or unutilized crops were predicted by using different software. All these software needs input file in FASTA format and also accepts the amino acid codes. The software used in the allergen prediction is discussed below.

1. **Algpred**: Algpred is an open access tool that is developed by iMtech, Chandigarh. This tool helps in identifying the allergen by using different approaches, which are (i) hybrid approach (SVM + IGE epitope + ARPs + BLAST + MAST), (ii) blast search on ARPS, (iii) motif based, (iv) support vector machine (SVM) based and (v) scanning of IgE epitopes. We have used the SVM-based analysis of Algpred for the prediction of allergen from the proteins of orphan crops [15].
2. **Allerdictor**: A Web-based tool that works on the basis of the SVM and uses the protein sequences for the allergen prediction [16].
3. **Allerhunter**: It is an online tool that has cross-reactive program for the prediction of allergen and is based on a combination of SVM and pairwise sequence similarity. It predicts the allergen and non-allergen by using the FAO/WHO evaluation schema and statistical learning method [17].

**Table 3** List of allergen prediction software and their URLs

| Software | URL | References |
|---|---|---|
| Algpred | http://www.imtech.res.in/raghava/algpred/ | [15] |
| Allerdictor | http://allerdictor.vbi.vt.edu/ | [16] |
| Allerhunter | http://tiger.dbs.nus.edu.sg/AllerHunter/ | [17] |
| Sortraller | http://sortaller.gzhmc.edu.cn/ | [18] |
| ProAp | http://gmobl.sjtu.edu.cn/proAP/prediction.html | [19] |
| PREAL | http://gmobl.sjtu.edu.cn/PREAL/predict.html | [20] |

4. **Sortaller**: It is a Web-based tool for allergen prediction that classifies allergen on the basis of family featured peptide data set and normalized blast e-values [18].
5. **ProAp**: Protein Allergenicity Prediction is allergen prediction tool which is available on ProApwebserver that has many integrated features of previously developed software for the prediction of allergenic proteins. With higher specificity and accuracy, it uses the SVM-AAC-based method for discriminating allergenic and non-allergenic proteins [19].
6. **PREAL**: It stands for **Pre**diction of **Al**lergenic protein. It is a Web server used to predict the allergenicity of protein(s) online and also evaluate its potential against allergenicity. It is a Web-based application with a friendly interface that allows the users to submit their sequences in the FASTA format for individual or batch prediction with the query proteins. Besides sequential protein character, a model has been developed for identifying the possible protein allergenicity by using various properties such as their physicochemical, biochemical, subcellular features in terms of locations which were ranked using mRMR (maximum relevance and minimum redundancy) method [20].

### *2.3 Equation*

Following equation is used for finding the confidence score (C.S) of protein sequences of the three major orphan crops by the help of the allergen prediction software [21].

$$\text{Confidence Score} = \frac{\text{No. of Software giving similar results}}{\text{No. of Software}} * 100$$

## 3 Results and Discussion

Nowadays many genetically modified (GM) foods and biopharmaceuticals are being used in daily life that is why the prediction of allergens is becoming an important issue. The three major orphan crops were used in this paper for the prediction of the potential allergenic protein which was present in the protein sequences of the underutilised crops such as "*Eleusine coracana*", "*Eragrostis tef*" and "*Vigna subterranea*". Allergens are the compounds that cause some allergic reaction in the body of few immune-deficient humans. All the protein sequences of the orphan crops were downloaded from the NCBI (National centre of biotechnology information) in the FASTA format there were 789 sequences out of which 418, 195 and 176 sequences were of *Eleusine coracana, Eragrostis tef* and *Vigna*

**Table 4** Number of allergenic protein predicted by different software in the orphan crops

| Software/crops | *Eleusine coracana* | *Eragrostis tef* | *Vigna subterranea* |
|---|---|---|---|
| Algpred | 10 | 3 | 0 |
| Allerdictor | 0 | 0 | 0 |
| Allerhunter | 9 | 0 | 0 |
| Sortaller | 6 | 1 | 0 |
| ProAp | 8 | 0 | 0 |
| PREAL | 28 | 3 | 80 |

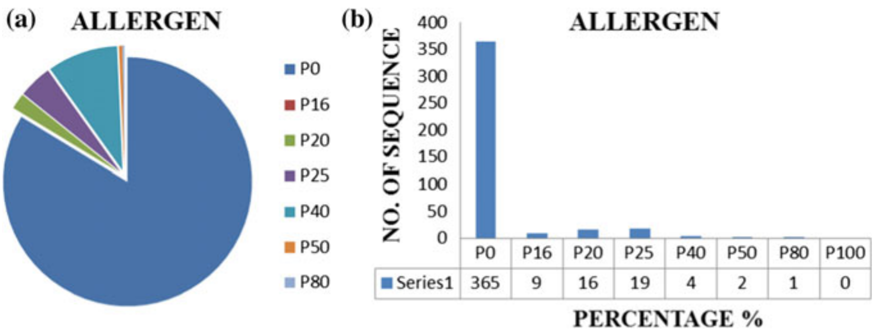
*subterranea* respectively. Total six web based servers were used to predict the allergenic protein sequences of the orphan crops (Table 4).

Algpred is a machine learning technique-based software that uses support vector machine (SVM) and blast algorithm. Default approach was selected for the prediction of allergen by using SVM method based on amino acid composition. *Ten and three protein sequences of Eleusine corocana and Eragrostis tef were found to be allergenic*. No allergenic protein was observed in *Vigna subterranea*. After that prediction of allergen was performed by Allerdicator, which uses the text classification system and SVM for fast allergen prediction. There was no allergenicity predicted in all the proteins of these orphan crops. Allerhunter program was then used that gives results on the basis of combinatorial study of SVM and pairwise sequence alignment. It compares the query sequence with the known allergen as well as with the potential non-allergen and detects the domain- or motif-sized similarities even if overall similarity of the sequence of the protein to the known allergen is low. It was found that only nine protein sequences were showing allergenic properties in *Eleusine coracana*. Sortaller is a software for allergen prediction based on Allegren family Featured Peptide (AFFP) algorithm and is an optimized software running on SVM. It has high specificity and sensitivity for predicting allergenic proteins by searching several independent data sets of protein sequence. In the study of these selected orphan crops, only six protein sequences of *Eleusine coracana* and three sequences of *Eragrostis tef* were found to be allergenic in Sortaller. ProAp is a web server that has many integrated features of previously developed software for the prediction of allergenic proteins. With higher specificity and accuracy, it uses the SVM-AAC-based method for discriminating allergenic and non-allergenic proteins. Only eight sequences of *Eleusine coracana* was predicted as allergenic protein by ProAp and no significant result was found in other two orphan crops. PREAL is software that is based on Incremental Feature Selection (IFS) and Maximum Relevance Minimum Redundancy (mRMR) method that enables to search allergen with accuracy of 94–100%. PREAL have given best result when compared with other allergen prediction tool used in this study. Twenty-eight, three and eighty protein sequences of *Eleusine coracana, Eragrostis tef* and *Vigna subterranea* allergenic protein were predicted through PREAL web server, respectively.

All the software and tools were showing different values of predicted allergenic proteins that is why we have used the confidence score to analyse the allergen. The confidence score gives the value in percentage occurrence, and the graph was plotted using same values. From the 418 protein sequences of *Eleusine coracana*, 365 sequences were assigned as a allergenic protein sequences showing very low percentage of confidence, nine sequences with 16% confidence score, 16 sequences with 20%, 19 sequences with 25% confidence score, four sequences with 40% confidence score and one sequence with 80% confidence score. The graphical representation of Table 5 is shown in Graph 1 (Table 5).

Likewise the confidence score calculated for the *Eragrostis tef*. From the 195 sequences, 190 sequences show very less confidence score, four sequences were assigned with 20% confidence level and only one sequence was assigned 40% of the confidence level (Graph 2) (Table 6).

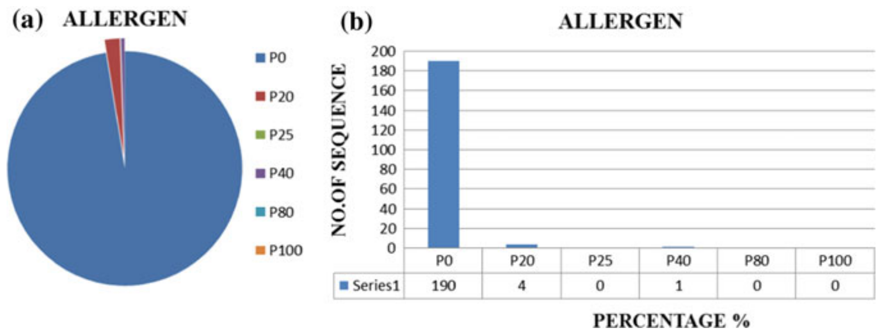
For the 176 sequences of *Vigna subterranea* proteins 98 crops were showing very less confidence score, 26 of the protein sequences were assigned 20% of confidence level and 53 sequences with 25% of confidence level. No crops were assigned with the maximum level of confidence. Lower the confidence score means the proteins are putative allergen and it has no proof to be 100% allergenic (Graph 3) (Table 7).




**Graph 1** **a** Pie chart and **b** bar graph of the confidence score for the *Eleusine coracana*

**Table 5** Percentage of allergen in protein sequences of *Eleusine coracana* (allergen)

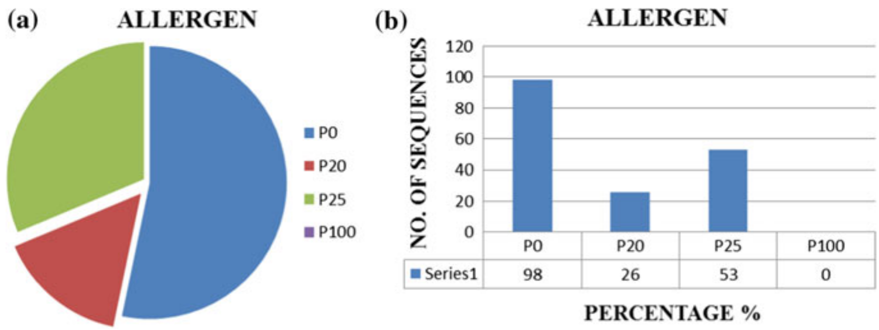
| Percentage % of allergen in protein sequences of *Eleusine coracana* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. of protein sequences | P0 | P16 | P20 | P25 | P40 | P50 | P80 | P100 |
| | 365 | 9 | 16 | 19 | 4 | 2 | 1 | 0 |




**Graph 2** **a** Pie chart and **b** bar graph of the confidence score for the *Eragrostis tef*

**Table 6** Percentage of allergen in protein sequences of *Eragrostis tef*

| Percentage% of allergen in protein sequences | | | | | | |
|---|---|---|---|---|---|---|
| No. of protein sequences | P0 | P20 | P25 | P40 | P80 | P100 |
| | 190 | 4 | 0 | 1 | 0 | 0 |




**Graph 3** **a** Pie chart and **b** bar graph of the confidence score for the *Vigna subterranea*

**Table 7** Percentage of allergen in protein sequences of *Vigna subterranea*

| Percentage % of allergen in protein sequences | | | | |
|---|---|---|---|---|
| No. of protein sequences | P0 | P20 | P25 | P100 |
| | 98 | 26 | 53 | 0 |

## 4 Conclusion

It has been reported that some of the orphan crops have allergenic properties. Our analysis was on three important orphan crops. Individuals with weak immunity get allergic response by consuming the allergenic protein found in these orphan crops. Realizing the importance of educating common people about possible ill effects of consuming food without prior knowledge of its contents, so there is an urgent need for scientific community to find non-allergenic derivatives. Various software were used to predict 28, 3 and 80 allergic protein sequences in *Eleusine coracana*, *Eragrostis tef* and *Vigna subterranea,* respectively. Because these identifications were performed through different software that works on different algorithm, thats why statistical comparison of these results were performed through confidence score. The level of confidence score determines the authenticity of the function assigned to a particular protein sequence. From the total 111 allergenic protein of different crops predicted through the six allergen prediction software, only one sequence has qualified the highest level of confidence score in *Eleusine coracana.* These predictions of allergenic proteins will be beneficial in developing dietary guidelines for individual patients and in the designing of specific immunotherapy.

**Acknowledgements** The authors express the deep sense of gratitude to the Department of Biotechnology of Graphic Era University for all the support, assistance and constant encouragements to carry out this work.

## References

1. Tadele, Z.: Role of orphan crops in enhancing and diversifying food production in Africa. Afr. Technol. Dev. Forum J. **6**(3), 9–15 (2009)
2. Padulosi, S., Heywood, V., Hunter, D., Jarvis, A.: Underutilized species and climate change: current status and outlook. In: Crop Adaptation to Climate Change, pp. 507–521, 1st edn. Wiley, New York (2011)
3. Bermejo, J.E.H., León, J. (eds.): Neglected crops: 1492 from a different perspective (No. 26). Food & Agriculture Org. (1994)
4. Crops for the Future, http://www.cropsforthefuture.org/default.aspx. Accessed 17 Sept 2016
5. Esfeld, K., Plaza, S., Tadele, Z.: Bringing High-throughput techniques to orphan crop of Africa: highlights from the tef tilling project. Gene Conserve **8**(33) (2009)
6. Huby, R.D., Dearman, R.J., Kimber, I.: Why are some proteins allergens? Toxicol. Sci. **55**(2), 235–246 (2000)
7. Gull, A., Jan, R., Nayik, G. A., Prasad, K., Kumar, P. Significance of finger millet in nutrition, health and value added products: a review. Magnesium (mg) **130**(32) (2014)
8. Spaenij-Dekking, L., Kooy-Winkelaar, Y., Koning, F.: The Ethiopian cereal tef in celiac disease. N. Engl. J. Med. **353**(16), 1748–1749 (2005)
9. Bultosa, G., Hall, A. N., Taylor, J.: Physico chemical characterization of grain tef [*Eragrostis tef* (Zucc.) Trotter] Starch. Starch Stärke **54**(10), 461–468 (2002)
10. Neumann, K.: Lost crops of Africa, vol. 1: Grains. National Academy Press, Washington, DC (1999)
11. Naluwairo, R.: Investing in orphan crops to improve food and livelihood security of uganda's rural poor. ACODE Policy Research Series No. 43 (2011)
12. Tadele, Z.: New approaches to plant breeding of orphan crops in Africa. In: New Approaches to Plant Breeding of Orphan Crops in Africa. The International Conference on New Approaches to Plant Breeding of Orphan Crops in Africa, Bern, Switzerland. (2009)
13. Patnaik, U.: Origins of the food crisis in India and developing countries. Monthly Rev. **61**(3) (2009)

14. Armstead, I., Huang, L., Ravagnani, A., Robson, P., Ougham, H.: Bioinformatics in the orphan crops. Briefings Bioinf. (2009)
15. Saha, S., Raghava, G.P.S.: AlgPred: prediction of allergenic proteins and mapping of Ig epitopes. Nucleic Acids Res. **34**(2), 202–209 (2006)
16. Dang, H.X., Lawrence, C.B.: Allerdictor: fast allergen prediction using text classification techniques. Bioinformatics **30**(8), 1120–1128 (2014)
17. Muh, H. C., Tong, J. C., Tammi, M. T.: AllerHunter: a SVM-pairwise system for assessment of allergenicity and allergic cross-reactivity in proteins. PLoS One **4**(6) (2009)
18. Zhang, L., Huang, Y., Zou, Z., He, Y., Chen, X., Tao, A.: SORTALLER: predicting allergens using substantially optimized algorithm on allergen family featured peptides. Bioinformatics **28**(16), 2178–2179 (2012)
19. Wang, J., Yu, Y., Zhao, Y., Zhang, D., Li, J.: Evaluation and integration of existing methods for computational prediction of allergens. BMC Bioinf. **14**(4) (2013)
20. Wang, J., Zhang, D., Li, J.: PREAL: prediction of allergenic protein by maximum relevance minimum redundancy (mRMR) feature selection. BMC Syst. Biol. **7**(5) (2013)
21. Kushwaha,S., Shakya,M.: Protocol of rice genome annotation through comparative functional genomics approach. Internet J. Genomics Proteomics **4**(1) (2008)

# Experimental Investigation of Thermal Energy Storage System for Hot Air Applications

**Prateek Negi, Satyendra Singh, Kapil Sharma, Jivesh Dixit and Shiv Kumar**

## 1 Introduction

Energy stockpiling is not simply accepting a key part in conservation of the energy; but it furthermore improves the execution and enduring nature of broad assortment of energy systems and end up being more basic, where the energy source is discontinuous, for example, solar energy. Energy stockpiling procedure can decrease the time or rates befuddle among energy supply and energy demands. The thermal energy stockpiling can be used as a piece of spots where there is a variety in solar energy or in domains where there is a high qualification of temperature amidst day and night.

The rate of heat transfer as of or to the solids in the packed bed of heat storage is a component of the thermal property of the liquid and solid. With a specific end goal to get a substantial proportion of face territory to quantity, the fluid may concede over packed bed of solid material. As the fluid flow over the heat transfer may occur. A large number of trial looks into have been done on the subject of packed bed, regenerator, as a fluid in a heat transfer medium. Many experimental

P. Negi (✉) · K. Sharma · J. Dixit · S. Kumar
Department of Mechanical Engineering, GEU, Dehradun 248002, India
e-mail: prateeknegi060@gmail.com

K. Sharma
e-mail: kapilsharma9999@gmail.com

J. Dixit
e-mail: jiveshdixit@gmail.com

S. Kumar
e-mail: shiv.kumar.mst13@itbhu.ac.in

S. Singh
Department of Mechanical Engineering, BTKIT, Dwarahat 263653, India
e-mail: ssinghiitd@rediffmail.com

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_12

study have been done so far for heat exchange from fluid flow to a bed of broken solids [1–3] using rocks, granite, gravels as storage material, and the result concludes that the coefficient of heat transfer varies along the straight line with velocity and it decreases with increase in particle diameter. Even as designing a packed bed, certain parameters need to find out such as air flow rate per unit face area of the bed, material equivalent diameter, bed length, and face area of the bed [4].

Different granular materials, pebbles and porcelain balls of different sizes were used [5] for heat transfer study between air flowing through a filled tube with granular materials and heat transfer coefficient was found to be dependent on the mass flow rate of air and particle to tube diameter ratio. Certain air heating system was designed [6, 7] with rock bed for energy storage which provides the evidence that well-designed system can work dependably over numerous years with little maintenance. The system can also act as storage system if the rocks are painted black with suitably glazed and collects in a galvanized iron box, when suitably constructed [8]. The main advantage of rock storage is that the high temperature of the rock is very much stratified all along its axis if effectively used for solar energy application. More than 60% of the energy put away can be recouped at nearly the most extreme putting away temperature [9] and with increment away medium thickness significantly builds the rate of charging and capability limit of the bed and decrease the solid temperature ascend within the bed.

The other parameter such as pressure drop additionally assumes an essential part for the efficient working of storage system. The pressure drop depends on the particle diameter, bed porosity, air flow rate [10, 11], and also as a function of friction due to wall surface [12]. In any case, enhancement of thermal performance and the decrease of resistance in the packed bed are an exchange off in outlining air-based solar heating system [13]. Jordanian rocks as heat storage medium can also be used as solar air heating unit for space heating [14]. High-density polyethylene spheres filled roughly 95% with water, and water was, likewise, utilized as the working fluid [15]. The determination of sensible heat storage system relies on the storage time, financial reasonability, and working conditions [16]. The decision of material depends to greater extent on the warmth level of the application [17]. Water being utilized temperature lower than 100 °C and refractory bricks utilized for temperature up to 1000 °C.

The literature review revealed that though many researchers have investigated the use of packed bed by using rocks, gravels, and other heat storage material for space heating methods and to enhance heat transfer, there is still a dearth of work to explain how the use of other heat storage materials explained by [18] like waste plastic as used in my study would affect the thermal energy storage techniques and heat transfer in flow through channels. The experimental work conducted focused on the study of heat storage material for thermal energy storage such as in space heating which includes residential building heating, solar water heating, agricultural applications, etc.

## 2 Experimental Setup

The experimental arrangement is shown schematically in Fig. 1. It basically consists of packed bed of cylindrical shape having the length of 1.5 m, and the diameter of packed bed is 0.10 m (4 inch), the material used for the cylindrical packed bed is polyvinylchloride (PVC), sixteen thermocouples were placed on the packed bed about their horizontal position. The bed was filled with large number of waste plastic, i.e., waste polycarbonate plastic with an average size of 40 mm diameter, both ends of cylindrical packed bed fixed with the reducer of 4 inch to 2 inch made of PVC material.

In this experiment, five ball valves were also used for the smooth functioning of the experiment. The valve number 4 is mounted on the extreme right side of the packed bed, and the remaining was placed on the left side of the packed bed. Valve number 5 was placed on the bypass tube which is open at the time of discharging. Valve 2 was placed perpendicular with the valve 1 and the valve 3. Mounting position of the valve was fixed throughout the experiment.

The electric heater is of 1.5 kW rating, 10 A current supply was used for the purpose of supplying hot air to the packed bed at the time of charging period. The outer surface of the cylinder was insulated with the insulating material made of plaster of Paris and gland thread. A blower of 374 W power is used to pump working fluid (air) into the packed bed regenerator. In between blower and the heater, a U-tube manometer was placed for measuring mass flow rate of air pumped by the blower. Different mass flow rates were used for the number of experiments. Fig. 2 shows the actual schematic diagram of experimental setup.

The material used as heat storage material inside the bed is an important feature of the present study. In the present study, the material used is plastic waste and it is assumed to be spherical having a diameter of 0.04 m. The density of the material is

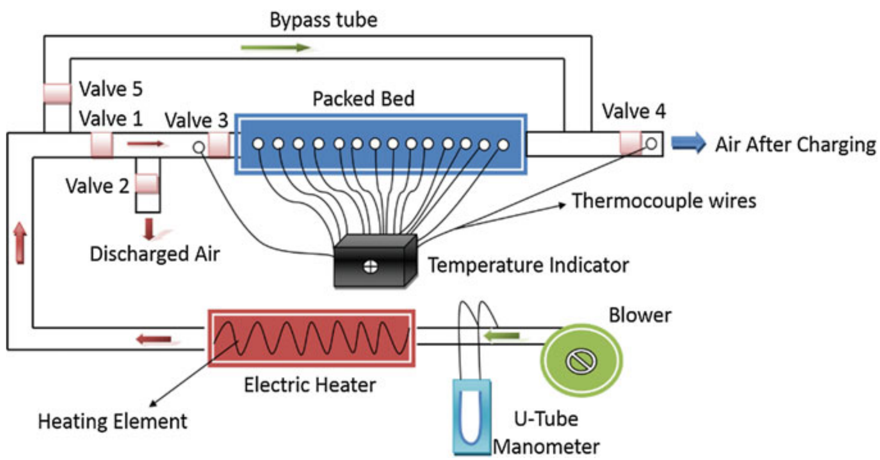



**Fig. 1** Schematic diagram of experimental setup

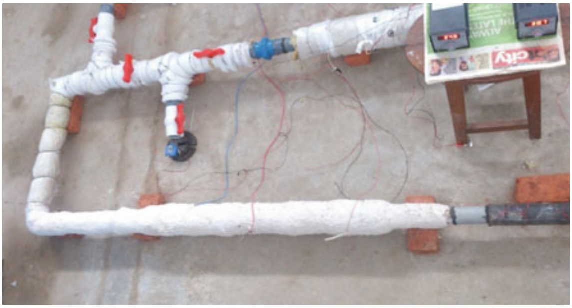


**Fig. 2** Photographic view of experimental setup

1200 kg/m$^3$, and specific heat is 1300 J/kg-K. Effective particle diameter is calculated by using the formula given by [12]

$$D = \frac{6}{S_v} \tag{1}$$

$$S_v = \frac{\text{Surface area of particle}}{\text{Volume of particle}} \tag{2}$$

## 3 Instrumentation

This section includes the analytical methods used in the present work. The experimental results were compared with analytical methods in order to verify the results obtained from packed bed heat regenerator. The physical and geometrical assumptions taken in the analytical methods were same as in experimental work. The comparison was done by variation of Nusselt number with Reynolds number for charging and discharging of packed bed heat regenerator. The following relations were used in the analytical method.

### *3.1 Porosity*

Porosity is associated with the packing of bed, and it is defined at the same time as the ratio of packed volume to the total volume of bed. Mathematically it is represented as:

$$\in = \frac{\text{Solid volume in the bed}}{\text{Total volume of the bed}} \tag{3}$$

### 3.2 Air Flow and Pressure Measurements

For the measurement of flow rate of air through the test ducts, an orifice plate has been used. It was fixed between two flanges fixed with straight pipe of mild steel. The length of pipe upstream of the orifice meter was 2 m and toward the downstream of the orifice meter, it was 0.8 m. The pressure measuring system consisted of a U-tube manometer. The pressure drops across two orifices were measured by a vertical scale manometer. The minor scale division and ranges in cm of water were 0–30. Further, mass flow can be calculated by using the pressure drop and velocity across orifice.

$$h_a = \frac{\rho_w - \Delta P}{\rho_a} \tag{4}$$

$$V_o = C_d \sqrt{\frac{2gh_a}{\left[1 - \left(\frac{d_o}{d_p}\right)^2\right]^4}} \tag{5}$$

### 3.3 Temperature Measurements

The temperature of the air flowing throughout the packed bed, the surface and interior of waste plastic inside the bed were considered at certain period of time and at certain location. The temperatures were considered by means of copper–constantan thermocouples. All thermocouples were placed at a distance of 0.1 m from the inlet to the outlet, and a total of 14 thermocouples were used for measuring the temperature of the packed bed storage material.

Two thermocouples were also placed, one at inlet and other at outlet chamber, in order to measure the air inlet temperature which were passed through the packed bed during charging cycle and to measure the ambient air temperature during discharging cycle. A digital temperature indicator was used with the thermocouple for measuring the temperature readings in degree Celsius.

### 3.4 Air Properties in Charging and Discharging

The air properties are density, dynamic viscosity, and specific heat which are taken at the bulk mean temperature at any instant of operation. The bulk temperature $T_b$ is defined as the mean of air and solid temperature at any instant. The properties of air at $T_b$ are taken from [19].

$$T_b = \frac{T_{\text{solid}} + T_{\text{air}}}{2} \tag{6}$$

## 4 Results and Discussion

The performance of the packed bed heat storage system depends upon various parameters such as material diameter, mass flow rate of air, inlet temperature of air, porosity, and dimensions of the packed bed. All these parameters have their own significance in the performance of packed bed heat storage system, although dimensions of the bed have negligible influence on the performance of storage system. In current, only two parameters namely: air inlet temperature (40 and 50 °C) and mass flow rate (0.00796, 0.0111 and 0.0125 kg/s) on charging and discharging profile of packed bed are studied experimentally by assuming remaining parameters to be constant.

### *4.1 Charging Profile of Packed Bed at Air Inlet Temperature 40 °C*

When hot air enters into the packed bed, due to convective heat transfer between hot air and storage material, i.e., waste plastic, the packed bed gets heated. Due to high air heat transfer coefficient and area product, packed bed gets heated initially up to a certain length and after a longtime, packed bed reaches to an uniform temperature. Once packed bed gets charged, it is now available to supply heat when discharged. For the study and optimization purposes, packed bed is heated with three mass flow rates, i.e., 0.00796, 0.0111 kg/s along with 0.0125 kg/s.

Charging of packed bed in minimum time was the objective as major part of solar insolation is available for 4–5 h in a single day, and it is found that 0.0125 kg/s mass velocity of hot air charged the bed in 55 min with particle diameter of 0.04 m. Temperature profiles of bed with three mass flow rates along the length of the packed bed are shown in Figs. 3, 4, and 5.

### *4.2 Charging Profile of Packed Bed at Air Inlet Temperature 50 °C*

Figures 6, 7, and 8 show the temperature profile of packed bed in charging with mass flow rate of 0.00796, 0.0111, 0.0125 kg/s and inlet air temperature of 50 °C. It is clear as of the figure that charging moment in time, when bed obtains the maximum temperature, is reduced as the mass flow rate increases.

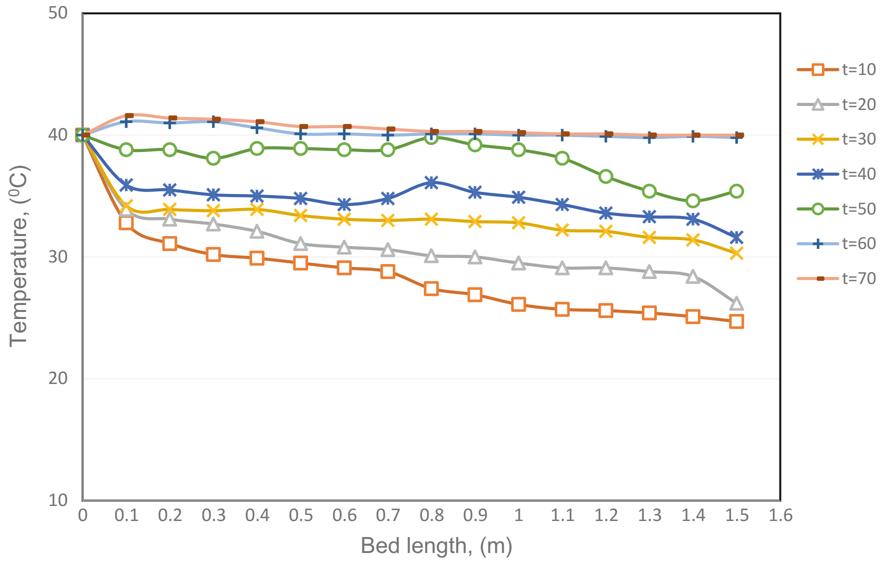



**Fig. 3** Temperature profile of charging packed bed with $\dot{m}$ = 0.00796 kg/s and air inlet temperature at 40 °C

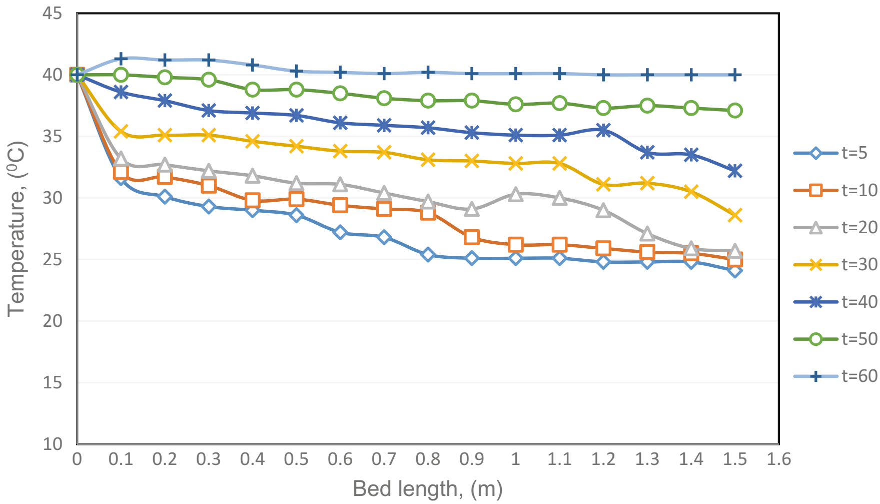



**Fig. 4** Temperature profile of charging packed bed with $\dot{m}$ = 0.0111 kg/s and air inlet temperature at 40 °C

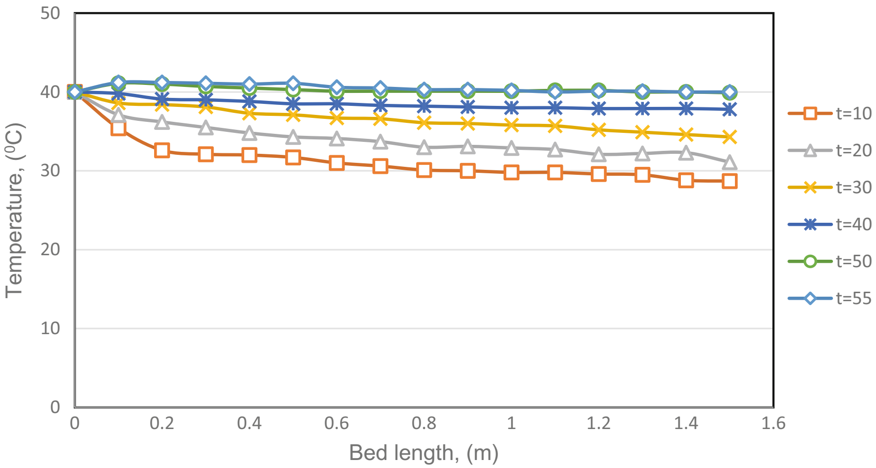



**Fig. 5** Temperature profile of charging packed bed with $\dot{m} = 0.0125$ kg/s and air inlet temperature at 40 °C

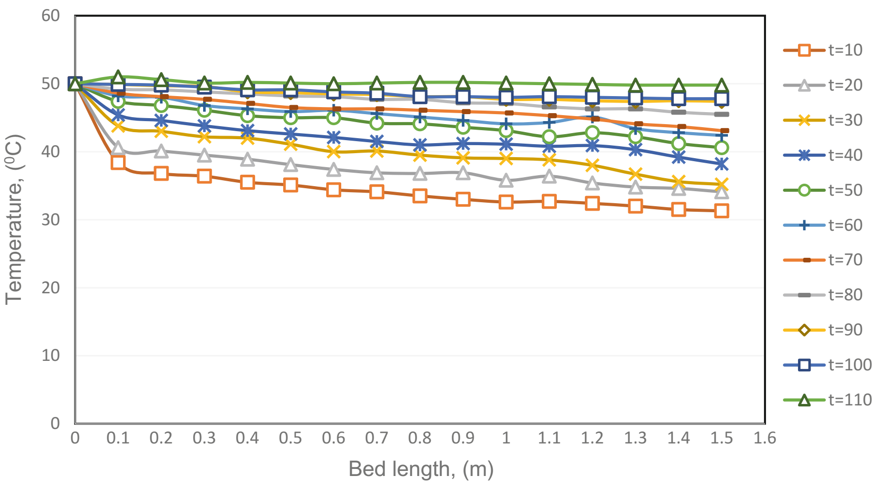



**Fig. 6** Temperature profile of charging packed bed with $\dot{m} = 0.00796$ kg/s and air inlet temperature at 50 °C

## *4.3 Discharging Profile of Packed Bed*

Figures 9 and 10 show the discharging temperature profiles with mass flow rate of 0.00796 kg/s and ambient air temperature of 29.7 °C.

For the space to be heated throughout the night, discharging time should be maximum. So the packed bed is discharged with lesser of the charging mass flow

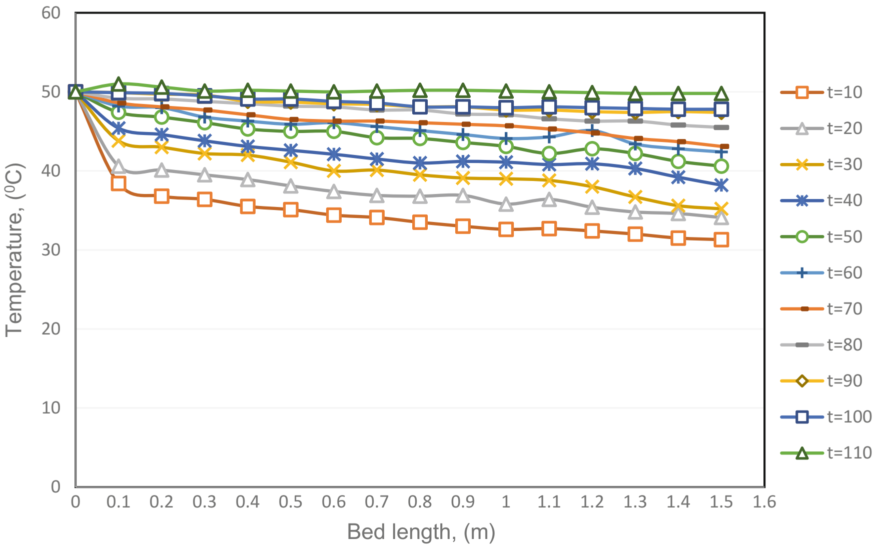



**Fig. 7** Temperature profile of charging packed bed with $\dot{m} = 0.0111$ kg/s and inlet air temperature at 50 °C

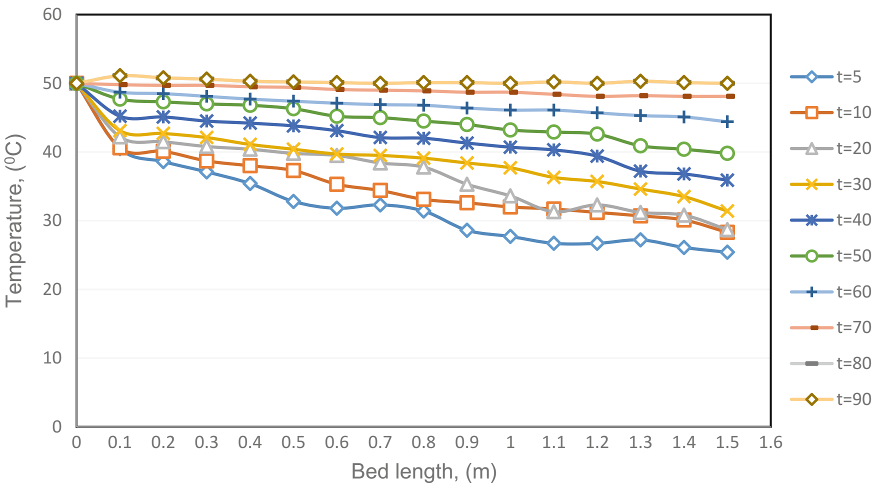



**Fig. 8** Temperature profile of charging packed bed with $\dot{m} = 0.0125$ kg/s and inlet air temperature at 50 °C

rate (0.00796 kg/s). If it is discharged with same mass flow rate in charging (0.0111 and 0.0125 kg/s), either the number of beds has to be increased or larger beds have to be used.

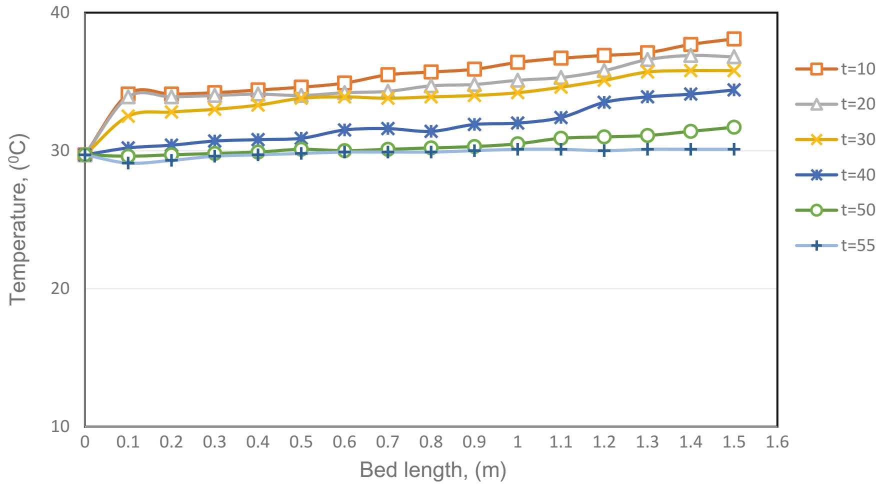



**Fig. 9** Temperature profile of discharging packed bed with $\dot{m}$ = 0.00796 kg/s and when air inlet temperature was 40 °C

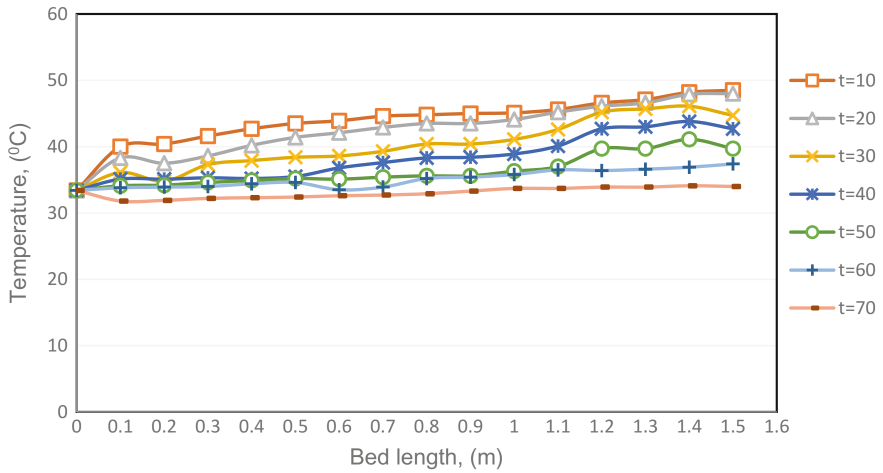



**Fig. 10** Temperature profile of discharging packed bed with $\dot{m}$ = 0.00796 kg/s and when air inlet temperature was 50 °C

## 4.4 *Effect of Mass Flow Rate of Air in Charging of Packed Bed*

Figure 11 shows the outcome of mass flow rate in charging profile of packed bed. As the mass flow rate is increased, the charging temperature profile of packed bed gets straighter. This is due to increased particle heat transfer coefficient.

This implies that if we charge the bed with higher mass flow rate, then it takes less time to charge the bed with uniform temperature of charging air. If a charging time of 4 h is to be considered as maximum solar insolation is available in the period of 11:00 AM–3:00 PM, then charging mass flow rate of 0.0125 kg/s with one or more bed is best suited for space heating of the present study.

## *4.5 Comparison Between Experimental and Analytical Results*

Comparison of the experimental work with the analytical methods is determined in this section. Dittus–Boelter correlation is used in the analytical solution. Nusselt number with Reynolds number is obtained with the help of this correlation.

**Charging**

Figures 12 and 13 show the comparison of experimental and analytical results for Nusselt number with Reynolds number during charging at 40 and 50 °C air inlet temperature. It is observed from the figure that Nusselt number decreases with decreasing Reynolds number, as viscosity of air increases due to increase in temperature as time increases. The maximum deviation of 9.14 and 8% variation is obtained which is in the acceptable region.

**Discharging**

Figures 14 and 15 show the comparison of experimental and analytical results for Nusselt number with Reynolds number during discharging. It is observed that the Nusselt number increases with increase in Reynolds number due to decrease in temperature inside the packed bed as time increases. This happened due to decrease in viscosity with decreasing temperature, hence Reynolds number increases. Here the maximum deviation is found out to be 8.48 and 6.66%.

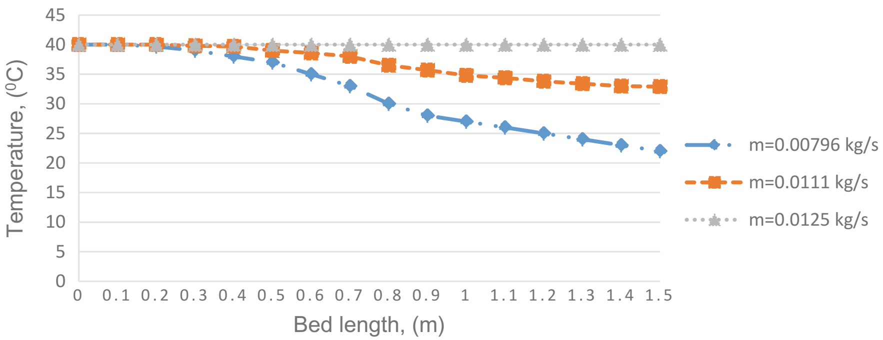



**Fig. 11** Temperature profile of packed bed charging at different mass flow rates

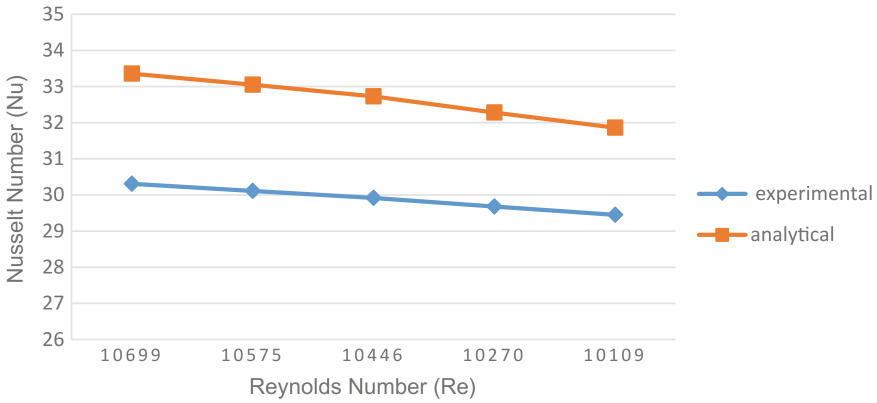



**Fig. 12** Comparative of experimental and analytical results during charging at 40 °C air inlet temperature

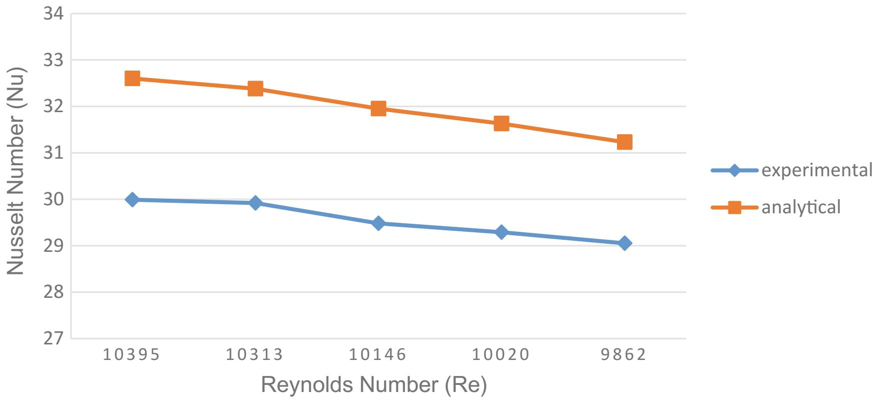



**Fig. 13** Comparative of experimental and analytical results during charging at 50 °C air inlet temperature

## 5 Conclusions

The results concluded that when the mass flow rate increases the charging time and discharging time decreases. From the results, the optimum mass flow rate for charging is found out to be 0.0125 kg/s and for the discharging period, the optimum mass flow rate should be 0.00796 kg/s. The results show that the effect of temperature is negligible on the charging and discharging characteristics of packed bed heat storage system. Therefore, it is recommended to store energy at maximum temperature and at moderate temperature. It has been also observed that the waste plastic which was used as heat storage material inside the bed works very fine and can store maximum heat as possible. The results have been concluded that it can be

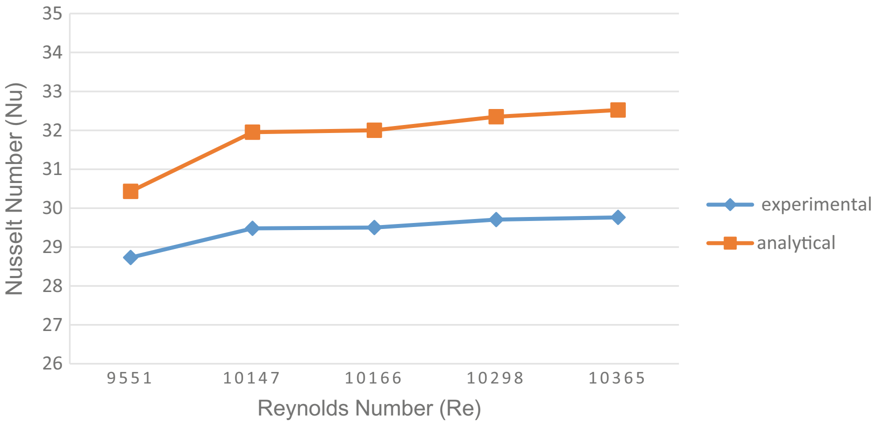



**Fig. 14** Comparative of experimental and analytical results during discharging when air inlet temperature is 40 °C

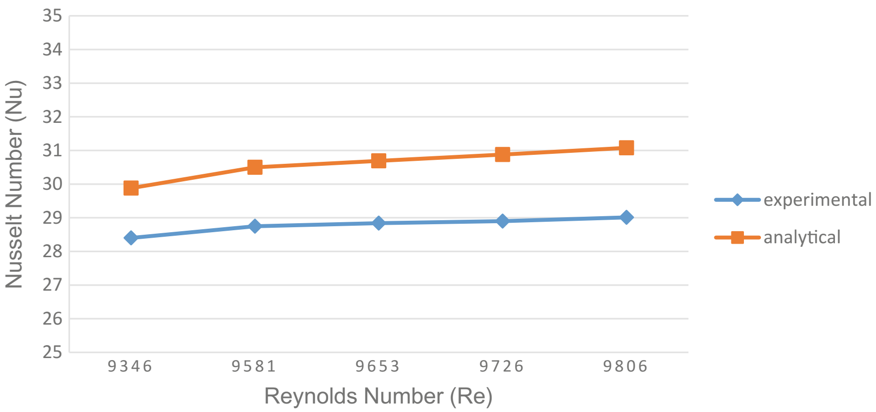



**Fig. 15** Comparative of experimental and analytical results during discharging when air inlet temperature is 50 °C

efficient to use such material as heat storage unit inside the packed bed as compared to rock which has low specific heat capacity in comparison to plastic and also has high thermal conductivity than plastic. So it is recommended to use such material for thermal energy storage unit such as for space heating, crop drying, solar water heating.

## References

1. Furnas, C.C.: Heat transfer from a gas stream to a bed of broken solids. Ind. Eng. Chem. J. 721–31 (1930)
2. Lof, G.O.C., Hawley, R.W.: Unsteady state heat transfer between air and loose solids. Ind. Eng. Chem. J. **40**(6), 1061–1071 (1948)
3. Hughes, P.J., Klein, S.A., Close, D.J.: Packed bed thermal storage models for solar air heating and cooling systems. Transac. ASME J. Heat Transf. **98**(2), 336–338 (1976)
4. Coutier, J.P., Faber, E.A.: Two applications of a numerical approach of heat transfer process within rock beds. Sol. Energy **29**(6), 451–462 (1982)
5. Colburn Allan, P.: Heat transfer and pressure drop in empty baffled, and packed tubes. Ind. Eng. Chem. J. **23**(8), 910–913 (1931)
6. Lof, G.O.C., Hawley, R.W.: Residential heating with solar heated air-the Colorado Solar House. Trans. ASHRAE. **77** (1963)
7. Close.: Design and performance of thermal storage air conditioner system. In: Mechanical and Chemical Engineering Transactions, vol. MC4. 45. Institution of Engineers, Australia (1968)
8. Garg, H.P., Bandyopadhyay, B., Sharma, V.K.: Investigation of rock bed solar collector cum storage system. Energy Con. Mgmt. **21**, 275–282 (1981)
9. Adnan, M.: Waked solar energy storage in rocks. Solar Wind Technol. **3**(1), 27–31 (1985)
10. Chandra, P., Willits, D.H.: Pressure drop and heat transfer characteristics of air rock bed thermal storage systems. Sol. Energy **26**(6), 547–553 (1981)
11. Shitzer, A., Levy, M.: Transient behavior of a rock bed thermal storage system subjected to variable inlet air temperature: analysis and design. Solar Energy Eng. (ASME Trans) **105**, 200–206 (1983)
12. Ergun, S.: Fluid flow through packed columns. Chem. Eng. Prog. **48**(2), 89–94 (1952)
13. Sagara, K., Nakahara, N.: Thermal performance and pressure drop of rock beds with large storage materials. Sol. Energy **47**(3), 157–163 (1952)
14. Mahmoud, S.A.: Experimental study of a solar space heating model using jordanian rocks for storage. Energy Convers. Mgmt. **33**(9), 833–842 (1992)
15. Sanderson, T.M., Cunningham, G.T.: Packed bed thermal storage system. Appl. Energy **51**, 51–67 (1995)
16. Dincer, I., Dost, S., Li, X.: Performance analysis of sensible heat storage systems for thermal applications. Int. J. Energy Res. **21**, 1257–1171 (1997)
17. Atear, O.E.: Storage of thermal energy. In: Encyclopedia of Life Support Systems (EOLSS) (2008)
18. Parfait, T., Nolwenn, L.P., Lingai, L.: A review of potential materials for thermal energy storage in building applications. Renew. Sustain. Energy Rev. **18**, 327–349 (2012). Elsevier
19. Incropera F.P., Dewitt D.P.: Fundamentals of Heat and Mass Transfer. New Delhi (2009)

# Sustainable Food Supply Chain Management Implementation Using DEMATEL Approach

**Yogesh Kumar Sharma, Sachin Kumar Mangla, Pravin P. Patil and Surbhi Uniyal**

## 1 Introduction

Food industry is one of the largest sectors in developed as well as developing countries. To fulfill the increasing demands, food production and distribution have become efficient in various aspects. Sustainable food supply has become a challenge in the manufacturing and production industries [1].

Despite these facts, the food industry is still facing problems with food security, farming, public health, and waste. Climate change is the upcoming challenge for the policy-makers in food industries. Due to this, there is a concern about environmental and social sustainability of the food industry. Some questions have been raised about the food supply, distribution, and consumption in more sustainable way without affecting the cost of the products. Standards and technologies should be improved to minimize the waste and reduce the costs. It is necessary for stakeholders in the food industry to look for their boundaries in SFSCM, including technology, environmental, scientific, and market. The aim of the SFSCM is to develop recent trends in food industries and to observe the research challenges regarding decision support, strategy, and technical levels.

Y. K. Sharma (✉) · S. K. Mangla · P. P. Patil · S. Uniyal
Department of Mechanical & Automobile Engineering,
Graphic Era University, Dehradun 248002, Uttarakhand, India
e-mail: yogeshsharmame355@gmail.com

S. K. Mangla
e-mail: sachinmangl@gmail.com

P. P. Patil
e-mail: deanresearch4geu@gmail.com

S. Uniyal
e-mail: surbhiuniyal@yahoo.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_13

For successful implementation of SFSCM, success factors are very important. Success factors are the factors that are essential for the organization to attain their objectives toward success.

Although SFs is not only a factor but is also free from errors. SF is reliable tool as it allows policy-makers to identify SFs and has more manager contribution because it assists in achieving better SFs and strategic goals [2]. In this paper, DEMATEL method was used to predict the correlation between the SFSCM execution of SFs by categorizing them into cause and effect. This paper comprises of different sections: Sect. 2 investigates the literature relevant to this paper; Sect. 3 investigates solution methodology applied to solve the given problem. Section. 4 comprises application of DEMATEL approach; Sect. 5 comprises of analysis of results and its implications; Sect. 6 comprises of conclusion and summarizes the limitations and scope of future.

## 2 Literature Review

This segment includes the literature on SFSCM and SFSCM implementation, and SFs were also discussed.

### *2.1 SFSCM*

In the direction to attain the sustainability in the food supply chain, food waste is the major challenge. It is evaluated that one-third of the world's production is wasted yearly [3]. Nowadays, food industries are still lacking with food security, safety, climate change, health risks, and waste. To overcome these issues in the food industries, SFs plays an essential role. Fuzziness is always a worst factor in any decision model. Thus, to decrease the impact of fuzziness is important for the research [4]. Risk management affects the performance of the chain and their related decisions. SFSCM is a tool for controlling social, environmental, and economic performance of the supply chain [5].

### *2.2 SFs Related to SFSCM*

SFs are identified as an important factor for targeting any aspects of a business. The areas like production, manufacturing, distribution, and packaging SFs are usually identified. Providing strength and identifying these factors are also considered as core competence factors in any industry [6]. In this context, we find out ten SFs on the basis of literature review which is necessary to achieve the objective. For the successful implementation of SFSCM, SFs are important. Uncertainty to market,

**Table 1** Identification of SFs in SFSCM

| S.No. | SFs | Explanation | Reference |
|---|---|---|---|
| 1 | Climatic change (CC) | Climatic change is the major issue for the policy-makers | [7] |
| 2 | Government regulation (GR) | Government regulations/policies are crucial to protect social and ethical issues in food supply chain | [8] |
| 3 | Implementing green practice (IGP) | It improves the ecosystem and proper selection of supplier, packing, and regulatory compliance, and having long-term competitive advantage | [9] |
| 4 | Food quality and safety (FQS) | It is a very important factor because consumers are increasingly aware and conscious about health risks | [10] |
| 5 | Cost assessment and benchmarking (CAB) | It is a tool for continuous improvement and cost evaluation of food products in this competitive world | [11] |
| 6 | Governance and cooperation (GC) | Corporate social responsibility is related to suppliers for better implementation of sustainable supply chain | [12] |
| 7 | Technological innovation (TI) | It is useful for the monitoring and traceability of the product | [13] |
| 8 | Containment and packing (CP) | It is used to preserve the product against broad range environmental stress | [14] |
| 9 | Operations and logistics (OL) | It is important to package, handle, and transport the food products for maintaining their taste and quality | [15] |
| 10 | Incentives (I) | It is crucial for maintaining the sustainability of products and process which helps food industry to decrease risks | [16] |

understanding of how and why customers buy, cooperate social responsibility, low cost, etc., are some of the examples of SFs. DEMATEL method had been used to demonstrate to construct interrelation between factors that represent the usefulness of the factors and to construct the research framework. Identification and implementation of SFs in SFSCM are illustrated in the (Table 1).

## 3 Solution Methodology

DEMATEL is a tool to estimate the importance of SFs to analyze the correlation between factors. The DEMATEL approach allows policy-makers to recognize the relationship among the factors by means of a causal diagram. It helps to plan long-term policies which are important for reaching the ultimate aim [17, 18].

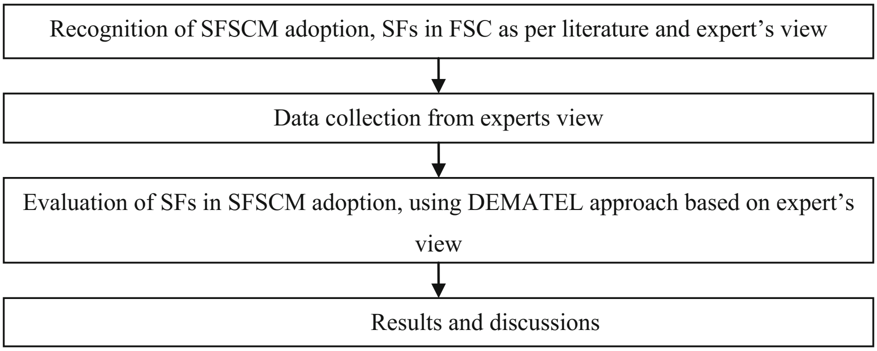



**Fig. 1** Flow chart showing methodology of present work

Therefore, DEMATEL method was implemented to evaluate SFs related to the successful adoption of SFSCM initiatives in SFSCM. The flow chart of this study is illustrated in Fig. 1.

## *3.1 DEMATEL Method*

The DEMATEL technique was developed by Battelle Memorial Institute (BMI) during 1972–1976 in the project of Geneva Research Center to scrutinize and resolve complicated problems [19]. In Japan, DEMATEL technique is mainly preferred for the analysis of decision-making problems [20, 21]. DEMATEL technique is used to recognize and categorize the factors into cause and effect groups [22]. DEMATEL technique has been used to formulate interrelation between factors that represent the usefulness of the factors [23, 24]. This method has been applied successfully in various areas like safety problems, control systems, group decision-making [25]. The DEMATEL technique [26, 27] consists of several basic steps such as:

1. Defining aim and assessment of factors: To collect the data and to achieve the objective of the problem, literature review and experts opinion are required. Possible associated factors that are important for the application of SFSCM are listed as assessment factors.
2. Formulation of direct-relation matrix and average matrix (M): This step provides relation matrix formulation and to find the direct impact of one factor over another factor. The factors were rated according to the given scale, and this scale was implemented by experts. Table 2 illustrates the rating scale.

**Table 2** Rating scale

| 0 | 1 | 2 | 3 |
|---|---|---|---|
| No Effect | Less Effect | High Effect | Very High Effect |

$$m_{ij} = \frac{1}{H}\sum_{K=1}^{H}\left(x_{ij}^{k}\right) \quad (1)$$

where,

$k$ number of participants;
$n$ factors with $1 \leq k \leq H$;
Xk [xkij].
xij degree of factor $i$ which affects factor $j$.
$H$ number of experts.

3. Calculate the normal direct-relation matrix ($D$): The average matrix ($M$) is changed into a normal direct-relation matrix using Eq. 2.

$$D = M \times S \quad (2)$$

$$S = \min\left[\frac{1}{\max\sum_{j=1}^{n}\{m_{ij}\}}, \frac{1}{\max\sum_{i=1}^{n}\{m_{ij}\}}\right]$$

4. To formulate the total relation matrix ($T$): The total relation matrix ($T$) can be calculated by using Eq. 3.

$$T = D(I - D)^{-1} \quad (3)$$

where $I$ = identity matrix.

Once the total relation matrix was developed, the sum of all the columns and rows was determined.

Let $[ri]n \times 1$ and $[cj]1 \times n$ be the vectors.
$ri$ gives the indirect and direct effects of factor ‘$i$’ with the other factors,
$cj$ explains the indirect and direct effects of factor ‘$j$’ with the other factors.
Sum ($ri + cj$) = the total effects given and received by factor ‘i’.
Difference ($ri - cj$) = the net effect of factor ‘$i$’ which influences the system.

If the value $(ri - cj)$ is +ve, then, factor '$i$' is in the cause group, and if the value $(ri - cj)$ is –ve, then the factor '$i$' is in the effect group [19, 28].

5. Calculating the threshold value: For constructing the causal diagram, the threshold value is calculated. In total relation matrix (T), average of all the factors was calculated [29]. For plotting causal relationship in the graph $(r + c,\ r - c)$, map-highlighted values are chosen in place of threshold value.

## 4 Data Collection for DEMATEL Approach

Data were collected and analyzed for their interrelations. Based on the literature review, ten SFs (CC, GR, IGP, FQS, CAB, GC, TI, CP, OL, I) were identified and already mentioned above in Sect. 2.2. For the determination of SFs, their interaction was analyzed, and the methodology used was DEMATEL. Interrelationship between factors was constructed in DEMATEL approach for representing the effectiveness of the SFs.

## 5 Results and Discussions

### *5.1 Relationship Between SFs of SFSCM*

Before finalizing, the SFs were determined by thorough study and discussing with experts. The SFs were given values as per their influence (Table 2).

On the other hand, these factors were assembled in the initial direct-relation matrix (Table 3).

**Table 3** Initial direct-relation matrix

| | CC | GR | IGP | FQS | CAB | GC | TI | CP | OL | I |
|---|---|---|---|---|---|---|---|---|---|---|
| CC | 0.00 | 1.00 | 1.50 | 3.00 | 1.50 | 0.50 | 1.00 | 1.50 | 0.50 | 1.00 |
| GR | 1.00 | 0.00 | 1.50 | 2.00 | 1.00 | 1.00 | 1.50 | 2.00 | 1.20 | 1.00 |
| IGP | 1.50 | 2.00 | 0.00 | 2.50 | 1.00 | 1.00 | 1.30 | 2.00 | 1.00 | 1.20 |
| FQS | 3.00 | 2.50 | 2.00 | 0.00 | 1.30 | 1.50 | 1.60 | 2.30 | 2.00 | 2.00 |
| CAB | 2.00 | 1.50 | 2.00 | 1.00 | 0.00 | 0.80 | 1.00 | 2.00 | 1.00 | 1.00 |
| GC | 1.20 | 2.00 | 2.00 | 2.90 | 1.00 | 0.00 | 0.50 | 2.60 | 0.50 | 0.50 |
| TI | 1.00 | 1.50 | 1.80 | 1.50 | 1.50 | 0.60 | 0.00 | 2.30 | 1.20 | 0.70 |
| CP | 2.70 | 1.00 | 2.20 | 1.50 | 1.30 | 1.20 | 1.40 | 0.00 | 1.20 | 0.80 |
| OL | 1.00 | 1.30 | 2.30 | 1.00 | 1.50 | 1.20 | 1.00 | 2.00 | 0.00 | 0.50 |
| I | 1.00 | 0.90 | 2.00 | 2.00 | 1.00 | 1.00 | 0.70 | 2.00 | 1.00 | 0.00 |

*Source* DEMATEL analysis

Then with the help of Eqs. 2 and 3, we derived normalized matrix (Table 4).

For the successful implementation of SFSCM, the total relation matrix required is illustrated in (Table 5).

According to (Table 6), the values of SFs (CC, GR, IGP, FQS, CAB, GC, TI, CP, OL, I) are obtained from (r−c). Figure 2 explains the cause and effect group of SFs according to their priority.

The factors CC, CP, IGP, and FQS fall in the effect group while the factors I, GC, OL, CAB, TI and GR come under cause group. Among all the cause factors, (GC) acquires highest score of 0.82 and thus has highest impact on other SFs. But the (r + c) score of GC has less value (4.12) in comparison with other factors therefore has less influence on other SFs. In SFSCM, implementation effect group can be easily influenced by other success factors but also plays a fundamental role.

**Table 4** Normalized direct-relation matrix

| | CC | GR | IGP | FQS | CAB | GC | TI | CP | OL | I |
|---|---|---|---|---|---|---|---|---|---|---|
| CC | 0.00 | 0.05 | 0.08 | 0.16 | 0.08 | 0.03 | 0.05 | 0.08 | 0.03 | 0.05 |
| GR | 0.05 | 0.00 | 0.08 | 0.11 | 0.05 | 0.05 | 0.08 | 0.11 | 0.06 | 0.05 |
| IGP | 0.08 | 0.11 | 0.00 | 0.13 | 0.05 | 0.05 | 0.07 | 0.11 | 0.05 | 0.06 |
| FQS | 0.16 | 0.13 | 0.11 | 0.00 | 0.07 | 0.08 | 0.09 | 0.12 | 0.11 | 0.11 |
| CAB | 0.11 | 0.08 | 0.11 | 0.05 | 0.00 | 0.04 | 0.05 | 0.11 | 0.05 | 0.05 |
| GC | 0.06 | 0.11 | 0.11 | 0.16 | 0.05 | 0.00 | 0.03 | 0.14 | 0.03 | 0.03 |
| TI | 0.05 | 0.08 | 0.10 | 0.08 | 0.08 | 0.03 | 0.00 | 0.12 | 0.06 | 0.04 |
| CP | 0.14 | 0.05 | 0.12 | 0.08 | 0.07 | 0.06 | 0.07 | 0.00 | 0.06 | 0.04 |
| OL | 0.05 | 0.07 | 0.12 | 0.05 | 0.08 | 0.06 | 0.05 | 0.11 | 0.00 | 0.03 |
| I | 0.05 | 0.05 | 0.11 | 0.11 | 0.05 | 0.05 | 0.04 | 0.11 | 0.05 | 0.00 |

*Source* DEMATEL analysis

**Table 5** Total relation matrix

| | CC | GR | IGP | FQS | CAB | GC | TI | CP | OL | I |
|---|---|---|---|---|---|---|---|---|---|---|
| CC | 0.19 | 0.22 | 0.28 | 0.35 | 0.21 | 0.14 | 0.18 | 0.29 | 0.15 | 0.17 |
| GR | 0.24 | 0.17 | 0.28 | 0.31 | 0.19 | 0.17 | 0.21 | 0.32 | 0.19 | 0.17 |
| IGP | 0.29 | 0.29 | 0.23 | 0.35 | 0.20 | 0.18 | 0.21 | 0.34 | 0.19 | 0.19 |
| FQS | 0.41 | 0.36 | 0.39 | 0.30 | 0.26 | 0.23 | 0.27 | 0.42 | 0.27 | 0.26 |
| CAB | 0.28 | 0.24 | 0.30 | 0.26 | 0.14 | 0.15 | 0.18 | 0.31 | 0.17 | 0.17 |
| GC | 0.28 | 0.29 | 0.33 | 0.37 | 0.20 | 0.13 | 0.18 | 0.37 | 0.17 | 0.16 |
| TI | 0.24 | 0.24 | 0.29 | 0.28 | 0.21 | 0.14 | 0.13 | 0.33 | 0.18 | 0.15 |
| CP | 0.33 | 0.23 | 0.33 | 0.31 | 0.21 | 0.18 | 0.21 | 0.24 | 0.19 | 0.17 |
| OL | 0.23 | 0.23 | 0.31 | 0.25 | 0.21 | 0.17 | 0.18 | 0.31 | 0.12 | 0.14 |
| I | 0.24 | 0.21 | 0.30 | 0.30 | 0.18 | 0.16 | 0.16 | 0.31 | 0.17 | 0.11 |
| cj | 2.72 | 2.49 | 3.04 | 3.09 | 2.02 | 1.65 | 1.91 | 3.24 | 1.81 | 1.68 |

Threshold value = 0.24

*Source* DEMATEL analysis

**Table 6** Assessment of cause and effect factors

| Success Factors | Sum = ri | Sum = cj | r + c | Rank | r − c | Cause/Effect |
|---|---|---|---|---|---|---|
| CC | 2.17 | 2.72 | 4.89 | 4 | −0.55 | Effect |
| GR | 2.24 | 2.72 | 4.73 | 6 | −0.24 | Effect |
| IGP | 2.47 | 2.72 | 5.51 | 3 | −0.56 | Effect |
| FQS | 3.18 | 2.72 | 6.28 | 1 | 0.09 | Cause |
| CAB | 2.21 | 2.72 | 4.24 | 5 | 0.19 | Cause |
| GC | 2.47 | 2.72 | 4.12 | 10 | 0.82 | Cause |
| TI | 2.21 | 2.72 | 4.12 | 7 | 0.30 | Cause |
| CP | 2.40 | 2.72 | 5.64 | 2 | −0.85 | Effect |
| OL | 2.15 | 2.72 | 3.96 | 8 | 0.33 | Cause |
| I | 2.15 | 2.72 | 3.83 | 9 | 0.47 | Cause |

*Source* DEMATEL analysis

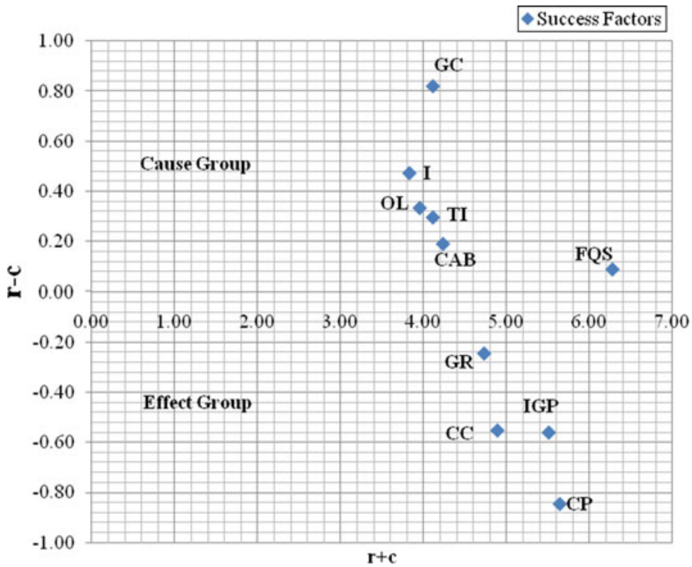



**Fig. 2** Cause and effect diagram of SFS in SFSCM

## 5.2 *Ranking of Success Factors*

Using DEMATEL approach, the SFs can be ranked as (Table 6)

FQS > CP > IGP > CC > CAB > GR > TI > OL > I > GC.

The FQS holds the first rank in the list and thus attains the highest priority in comparison to other success factors for implementing SFSCM. Thus, higher authorities should take FQS as a serious concern for maintaining the product image.

‘CP’ occupies second rank in the priority list and is essential for implementing an efficient SFSCM concept. By using this, managers can preserve the products against broad range environmental stress.

‘IGP’ attains third rank in the list which is essential to improve the ecosystem and proper selection of supplier to achieve long-term competitive advantages.

‘CC’ holds forth rank in the list and is essential for managers to design various policies in this context.

‘CAB’ comes in fifth place and is a cost-effective tool for improvement of food products.

‘GR’ attains sixth position in the priority list and is important to protect social as well as ethical issues in the food supply chain.

‘TI’ holds seventh rank in the list, in this competitive world, monitoring and traceability in food supply are very important. Information technology (IT) plays a crucial role for the successful adoption of SFs in SFSCM.

‘OL’ comes at eighth position in the list. Manager’s point of view is essential for packing and transporting the food safely to maintain their taste and quality at the consumers end.

‘I’ attains the second last position in the list, and it maintains the sustainability of products as result decreases the risks.

‘GC’ holds the last position and is related to suppliers for better implementation of sustainable supply chain.

## 6 Conclusion, Limitation of Work and Future Scope

From the last two centuries, there is an exceptional growth in the consumed resources, output, and environmental effect on Indian economy. Now India ranks fourth position in the world’s total economy. Our conclusion emphasize on the consequence of SFs for the successful implementation of SFSCM. For the better understanding of the factors such as: customers needs, food quality and safety, governance and social responsibility, environmental regulations, climate change, containment in the food and different logistics operations, SFSCM is one of most essential tools to understand supply chain management concept. In developing nations like India and China, adoption of SFSCM is very important in the food industries because the population of these countries is half of the global population. SFs are important for the execution of SFSCM in the present situation. Due to the increasing contamination in the food industries, SFSCM turns into a crucial tool for the industries.

The objectives of the work are to propose and support the system to assist the SFs for SFSCM in supply chain with the help of DEMATEL approach. DEMATEL method ranks the success factor according to their priority and then divides into cause and effect group. The outcome of this study is that food quality and safety is an essential cause and has a direct influence on other factors. Thus, policy-makers, managers, and experts need to focus on this factor to expand the SFSCM adequacy.

In this work, we suggest a structural framework for the assessment of ten SFs in SFSCM. The proposed model has its own limitations and care should be taken for assessment of SFSCM execution. However, some errors may be there due to human judgment.

**Acknowledgements** The authors acknowledge and express the gratitude for the support of the research facilities and funds provided by the Department of Mechanical and Automobile Engineering, Graphic Era University, Dehradun, India.

## References

1. Brown, R.L.: Full Planet, Empty Plates: The New Geopolitics of Food Scarcity. Earth Policy Institute, WA, USA (2012)
2. Ab Talib, M.S., Abdul Hamid, A.B.: Application of critical success factors in supply chain management. Int. J. Supp. Chain Mgmt. **3**, 1–11 (2014)
3. Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., Meybeck, A.: Global food losses and food waste. Food and Agriculture Organization of the United Nations, Rome (2011)
4. Ilbery, B., Maye, D., Kneafsey, M., Jenkins, T., Walkley, C.: Forecasting food supply chain developments in lagging rural regions: evidence from the UK. J. Rural Stud. **20**(3), 331–344 (2004)
5. Hamprecht, J., Corsten, D., Noll, M., Meier, E.: Controlling the sustainability of food supply chains. Supp. Chain Manag. Inter. J. **10**, 7–10 (2005)
6. Rockart, J.F., Bullen, C.V.: The rise of managerial computing: the best of the Center for Information Systems Research. Dow Jones-Irwin. (1986)
7. Garnett, T.: Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food Policy **36**, S23–S32 (2011)
8. Jiang, B., Yin, J., Zhao, S.: Characterizing the human mobility pattern in a large street network. Phys. Rev. E **80**(2), 021136 (2009)
9. Hervani, A.A., Helms, M.M., Sarkis, J.: Performance measurement for green supply chain management. Benchmarking An Int. J. **12**, 330–353 (2005)
10. Boyacı, I.H., Temiz, H.T., Uysal, R.S., Velioğlu, H.M., Yadegari, R.J., Rishkan, M.M.: A novel method for discrimination of beef and horsemeat using Raman spectroscopy. Food Chem. **148**, 37–41 (2014)
11. McKenna, R., Reith, S., Cail, S., Kessler, A., Fichtner, W.: Energy savings through direct secondary reuse: An exemplary analysis of the German automotive sector. J. Clean. Produc. **52**, 103–112 (2013)
12. Chiou, T.Y., Chan, H.K., Lettice, F., Chung, S.H.: The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan Transport. Res. Part E Logist. Trans. Rev. **47**, 822–836 (2011)
13. Buhr, B.L.: Traceability and information technology in the meat supply chain: Implications for firm organization and market structure. J. Food Dis. Res. **34**, 13–26 (2003)
14. Wild, Y.: Container Handbook. Gesamtverb and der Deutschen Versicher- ungswirtschaft e. V. (GDV), German Insurance Association. (2012)
15. Manzini, R., Accorsi, R.: The new conceptual framework for food supply chain assessment. J. Food Eng. **115**(2), 251–263 (2013)
16. Smith, B.G.: Developing sustainable food supply chains. Philos. Trans. Royal Soc. B Biol. Sci. **363**, 849–861 (2008)

17. Chou, Y.C., Sun, C.C., Yen, H.Y.: Evaluating the criteria for human resource for science and technology (HRST) based on an integrated fuzzy AHP and fuzzy DEMATEL approach. Appl. Soft. Comput. **12**(1), 64–71 (2012)
18. Gandhi, S., Mangla, S.K., Kumar, P., Kumar, D.: A combined approach using AHP and DEMATEL for evaluating success factors in implementation of green supply chain management in Indian manufacturing industries. Int. J. Logist. Res. App. **19**, 1–25 (2016)
19. Moghadam Bagheri N, Shafiei Alavijeh A.: Offering an analytical model for organization environment by systematic approach, Case study: A research institute in energy field. In: 4th International Conference of Strategic Management, Tehran, Iran. (2009)
20. Tzeng, G.H., Chiang, C.H., Li, C.W.: Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL. Expert Sys. App. **32**, 1028–1044 (2007)
21. Zhu, Q., Sarkis, J., Lai, K.H.: Examining the effects of green supply chain management practices and their mediations on performance improvements. Int. J. Pro. Res. **50**, 1377–1394 (2012)
22. Lin, R.J.: Using fuzzy DEMATEL to evaluate the green supply chain management practices. J. Clean. Prod. **40**, 32–39 (2013)
23. Fontela, E., Gabus, A.: DEMATEL, innovative methods. Report no. 2, Structural Analysis of the World Problematique. Battelle Geneva Research Institute (1974)
24. Fontela, E., Gabus, A.: The DEMATEL Observer. Battelle Institute, Geneva Research Center (1976)
25. Wu, W.W., Lee, Y.T.: Developing global managers' competencies using the fuzzy DEMATEL method. Expert Syst. Appl. **32**(2), 499–507 (2007)
26. Tzeng, G.H., Huang, J.J.: Multiple attribute decision making. Methods and Applications. (2011)
27. Gandhi, S., Mangla, S.K., Kumar, P., Kumar, D.: Evaluating factors in implementation of successful green supply chain management using DEMATEL: A case study. Int. Strateg. Manag. Rev. **3**, 96–109 (2015)
28. Luthra, S., Govindan, K., Kharb, R.K., Mangla, S.K.: Evaluating the enablers in solar power developments in the current scenario using fuzzy DEMATEL: An Indian perspective. Ren. Sustain. Ener. Rev. **63**, 379–397 (2016)
29. Lee, Y.C., Yen, T.M., Tsai, C.H.: Using importance-performance analysis and decision making trial and evaluation laboratory to enhance order-winner criteria-a study of computer industry. Info. Tech. J. **7**, 396–408 (2008)

# Biodiversity and Conservation of Medicinally Important Plants by Cultivation Method of Shivalik Hills of Sahaspur Block, Dehradun, Uttarakhand

**Kanchan D. Bahukhandi, Tanuja Uniyal and Neelu J. Ahuja**

## 1 Introduction

India is an agricultural country and has rich biodiversity of both flora and fauna [1]. East to west and north to south it shows variation in culture as well as in vegetation. Traditional knowledge plays an important role in the conservation of biodiversity. [2, 3]. The Himalaya is well known for medicinally important plant species such as Kuth, Kutki, Jatamansi which now became endangered due to their overexploitation and encroachment from their natural wild habitat [4–10]. A number of authors [11–17] have studied the forest flora of Chakrata, Dehraun and Saharanpur.

To fulfil the demand of such vast population and to reduce pressure on wild varieties, we need cultivated varieties of medicinal plants also. Awareness towards agricultural diversification among native people creates a difference especially in rural areas where people are using the sources unscientifically. However, in order to provide market to the cultivators is a great challenge in this way because demand and quality influence the value of cultivated medicines, so proper techniques make this area beneficial for farmers and socio-economically important.

K. D. Bahukhandi (✉) · T. Uniyal · N. J. Ahuja
University of Petroleum & Energy Studies, Dehradun, India
e-mail: kanchan@ddn.upes.ac.in

T. Uniyal
e-mail: tanuja@ddn.upes.ac.in

N. J. Ahuja
e-mail: neelu@ddn.upes.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_14


**Fig. 1** Location map of the study area

## 2 Study Area

The present study is confined to Misras Patti gramsabha of Sahaspur block of Dehradun district of Uttarakhand, it comprises of 7–8 villages and lies between 30° 25.655′–30°20.090′ N and 77°58.338′–78°00.141′ E. It is a part of Shivalik range of lower west Himalaya and situated on 1000–1050 m altitude. Dehradun comprises of both plain as well as hilly areas. The study area comes under hilly region of Dehradun and 25 km approximately from main city. The gramsabha is surrounded by two forest ranges, Langha forest range and Campty forest range from southern and northern sides, respectively. The study area becomes transition zone between two different types of forest range altitudinal. The Langha forest has Sal (*Shorea robusta* C.F. Gaertn.) as a major species, whereas Deodar (*Cedrus deodara* Roxb. G.Don.) is the major species of Campty forest area. Both of the forest area show different types of phytosociology. Inhabitants of the study area depend on both forest for their daily requirements and also responsible for its conservation (Fig. 1).

## 3 Materials and Methods

The study was based on personal interview with the selected local villagers with the help of questionnaire. The documentation was done based on interview, discussion in gramsabha meeting and observation of different age group people and some local herbal doctors (Vaidyas) of this area who were working here from many years. Several field trips were made to this area between July 2015 and August 2016, in order to collect maximum information of the plants found in this region. For cultivation of important medicinal plants, we conducted awareness generation programme in study area and selected some women farmers for MAP cultivation.

## 4 Results and Discussion

In door-to-door survey of study area, we have found that the inhabitants of area have lots of agricultural land, but because of unfavourable conditions, the agriculture became secondary and not for commercial purpose. People are engaged in other works beyond agriculture. The major causes for change in land use pattern are mentioned in Table 1, and this causes changes in overall land use pattern in Dehradun district. (Table 2). The study area comes under the rainfed area, and it also affects the agricultural practices. A total of 150 people were interviewed in all villages of gramsabha such as Than, Bharapur, Patti, Misras, Bakarna, Nunyas and conducted four awareness generation camps for cultivation of medicinally important plants with buyback guarantee such as *Origanum vulgare*, *Rauvolfia serpentine*, *Gloriosa superba*, *Perilla frutescens* and also other species which are found in adjoining forests and become vulnerable or endangered nowadays. We had listed out many medicinally important plant species found and used by the inhabitants of this region (Table 3) and conserve them by developing agro-technology for them. Cultivation of medicinal and aromatic plants in hilly region is the best method to conserve biodiversity of highly demanded plants and protection of agricultural land.

**Table 1** Socioeconomic data of villages

| | |
|---|---|
| No irrigation facility | 90% |
| Human–wildlife conflict | 100% |
| Change in land use pattern | 80% |
| Land selling to outsiders or industry owners | 50% |
| Very less outcome from traditional crops | 80% |
| Another sources of income beyond agriculture | 90% |
| Less diversification of agriculture | 100% |
| Poor market knowledge | 40% |

Based on door-to-door survey

**Table 2** Land use pattern of Dehradun district

| Dehradun profile | Area in hectare |
|---|---|
| Total land under different land use | 364,830 |
| Cultivable land | 45,459 |
| Cultivable wasteland | 45,976 |
| Land under cultivation twice in a year | 20,780 |
| Land under kharif crop in hilly areas | 14,227 |
| Land under rabi crop in hilly areas | 8779 |

From census of Dehradun land 2009–10

**Table 3** List of some medicinal plant of the study area which has been conserved by cultivation methods

| S. no. | Botanical name | Common name | Family | Life form | Availability in study area |
|---|---|---|---|---|---|
| 1 | *Achyranthes aspera L.* | Latzeera/Apamarg/Chirchira | Amaranthaceae | Herb | Common |
| 2 | *Achorus calamus L.* | Bach | Araceae | Herb | Common |
| 3 | *Adhatoda vasica Nees.* | Basinga | Acanthaceae | Shrub | Rare |
| 4 | *Asparagus adscendens Buch.-Ham. Ex Roxb.* | Satawar | Liliaceae | Shrub | Rare |
| 5 | *Bacopa monnieri (L.) Pen-nell* | Brahmi | Scrophulariaceae | Herb | Endangered |
| 6 | *Boerhavia diffusa L.* | Punarnava | Nyctaginaceae | Herb | Rare |
| 7 | *Catamixis baccharoides Thomson* | Vispatra | Asteraceae | Shrub | Rare |
| 8 | *Dioscorea bulbifera L.* | Genthi | Dioscoreaceae | Climber | Common |
| 9 | *Evolvulus alsenoides L.* | Sankhpuspi | Convulvulaceae | Herb | Rare |
| 10 | *Gloriosa superba L.* | Kalihari | Liliaceae | Shrub | Endangered |
| 11 | *Perilla frutescens Linn.* | Bhanjir | Lamiaceae | Shrub | Common |
| 12 | *Plumbago zeylanica L.* | Chitra | Plumbaginaceae | Herb | Common |
| 13 | *Rauvolfia serpentine Benth.* | Sarpgandha | Apocynaceae | Herb | Endangered |
| 14 | *Origanum vulgare Linn.* | Jungal Tulsi | Lamiaceae | Herb | Rare |
| 15 | *Tinospora cordifolia (Lour.) Merrill* | Giloy | Menispermaceae | Climber | Endangered |
| 16 | *Vitex negundo Linn.* | Nirgundi | Lamiaceae | Shrub | Rare |

# 5 Conclusion

Cultivation of medicinal and aromatic plants in hilly region is the best method to conserve biodiversity of highly demanded plants and protection of agricultural land. Commercial scale cultivation definitely will reduce fast depletion as well as extinction of medicinally important plant species. Involvement of the inhabitants can play a useful role in conservation of locally found species.

**Acknowledgements** The authors are highly thankful to the Chancellor, Head of R&D Department, UPES, Dehradun, for their active support during fieldwork and documentation and also grateful to the Department of Science and Technology, SEED Division, New Delhi for their kind and continuous support.

# References

1. Kirtikar K.R., Basu B.D.: Indian Medicinal Plants, vols. I–V. Allahabad (1935)
2. Uniyal, B., Shiva, V.: Traditional knowledge on medicinal plants among rural women of the Garhwal Himalaya. Uttaranchal. Indian J. Tradit. Knowl. **4**(3), 259–266 (2005)
3. Anthwal, A., Sharma, R.C., Sharma, A.: Sacred Groves: Traditional Way of Conserving Plant Diversity in Garhwal Himalaya. Uttaranchal. J. Am. Sci. **2**(2), 35–43 (2006)
4. Kala C.P.: Medicinal Plants of Indian Trans-Himalaya, (Bishen Singh Mahendra Pal Singh, Dehradun) (2002)
5. Kala, C.P., Faroouquee, N.: Dhar U: Prioritization of medicinal plants on the basis of available knowledge, existing practices and use value status in Uttaranchal. India. Biodivers. Conserv. **13**, 453–469 (2004)
6. Chaudhuri, A.B.: Endangered Medicinal Plants, p. 312. Daya Publications, Delhi (2007)
7. Duthie, J.F.: Flora of the Upper Gangetic Plain and of the adjacent Siwalik and Sub Himalayan Tracts. vols. 3, Calcutta (1911)
8. Gokhle, Y., Negi, A.K.: Community—Based Biodiversity Conservation in the Himalayas. The Energy Resources Institute, New Delhi (2011)
9. Badola, H.K., Pal, M.: Endangered medicinal plant species in Himachal Pradesh. Curr. Sci. **83**(7), 797 (2002)
10. Adhikari B.S., Babu M.M., Saklani P.L., Rawat S.S.: Medicinal trees of Uttaranchal State. In: Medicinal and Aromatic plant. Taxonomy, Conservation, Cultivation, Economics & Marketing (2007)
11. Raizada, M.B., Saxena, H.: Flora of Mussorie. Bishen Singh Mahendra Pal Singh, Dehradun (1978)
12. Pandey, H.K., Deendayal, Das, S.C.: Threatened Medicinal Plant Bio-diversity of Western Himalaya and its Conservation. Ministry of Defense; Defense Research & Development Organization; Defense Agricultural Research Laboratory, Pithoragarh, Uttaranchal-262501 (2006)
13. Sharma, J., Gaur, R.D., Painuli, R.M.: Conservation status and diversity of some important plants in the Shiwalik Himalaya of Uttarakhand, India. Int. J. Med. Arom. Plants **1**(2), 75–82. ISSN 2249–4340 (2011)
14. Shiva, V., Bhatt, V.K.: Nature's Harvest: Rejuvenating Biodiversity in Doon Valley, *Navdanya*, (2002)

15. Upadhyay, D.: Ethno-botanical Important Plants in the parts of Shivalik Hills of Kangra district, Himachal Pradesh. Int. J. Sci. Res. Publ. **3**(6) (2013)
16. Upadhyay, D.: An ethno-botanical study of plants found in Timli Forest Range, District Dehradun Uttarakhand, India. Int. J. Adv. Herbal Sci. Technol. **1**(1), 13–19 (2014)
17. Gupta, B.L.: Forest Flora of the Chakrata, Dehradun and Saharanpur Forest Divisions. Uttar Pradesh. International Book Distributors, Dehradun (1928)

# Implementation of Sustainable Consumption and Production Using DEMATEL

**Surbhi Uniyal, Sachin Kumar Mangla, Pravin P. Patil and Yogesh Kumar Sharma**

## 1 Introduction

With regard to environmental change, natural debasement, asset issues, and declining bio-differences, research on two crucial regions (sustainable consumption and sustainable production) of human action has strengthened as a result of the acknowledgment that both areas need to change in pair to accomplish extensive increase in ecological sustainability. Sustainable consumption and production is a heterogeneous arrangement of ideas and methodologies, e.g., natural product benefit frameworks, eco-naming, new financial aspects, group grassroots advancement [1].

As per the UNEP's meaning of SCP, we comprehend sustainable production to be the creation of farming products and administrations through procedures and frameworks that are insignificantly dirtying, preserve vitality, and common assets, are nutritious and safe, and are monetarily effective and socially compensating for all required in the product chain. Sustainable production is characterized as 'the utilization of products and administrations that respond to key needs and bring an unrivaled individual fulfillment, while minimizing the utilization of regular assets,

S. Uniyal (✉) · S. K. Mangla · P. P. Patil · Y. K. Sharma
Department of Mechanical & Automobile Engineering,
Graphic Era University, Dehradun, Uttarakhand, India
e-mail: surbhiuniyal.87@gmail.com

S. K. Mangla
e-mail: sachinmangl@gmail.com

P. P. Patil
e-mail: deanresearch4geu@gmail.com

Y. K. Sharma
e-mail: yogeshsharmame355@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_15

dangerous materials, and outflows of waste and toxins over the phase of life, so as not to imperil the requirements of future eras' [2].

The major target of this research paper is to assess the success factors of SCP. The recognized success factors are very significant and play an important part in adoption of SCP patterns. To accomplish the mentioned target, the paper is divided into two parts. The first part comprises of the success factors responsible for the execution of the SCP by means of investigation of the literature, and in the second part, the relation between these success factors is evaluated by the help of Decision-Making Trial and Evaluation Laboratory (DEMATEL).

This research aims in achieving three objectives, mentioned as: (1) to identify the success factors of SCP; (2) to rank the success factors on priority basis; (3) to classify the factors into cause and effect group.

In this paper, an effort has been made to recognize the success factors responsible for the effective implementation of SCP patterns. The classification of the factors responsible for SCP in two different groups (cause and effect) is done by DEMATEL which is a multi-criteria decision-making (MCDM) technique [3–5]. Therefore, DEMATEL is used because it helps with catching the logical relations between the factors.

The remainder of this paper comprises of the following: Sect. 2 contains the literature relevant to this study; Sect. 3 contains the research methodology applied to solve the given problem followed by the collection of data; Section 4 comprises of analysis of cause and effect factors, results, and managerial implications; Sect. 5 composes of conclusion, limitations, and future scope.

## 2 Literature Survey

Four classes of activities to advance sustainability are recognized: consumption, investment, production, and distribution [6]. Consumption activities for the most part include informing buyers about the effects of their obtaining choices; investment activities incorporate government backing of ecologically inviting items and assembling; distribution activities strengthen showcasing and publicizing of green generation strategies, for example, including natural effect data on item names; and creation activities energize the application of green generation techniques all through the production network [7].

Recent consumption pattern has two emerging problems: extra consumption and less consumption [8]. To fill the 'knowledge to action' gap in sustainable consumption, it would appear to be vital to furnish end users with ecological data that makes accessible numerous diverse positive methods for considering and following up on sustainable consumption and to diminish the digressive confusion [9].

It gives off an impression of being indispensable to supplement the experiences and attempt of area, spot, item and consumers masterminded techniques with symptomatic perspectives and sensible exercises treating generation likewise, consumption in a feasible economy together and in an overall perspective. This would permit uncovering those 'ecological upgrades' in wealthy nations accomplished by migrating contaminating commercial ventures to developing economies [10–12].

There are a number of success factors that can influence the adoption and application of SCP in various industries to successfully enhance the quality of nature with improved social culture. The successful implementation of SCP is not possible without the involvement of certain factors. Therefore, identification of success factors (SFs) and their subsequent analysis is very important to understand.

## 2.1 *Success Factors of SCP*

Current human exercises are genuinely dissolving the capacity of standard and social frameworks by means of industrial growth and development. In context with environmental, social, and economical change, it has turned out to be clear that our

**Table 1** Identification of SCP success factors

| S. No | Factors | Description | References |
|---|---|---|---|
| 1 | International pressure | Acquisitions, joint endeavors and different partnerships, and particularly worldwide supply chains are confirmation of some of these international pressures | [14, 15] |
| 2 | Globalization | It is extremely important to follow the global requirements and policies related to the business ethics | [16] |
| 3 | Government support and policies | Government support and policies are found to occupy a noteworthy position in implementation of SCP | [17–20] |
| 4 | Competition | To compete in the business and to sustain in the market SCP is required | [16] |
| 5 | Customer attitude and awareness | Customers have a noteworthy part in deciding the sort of materials | [21, 16, 22, 23] |
| 6 | Employee expertise | Knowledgeable employee is a key factor to achieve SCP patterns | [24] |
| 7 | Integration and coordination | Coordination and sharing of information between stakeholders is essential to achieve SCP patterns | [24, 25] |
| 8 | Waste management | Reduce the usage of natural materials, and recyclability is an important aspect of SCP implementation | [26] |
| 9 | Certification | Certification of quality measures for environment safety is highly solicited which can be achieved by the business firms by incorporating SCP patterns | [27–29, 24] |
| 10 | Reverse logistics | Reverse logistics can help to recycle waste or disposing the waste safely in an environment safely manner | [30] |
| 11 | Resource and expertise | Expert opinions and capabilities are highly solicited to produce more with less input | [31] |

worldwide group directly needs to receive more sustainable ways of life. Human cannot proceed with the present way without harming the environment and community to cope with their requirements [13].

The identified success factors for effective implementation of SCP are given in Table 1.

## 3 Solution Methodology

The importance of the success factors is estimated with the help of a decision-making tool DEMATEL, which analyzes the interrelationship between the success factors and based on the results characterized the factors into cause and effect groups. The DEMATEL method [32] was originated in Science and Human Affairs Program held in Battelle Memorial Institute of Geneva. DEMATEL helps in recognizing the cause and effect group [33] by analyzing the interrelationship among the factors. The solution methodology adopted for the current study to recognize the success factors responsible for the accomplishment of SCP is given in Fig. 1.

### *3.1 Dematel*

The DEMATEL approach is summarized in following steps [4, 5]:

(1) To describe the objective and assessment factors: In the first step, the required data is collected through literature review so as to identify the success factors related to SCP implementation. The factors are then discussed among the group of academicians before finalization.
(2) To create the initial direct relation matrix by rating the factors as per the scale shown in Table 2.

The average initial direct relation matrix is represented by $B = [b_{ij}]$ and can be constructed by the given formula as in Eq. (1):

$$b_{ij} = 1/H \sum_{A=1}^{H} xij \tag{1}$$

where $A$ is the number of participants such that $1 \leq A \leq H$, and $xij$ is the score to which one factor '$i$' affects the other factor '$j$'.

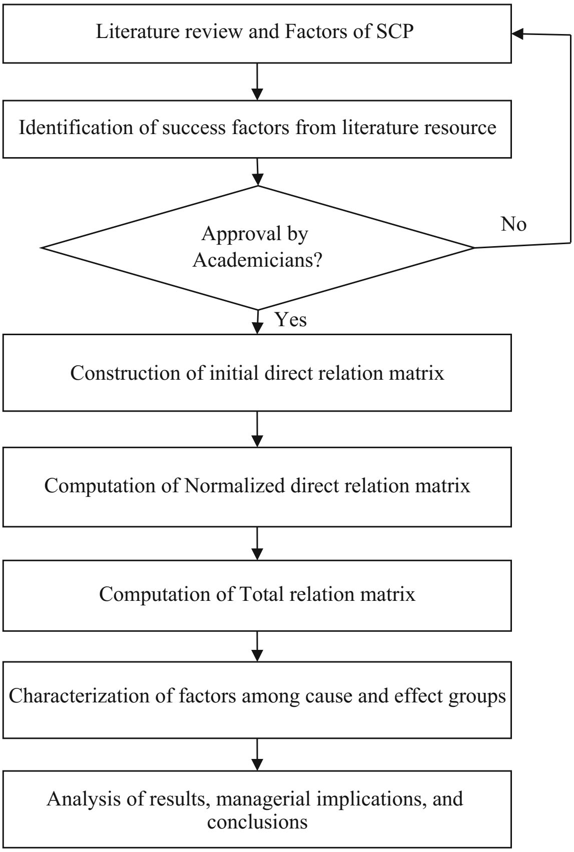



**Fig. 1** Research flow chart by DEMATEL technique [3]

**Table 2** Significance of scores in DEMATEL [34]

| Score | Definition |
|---|---|
| 0 | Both factors have no influence on each other |
| 1 | One factor has very low influence over another |
| 2 | One factor has low influence over another |
| 3 | One factor has strong influence over another |
| 4 | One factor has very strong influence over another |

(3) To calculate the normalized initial direct relation matrix: The normalized initial direct relation matrix can be represented by '*D*' and can be constructed by the given formula as in Eqs. (2) and (3):

$$D = \frac{B}{Z} \tag{2}$$

$$Z = \max\left\{\max \sum_{j=1}^{n} bij, \quad \max \sum_{i=1}^{n} bij\right\} \tag{3}$$

where '*n*' is the order of the square matrix.

(4) To calculate the total relation matrix: The total relation matrix is represented by '*T*' and can be calculated by the given formula as in Eq. (4):

$$T = D(I - D)^{-1} \tag{4}$$

where $I$ = Identity matrix.

(5) To compute cause and effect factors: After the calculation of the total relation matrix, the sum of each row ($r_i$) and column ($c_j$) is obtained so as to calculate the value of ($r_i + c_j$) which is known as 'Prominence' and ($r_i - c_j$) which is known as 'Relation'. Positive value of ($r_i - c_j$) signifies that the factor '*i*' is in cause group otherwise it falls into the effect group.
(6) To calculate the threshold value: The threshold value is calculated by taking the mean of the elements of the total relation matrix.

## 4 Data Analysis and Results

In this current research, the data is collected in three steps: first, recognition of most significant factors related to adoption of SCP patterns, second, arranging the factors according to their ranks obtained, and third, classification of listed factors to put them into cause and effect group by analyzing them.

In the preliminary step of data collection and based on the critical review of literature, eleven success factors (IP, G, GP, CO, CA, EE, IC, W, C, RL, and RE) were recognized and have already been mentioned in Table 1.

The success factors were then analyzed for determining their respective priority and to get the interrelation among the factors in terms of causal effect map. The DEMATEL methodology is used for this purpose (Fig. 2).

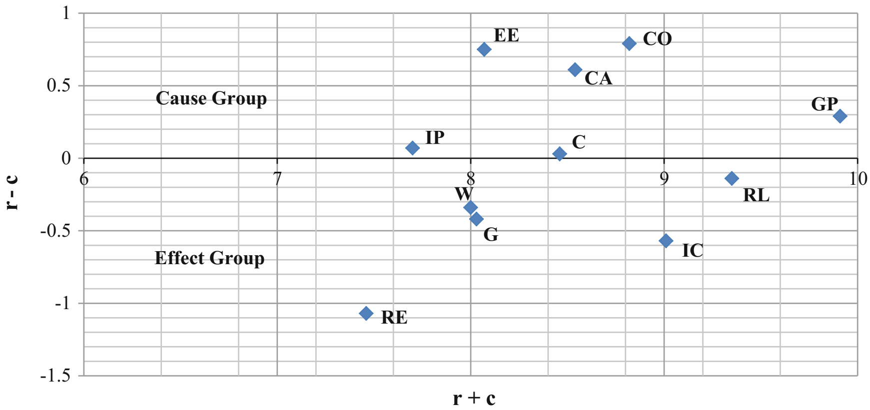



**Fig. 2** Cause—effect diagram of success factors of SCP. *Source* DEMATEL analysis

# 5 Managerial Implications

## *5.1 Causal Relationship Among Success Factors of SCP*

The success factors were identified through the intense literature review and were finalized after discussing them with the academicians. These success factors were then scored as per their influence (Table 2) on other factors and assembled in an initial direct relation matrix (Table 3). Then, the normalized matrix (Table 4) was derived by using the Eqs. (2) and (3). The total relation matrix (Table 5) of success factors for effective implementation of SCP is obtained by using the Eq. (4). According to the (r − c) score (Table 6) of all the success factors, international pressure (IP), government support and policies (GP), competition (CO), customer attitude and awareness (CA), employee expertise (EE), and certification © come under cause group, whereas globalization (G), integration and coordination (IC), waste management (W), reverse logistics (RL), and resource and expertise (RE) fall into effect group. Among all cause groups, 'competitiveness' acquired highest score (0.79) and therefore have highest impact on other success factors, but as the (r + c) score of 'competitiveness' is comparatively less (8.82), it gained very less influence from other factors. Factors of effect group can easily be influenced by other success factors. They do not have direct impact on SCP but plays a crucial role in implementation of SCP patterns.

**Table 3** Initial direct relation matrix

| | IP | G | GP | CO | CA | EE | IC | W | C | RL | RE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IP | 0 | 1 | 2 | 2 | 3 | 1 | 2 | 1 | 3 | 2 | 1 |
| G | 3 | 0 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 2 |
| GP | 3 | 3 | 0 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 3 |
| CO | 3 | 3 | 3 | 0 | 2 | 3 | 2 | 1 | 2 | 2 | 2 |
| CA | 1 | 2 | 2 | 3 | 0 | 1 | 3 | 3 | 1 | 3 | 3 |
| EE | 2 | 2 | 2 | 1 | 2 | 0 | 3 | 3 | 2 | 3 | 1 |
| IC | 2 | 3 | 3 | 2 | 1 | 3 | 0 | 1 | 1 | 2 | 2 |
| W | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 2 | 3 | 2 |
| C | 1 | 2 | 2 | 2 | 2 | 1 | 3 | 3 | 0 | 3 | 1 |
| RL | 1 | 1 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 0 | 3 |
| RE | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 3 | 2 | 1 | 0 |

*Source* DEMATEL analysis

**Table 4** Normalized direct relation matrix

| | IP | G | GP | CO | CA | EE | IC | W | C | RL | RE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IP | 0.00 | 0.04 | 0.08 | 0.08 | 0.12 | 0.04 | 0.08 | 0.04 | 0.12 | 0.08 | 0.04 |
| G | 0.12 | 0.00 | 0.08 | 0.08 | 0.08 | 0.04 | 0.08 | 0.04 | 0.04 | 0.08 | 0.08 |
| GP | 0.12 | 0.12 | 0.00 | 0.08 | 0.08 | 0.08 | 0.12 | 0.08 | 0.12 | 0.08 | 0.12 |
| CO | 0.12 | 0.12 | 0.12 | 0.00 | 0.08 | 0.12 | 0.08 | 0.04 | 0.08 | 0.08 | 0.08 |
| CA | 0.04 | 0.08 | 0.08 | 0.12 | 0.00 | 0.04 | 0.12 | 0.12 | 0.04 | 0.12 | 0.12 |
| EE | 0.08 | 0.08 | 0.08 | 0.04 | 0.08 | 0.00 | 0.12 | 0.12 | 0.08 | 0.12 | 0.04 |
| IC | 0.08 | 0.12 | 0.12 | 0.08 | 0.04 | 0.12 | 0.00 | 0.04 | 0.04 | 0.08 | 0.08 |
| W | 0.04 | 0.08 | 0.08 | 0.08 | 0.08 | 0.04 | 0.04 | 0.00 | 0.08 | 0.12 | 0.08 |
| C | 0.04 | 0.08 | 0.08 | 0.08 | 0.08 | 0.04 | 0.12 | 0.12 | 0.00 | 0.12 | 0.04 |
| RL | 0.04 | 0.04 | 0.12 | 0.08 | 0.08 | 0.08 | 0.12 | 0.08 | 0.12 | 0.00 | 0.12 |
| RE | 0.04 | 0.04 | 0.08 | 0.04 | 0.04 | 0.08 | 0.04 | 0.12 | 0.08 | 0.04 | 0.00 |

*Source* DEMATEL analysis

## 5.2 Ranking of Success Factors of SCP

The ranking (Table 6) of success factors by DEMATEL approach is given as

$$\text{GP} > \text{RL} > \text{IC} > \text{CO} > \text{CA} > \text{C} > \text{EE} > \text{G} > \text{W} > \text{IP} > \text{RE}.$$

The government support and policies (GP) ranked first in the list and thus acquires the highest priority in reference to other success factors as government affiliations, executives, and organization that synchronize the activities of successful implementation of SCP [19, 20]. Thus, managers should take government support and policies at highest priority level.

**Table 5** Total relation matrix

| | IP | G | GP | CO | CA | EE | IC | W | C | RL | RE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IP | 0.26 | 0.33 | 0.40 | 0.35 | 0.38 | 0.29 | 0.41 | 0.33 | 0.40 | 0.40 | 0.33 |
| G | 0.37 | 0.28 | 0.40 | 0.34 | 0.34 | 0.29 | 0.40 | 0.32 | 0.32 | 0.39 | 0.36 |
| GP | 0.45 | 0.49 | 0.43 | 0.43 | 0.43 | 0.40 | 0.54 | 0.45 | 0.49 | 0.50 | 0.49 |
| CO | 0.44 | 0.47 | 0.52 | 0.34 | 0.41 | 0.42 | 0.48 | 0.39 | 0.43 | 0.48 | 0.43 |
| CA | 0.35 | 0.42 | 0.47 | 0.43 | 0.32 | 0.34 | 0.49 | 0.44 | 0.38 | 0.49 | 0.46 |
| EE | 0.37 | 0.40 | 0.45 | 0.35 | 0.38 | 0.28 | 0.48 | 0.43 | 0.40 | 0.48 | 0.37 |
| IC | 0.36 | 0.42 | 0.47 | 0.37 | 0.34 | 0.38 | 0.36 | 0.35 | 0.36 | 0.43 | 0.39 |
| W | 0.30 | 0.36 | 0.40 | 0.35 | 0.34 | 0.29 | 0.36 | 0.28 | 0.36 | 0.43 | 0.37 |
| C | 0.32 | 0.39 | 0.44 | 0.38 | 0.37 | 0.32 | 0.47 | 0.42 | 0.31 | 0.46 | 0.36 |
| RL | 0.35 | 0.39 | 0.50 | 0.40 | 0.39 | 0.37 | 0.50 | 0.42 | 0.45 | 0.39 | 0.46 |
| RE | 0.25 | 0.28 | 0.34 | 0.26 | 0.26 | 0.28 | 0.31 | 0.35 | 0.31 | 0.31 | 0.24 |
| Threshold value = 0.39 | | | | | | | | | | | |

*Source* DEMATEL analysis

**Table 6** Assessment of cause and effect factors

| Success factors | Sum = r*i* | Sum = c*j* | r + c | Rank | r − c | Cause/effect |
|---|---|---|---|---|---|---|
| IP | 3.89 | 3.82 | 7.704 | 10 | 0.070 | Cause |
| G | 3.81 | 4.23 | 8.034 | 8 | −0.422 | Effect |
| GP | 5.10 | 4.81 | 9.913 | 1 | 0.289 | Cause |
| CO | 4.81 | 4.02 | 8.820 | 4 | 0.790 | Cause |
| CA | 4.57 | 3.97 | 8.542 | 5 | 0.606 | Cause |
| EE | 4.41 | 3.66 | 8.067 | 7 | 0.750 | Cause |
| IC | 4.22 | 4.79 | 9.013 | 3 | −0.566 | Effect |
| W | 3.83 | 4.17 | 8.003 | 9 | −0.339 | Effect |
| C | 4.24 | 4.21 | 8.455 | 6 | 0.029 | Cause |
| RL | 4.61 | 4.74 | 9.354 | 2 | −0.136 | Effect |
| RE | 3.20 | 4.27 | 7.463 | 11 | −1.071 | Effect |

*Source* DEMATEL analysis

Reverse logistics (RL) occupies the second rank in the priority list and plays an important role in implementing an efficient SCP concept. By using the concept of reverse logistics, managers can evaluate the level of recyclability of product reusing system [30].

Integration and coordination (IC) stand third in the priority list. Coordination and sharing of information between stakeholders is essential to achieve SCP patterns [24, 25].

Competitiveness (CO) gained fourth position. Competition is an essential factor to compete in the business and to sustain in the market [16].

Customer attitude and awareness (CA) holds fifth rank. Customers have a noteworthy part in deciding the sort of materials. Therefore, the awareness of customers for eco-friendly products is extremely important [21, 16].

Certification (C) holds the sixth place. Certification of quality measures for environment safety is highly solicited which can be achieved by the business firms by incorporating SCP patterns [24].

Employee expertise (EE) acquires the seventh rank in the list. Knowledgeable employee is a key factor to achieve SCP patterns [21, 24].

Globalization (G) comes eighth in the priority list. It is extremely important to follow the global requirements and policies related to the business ethics [16].

Waste management (W) holds ninth position in the list. Reduction of the usage of natural materials and recyclability is an important aspect of SCP implementation [26].

International pressure (IP) comes tenth in the priority ranking. Acquisitions, joint endeavors and different partnerships, and particularly worldwide supply chains are very important in establishment of SCP patterns [14, 15].

Resource and expertise (RE) stands last in the ranking of SCP success factors. Expert views and capabilities are highly solicited to produce more with less input [31].

## 6 Conclusion, Limitation, and Future Scope

SCP is a standout among the most imperative and vital choice to control the counter social and non-ecological practices in business exercises. Along this, a tremendous significance has been given to the selection of SCP examples in emerging economy. UNEP has started toward the advance of execution of SCP examples by setting the rules. With the advancement in innovation, it gets to be vital for creating nations to execute SCP to amplify monetary picks up and decrease natural contacts with the welfare of the general public. Seeing the present situation, SCP usage turns into a requesting assignment.

The motive of this exploration is to propose an auxiliary system to assess the SFs for SCP in supply chain by confining strategic choice of procedures by DEMATEL approach. By DEMATEL technique, the ranks of priority for the success factors are calculated and then divide them into cause and effect group. The examination result uncovers that the 'government support and policies' needs to be profoundly organized. Further, this factor falls into cause group which signifies that it has direct influence to the system. Thus, managers and experts need to tremendously concentrate on this variable to expand the SCP adequacy. The relative priority rank of the rest of the success factors is given as:

$$GP > RL > IC > CO > CA > C > EE > G > W > IP > RE.$$

This research utilizes DEMATEL approach and distinguishes 11 SFs identified with the execution of SCP patterns in supply chain. The fundamental model proposed in this work has its own particular restrictions. Extraordinary care was taken in distinguishing proof and assessment of the SCP execution SFs; however still, some inaccuracy may exist because of human inclination.

**Acknowledgements** The authors acknowledge the support of the research facilities and funds provided by the ME & AME Department, GEU, Dehradun, India.

## References

1. Geels, F.W., McMeekin, A., Mylan, J., Southerton, D.: A critical appraisal of Sustainable Consumption and Production research: The reformist, revolutionary and reconfiguration positions. Glo. Env. Change. **34**, 1–12 (2015)
2. Ofstad, S.: Symposium: Sustainable Consumption. Ministry of the Environment, Oslo (1994)
3. Gandhi, S., Mangla, S.K., Kumar, P., Kumar, D.: Evaluating factors in implementation of successful green supply chain management using DEMATEL: a case study. Int. Strat. Mgmt. Rev. **3**(1), 96–109 (2015)
4. Tzeng Tzeng, G.H., Chiang, C.H., Li, C.W.: Evaluating intertwined effects in e-learning programs: a novel hybrid MCDM model based on factor analysis and DEMATEL. Exp. Sys. App. **32**(4), 1028–1044 (2007)
5. Zhu, Q., Geng, Y., Sarkis, J., Lai, K.H.: Evaluating green supply chain management among Chinese manufacturers from the ecological modernization perspective. Trans. Res. Part E: Log. Trans. Rev. **47**(6), 808–821 (2011)
6. Barber, J.: Mapping the movement to achieve sustainable production and consumption in North America. J. Clean Prod. **15**(6), 499–512 (2007)
7. Nazzal, D., Batarseh, O., Patzner, J., Martin, D.R.: Product servicing for lifespan extension and sustainable consumption: an optimization approach. Int. J. Prod. Eco. **142**(1), 105–114 (2013)
8. Clark, G.: Evolution of the global sustainable consumption and production policy and the United Nations Environment Programme's (UNEP) supporting activities. J. Clean Prod. **15** (6), 492–498 (2007)
9. Markkula, A., Moisander, J.: Discursive confusion over sustainable consumption: a discursive perspective on the perplexity of marketplace knowledge. J. Cons. Pol. **35**(1), 105–125 (2012)
10. Bruckner, M., Giljum, S., Lutz, C., Wiebe, K. S.: Materials embodied in international trade–global material extraction and consumption between 1995 and 2005. Glo. Env. Chan. **22**(3), 568–576 (2012)
11. Dittrich, M., Bringezu, S., Schütz, H.: The physical dimension of international trade, part 2: indirect global resource flows between 1962 and 2005. Eco. Eco. **79**, 32–43 (2012)
12. Lorek, S., Spangenberg, J.H.: Sustainable consumption within a sustainable economy–beyond green growth and green economies. J. Clean. Prod. **63**, 33–44 (2014)
13. Lorek, S., Fuchs, D.: Strong sustainable consumption governance–precondition for a degrowth path? J. Clean. Prod. **38**, 36–43 (2013)
14. Park, J., Sarkis, J., Wu, Z.: Creating integrated business and environmental value within the context of China's circular economy and ecological modernization. J. Clean. Prod. **18**(15), 1494–1501 (2010)
15. Zhu, Q., Geng, Y.: Integrating environmental issues into supplier selection and management; a study of large and medium-sized state-owned enterprises in China. Green Mgmt. Int. 27–41 (2001)
16. Gandhi, S., Mangla, S.K., Kumar, P., Kumar, D.: A combined approach using AHP and DEMATEL for evaluating success factors in implementation of green supply chain management in Indian manufacturing industries. Int. J. Logis. Res. App. 1–25 (2016)
17. Gerrard, J., Kandlikar, M.: Is European end-of-life vehicle legislation living up to expectations? Assessing the impact of the ELV Directive on green innovation and vehicle recovery. J. Clean. Prod. **15**(1), 17–27 (2007)

18. Hitchcock, T.: Low carbon and green supply chains: the legal drivers and commercial pressures. Supp. C. Mgmt. Int. J. **17**(1), 98–101 (2012)
19. Luthra, S., Mangla, S. K., Xu, L., & Diabat, A.: Using AHP to evaluate barriers in adopting sustainable consumption and production initiatives in a supply chain. Int. J. Prod. Eco. **181**, 342–349 (2016)
20. Vergragt, P., Akenji, L., Dewick, P.: Sustainable production, consumption, and livelihoods: global and regional research perspectives. J. Clean. Prod. **63**, 1–12 (2014)
21. Abdulrahman, M.D., Gunasekaran, A., Subramanian, N.: Critical barriers in implementing reverse logistics in the Chinese manufacturing sectors. Int. J. Prod. Eco. **147**, 460–471 (2014)
22. Shaik, M., Abdul-Kader, W.: Performance measurement of reverse logistics enterprise: a comprehensive and integrated approach. Meas. Bus. Excell. **16**(2), 23–34 (2012)
23. Subramanian, N., Ramanathan, R.: A review of applications of Analytic Hierarchy Process in operations management. Int. J. Prod. Eco. **138**(2), 215–241 (2012)
24. Mangla, S.K., Govindan, K., Luthra, S.: Critical success factors for reverse logistics in Indian industries: a structural model. J. Clean. Prod. **129**, 608–621 (2016)
25. Rahman, S., Subramanian, N.: Factors for implementing end-of-life computer recycling operations in reverse supply chains. Int. J. Prod. Eco. **140**(1), 239–248 (2012)
26. Pan, S.Y., Du, M.A., Huang, I.T., Liu, I.H., Chang, E.E., Chiang, P.C.: Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system: a review. J. Clean. Prod. **108**, 409–421 (2015)
27. Hung Lau, K., Wang, Y.: Reverse logistics in the electronic industry of China: a case study. Supp. C. Mgmt. Int. J. **14**(6), 447–465 (2009)
28. Knemeyer, A.M., Ponzurick, T.G., Logar, C.M.: A qualitative examination of factors affecting reverse logistics systems for end-of-life computers. Int. J. Phy. Distri. Logis. Mgmt. **32**(6), 455–479 (2002)
29. Kumar, S., Putnam, V.: Cradle to cradle: reverse logistics strategies and opportunities across three industry sectors. Int. J. Prod. Eco. **115**(2), 305–315 (2008)
30. Millet, D., Yvars, P.A., Tonnelier, P.: A method for identifying the worst recycling case: application on a range of vehicles in the automotive sector. Res. Cons. Rec. **68**, 1–13 (2012)
31. Mutz, D.: Circular economy and informal waste management in India—a contradiction?" 2015
32. Gabus, A., Fontela, E.: World problems, an invitation to further thought within the framework of DEMATEL. Battelle Geneva Research Center, Geneva, Switzerland (1972)
33. Lin, R.J.: Using fuzzy DEMATEL to evaluate the green supply chain management practices. J. Clean. Prod. **40**, 32–39 (2013)
34. Luthra, S., Govindan, K., Kharb, R.K., Mangla, S.K.: Evaluating the enablers in solar power developments in the current scenario using fuzzy DEMATEL: an Indian perspective. Ren. Sus. E. Rev. **63**, 379–397 (2016)

# A Review of CSR Activities Under Companies Act 2013 and Enterprise Social Commitment Under Environment Clearance for Major Cement Industries in India

**Shraddha Mishra and N. A. Siddiqui**

## 1 Introduction

Sustainable development has three components viz. social, economic and environmental, and these all are closely interrelated. Considering the same the EIA notification mentions requirement of public consultation, social impact assessment and R&R action plan along with environment management plan. As per EIA notification in India, the environmental clearance process is required for 39 types of projects and cement industry is one of these. The main purpose of this process is to assess impacts of the planned project on the environment and society and to try to identify abatement mechanism for the same [1].

Indian cement industry has been considered the second largest in the world [2]. The cement manufacturing units are located in various locations all across India, and majorly the plants are situated in vicinity of limestone deposits. Cement industry is using the natural resources to the maximum extent. It is mandatory for the cement industry to earmark CSR fund in some percentage of project cost as per environment clearance mandate for social and sustainable development activities. It was obligatory requirement for cement industries even before the Companies Act 2013 Corporate Social Responsibility mandate was introduced.

This paper focuses on the CSR activities of cement industries, and finding out whether the CSR Mandate in Companies Act 2013 has made any significant impact on the Enterprise Social Commitment activities of major cement industries. There are many similarities in activities under Enterprise Social Commitment made during

S. Mishra (✉) · N. A. Siddiqui
Health, Safety & Environment Department, University
of Petroleum & Energy Studies, Dehradun, Uttarakhand, India
e-mail: smishra9@gmail.com

N. A. Siddiqui
e-mail: nsiddiqui57@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_16

public hearing and CSR activities as mandated in seventh schedule of the Companies Act 2013.

## 2 EC Requirements for Enterprise Social Commitment

As a part of environmental clearance, few mandates are given in general condition which includes spending towards Enterprise Social Commitment. EC requirements for Enterprise Social Commitment have similarities with Companies Act 2013 Corporate Social Responsibility mandate requirements.

Requirements such as some percentage of cost of the project shall be allocated towards the Enterprise Social Commitment based on the needs of locals, compliance with all the environmental protection measures and to take preventative measures to conserve and protect the endangered fauna during mining operations, to undertake measures for eco-development which should include measures towards welfare of nearby community who could be impacted by the project, to carry out development activities related to socio-economic upliftment of communities in the nearby villages. Such projects should be like community development programmes, promotional programmes for education, supply of drinking water and health care facilities [2, 3].

## 3 The Companies Act 2013 Requirements for Corporate Social Responsibility

The Act is applicable to certain set of companies which meet the criteria as mentioned in section 135(1) of the Act. Those companies which have had a net profit of Rs. 5 crores or more or having net worth of Rs. 500 crores or more or they have a turnover of Rs. 1000 crores or more in any fiscal year. The companies meeting the aforesaid criteria must spend at least 2% of the average net profit of the three immediately preceding fiscal years [4].

Schedule VII of the Act gives the clarity for undertaking the activities which would qualify for CSR. Such activities may include issues related to eradication of extreme hunger and poverty, reduction in child mortality and mental health improvement, promotional activities for education, training programmes on vocational skills, women empowerment and gender equality. Taking initiatives such as malaria eradication, awareness on HIV, AIDS and other diseases towards the health care and hygiene would be considered for CSR. Projects related to environmental sustainability will also be considered as CSR which may include ecological balance, natural resource conservation, protection of flora and fauna, animal welfare, agroforestry along with maintaining quality of air, water and soil. Besides the above-mentioned activities, the development and protection of national heritage, promoting sports and contributing towards the Prime Minister's National Relief Fund or any other socio-economic development and relief fund set up by the governments which are focusing on measures for reducing social and economic inequalities in backward groups. Under the Companies Rules that have become effective from 1 April 2014, MCA has specified the governance regime for implementation and enforcement of CSR expenditure [5, 6].

## 4 Methodology and Data Collection

This study has used exploratory research methodology to understand the requirements related to CSR and environment clearance. An extensive literature survey has been done regarding the CSR concepts and environment clearance requirements. The top five major cement industries in India have been selected for the study. The study is conducted by using secondary data. CSR activities and expenditure understudy for analysis have been taken up by the cement companies as disclosed on their websites, information provided in their annual reports, sustainability reports and other disclosure reports. This paper tries to analyse the various CSR activities of cement industries over the last three financial years (2013–14, 2014–15 and 2-15–16).

## 5 CSR Activities and the Projects Undertaken for Environment Sustainability

CSR reports, annual reports and environment compliance reports of major cement industries have been studied and identified the activities and projects undertaken for CSR [7–9]. Cement industries are undertaking CSR activities as recommended under the environment clearance requirement under EIA which includes compliance with the environmental protection measures and safeguarding environment. It also mandates to carry out eco-development activities which include measures for welfare of community measures around the project area. Under the Companies Act, requirement activities and projects have been carried out which includes health care initiatives, providing safe drinking water for nearby communities, agriculture support to farmers, initiatives to promote education including consumer education, income generation programmes and skill enhancement trainings, women empowerment and capacity building, basic amenities, security and medical services to old-aged people, plantation programme, protection of environment including non-conventional, biogas, solar, plantation, water resources conservation, watershed management, animal welfare, sponsorship/contribution to community/social/cultural institutions of repute engaged in activities in line with the CSR policy, promotion of sports, integrated rural and infrastructure development, etc. [10, 11].

Environment sustainability-related projects have been identified under CSR activity which includes [12, 13]:

- Programmes related to conservation of natural resource and use of non-conventional energy,
- Supporting programmes related to biogas,
- Supporting solar energy-related projects and other energy conservation programmes,
- Supporting and organizing tree rives,
- Developing green belt areas and conducting roadside plantation drives,
- Supporting farmers in soil conservation projects and land improvement,
- Undertaking water conservation projects and harvesting rainwater,
- Developing community pasture land and orchards,
- Saplings distribution in nearby villages for mass tree plantation,
- Water harvesting structures construction in villages for benefiting communities,
- Harvesting the rainwater from the rooftops and to recharge the groundwater.

## 6 Trend of CSR Expenditure on Environment Sustainability Projects

Three financial year CSR data of top five major cement industries have been studied, and the results identified that approximately 7% of the total CSR spend is used for environment sustainability projects. The expenditure trend for environment sustainability projects shows year-on-year increase towards safeguarding environment for the society [12] (Figs. 1 and 2).

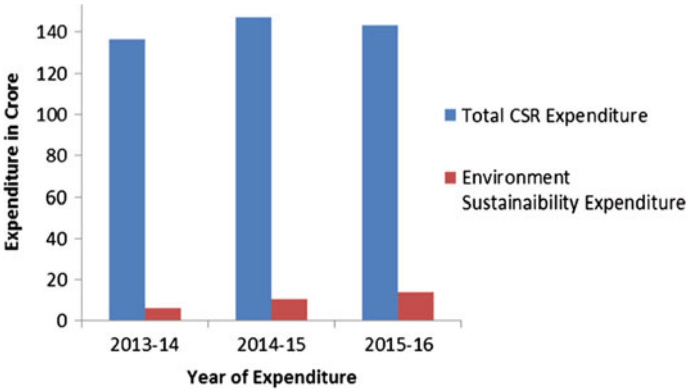



**Fig. 1** Expenditure on environment under CSR of five major cement industries in India

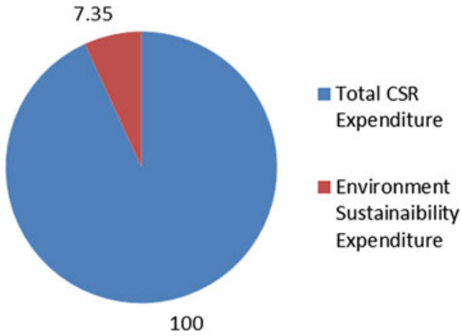



**Fig. 2** Percentage expenditure on environment under CSR by five major cement industries in India

# 7 Summary and Conclusion

To a certain extent, CSR Mandate was an already mandatory requirement for cement sector. Cement industries were involved in CSR activities before the Companies Act required a compulsory 2% from net profit. The reporting system of CSR activities has been evolved with the Companies Act mandate. This paper emphasizes the contribution of CSR towards the environment sustainability shows the positive trend but the impact of these projects has not been quantified. Although various environmental parameters are quantified and reported in sustainability reports in terms of energy conservation and corresponding emission reduction, other initiatives for environment protection. Similarly, environmental impact of such expenditure towards environment should be quantified for analysing effectiveness of this policy. The study has further scope of research towards the impact of CSR on the environmental performance of other companies.

# References

1. Gautam, R., Singh, A.: Corporate social responsibility practices in India: a study of top 500 companies. Glob. Bus. Manag. Res. Int. J. **2**(1), 41–56 (2010)
2. Vani, M.M., Krishna, P.M.: Corporate social responsibility: a glance at the practices of Cement Industry. Int. J. Mark. Fin. Serv. Manage. Res. **4**(8), (2015)
3. Technical EIA Guidance Manuals Project for Cement Industry, 2010
4. Companies Act Notification, 2014
5. General Circular No. 21/2014, Government of India Ministry of Corporate Affairs, 2014
6. Office Memorandum, Environment sustainability and CSR related issues guidelines, 2014
7. Agarwal, S.: Corporate social responsibility versus corporate sustainability in India: a case study on Aditya Birla Group. Int. J. Innov. Res. Multidiscip. Field **2**(6), 13 (2016)
8. Handbook on Corporate Social Responsibility in India, CII, 2013
9. Lyon, T.P., Maxwell, J.W.: Corporate social responsibility and the environment: a theoretical perspective. Rev. Environ. Econ. Policy **2**(2), 240–260 (2008)
10. Kurian, M.D.A., Pancholi, N.: Does the corporate social responsibility mandate in the company's act, 2013 have an impact on Reliance Industries Ltd? Imperial J. Interdisc. Res. **2**(4), (2016)

11. Patil, M.R., Sawant, P.: Corporate social responsibility, performance and sustainability reporting of shree cement company in India: a case study. J. Res. Manag. Tech. **3**(4), 74–87 (2014)
12. Annual Reports of Ultratech Cement, Ambuja Cement, Shree Cement, ACC, India Cement, 2013–16
13. Shankar, T., Rajashekar, H.: Impact of the proposed corporate social responsibility mandate in the new companies bill 2012 of India. Asian J. Manag. **4**, 317–324 (2013)

# Multivariate Analysis of Heavy Metals in Topsoil: An Impact of Thermal Power Plants of Maharashtra (India)

**Divya Patel, P. V. Thakare and Shivakshi Jasrotia**

## 1 Introduction

India is the third largest producer of coal. Coal based thermal power plant installations in India contributes about 70% of the total power generation [1]. However, the bituminous and sub-bituminous coals used contain over 40% ash content. In coming years, 120–140 million tons of coal fly ash will be generated from 120 existing coal-based thermal power plants in India. Generations of fly ash from coal-based thermal power plants all over the world are cited as one of the major sources of pollution which affect the environmental component [2]. Heavy metals from fossil fuel combustion are common source of pollution for surface soils [3, 4]. Presence of toxic heavy metals in fly ash may leads to the leaching of metals in the environment [5].

Generation of fly ash depends upon the quality of the coal that leads to the formation of 10–30% of fly ash [6]. Fly ash is mostly alkaline, sometimes acidic in nature depending on the sulfur content of parent coal [7, 8] and contains elements like S, B, N, K, P, Al, Si, Ca, Mg, Fe, Cu, Zn, Mn along with heavy metals such as Cr, Pb, Hg, Ni, As, Cd [9–12]. Fly ash is mostly alkaline and has low bulk density, high surface area, and light texture [8]. Physicochemical parameters and organic

D. Patel (✉) · P. V. Thakare
Department of Biotechnology, Sant Gadge Baba Amravati University,
Amravati, Maharashtra, India
e-mail: divya_patel28@hotmail.com

P. V. Thakare
e-mail: prashantthakare@sgbau.ac.in

S. Jasrotia
Centre for Global Environment Research, Earth Science and Climate
Change Division, The Energy and Resources Institute (TERI), New Delhi, India
e-mail: shivakshi_jasrotia@yahoo.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_17

composition of soil are also important factors leading to the accumulation and availability of heavy metals in the soil environment [13–15].

The aim of present study was to determine the extent, distribution of selected heavy metals (Fe, Cu, Cd, Cr, Co, Zn, Mo, Mn, Pb, Hg) in soil around selected thermal power stations of Vidarbh region of Maharashtra state, India. The concentrations level for each metal was compared with the respective levels from the background soil using geo-accumulation index ($I_{geo}$). Principal component analysis (PCA) was performed. Concentration of metals such as As, V, and Sr was also analyzed and found to be negligible. On the whole, the interest was to characterize soil around power plants for its elemental, physicochemical concentrations in Vidarbh region and to compare it with the background levels.

## 2 Materials and Methods

### *2.1 Study Sites*

Present study was conducted around selected coal-based thermal power plants (TPP) of Maharashtra, India. The three power plants from Vidarbha region of Maharashtra were: TPP Paras (20° 42′ 55″N, 76° 47′ 37″E), TPP Koradi (21° 14′ 52″N, 79° 05′53″E), and TPP Khaperkheda (21° 16′ 55″N, 79° 06′ 54″E). TPP Koradi and TPP Khaperkheda are situated very near to each other therefore commonly represented as TPP Koradi. Details about the year of establishment, installed capacity, fly ash generation, and utilization are given in Table 1. The selected sampling locations were the nearby agricultural lands around the plant shown in Fig. 1. At TPP Paras, five composite soil sampling sites were identified, along with one pond ash and fly ash site. The control soil was collected from land 18 km away from plant in (East direction). At TPP Koradi, ten composite soil sampling sites, two pond ash, and two fly ash sites were selected. The control was selected 23 km away from plant in (South–East direction).

**Table 1** Details of thermal power plant selected for sampling

| State | Name of power plant | Year of establishment | Installed capacity (MW) | Prevailing wind directions |
|---|---|---|---|---|
| Maharashtra (Vidarbh Region) | Koradi power plant, Koradi | 1974 | 4 × 105<br>1 × 200<br>2 × 210<br>(1040 MW) | N, NW, NE, SW, S |
| | Khaperkheda power plant, Koradi | 1989 | 4 × 210<br>(840 MW) | N, NW, NE, SW, S |
| | Paras power plant, Akola | 1961 | 1 × 55<br>1 × 250<br>(305 MW) | N, NW, SW, S |

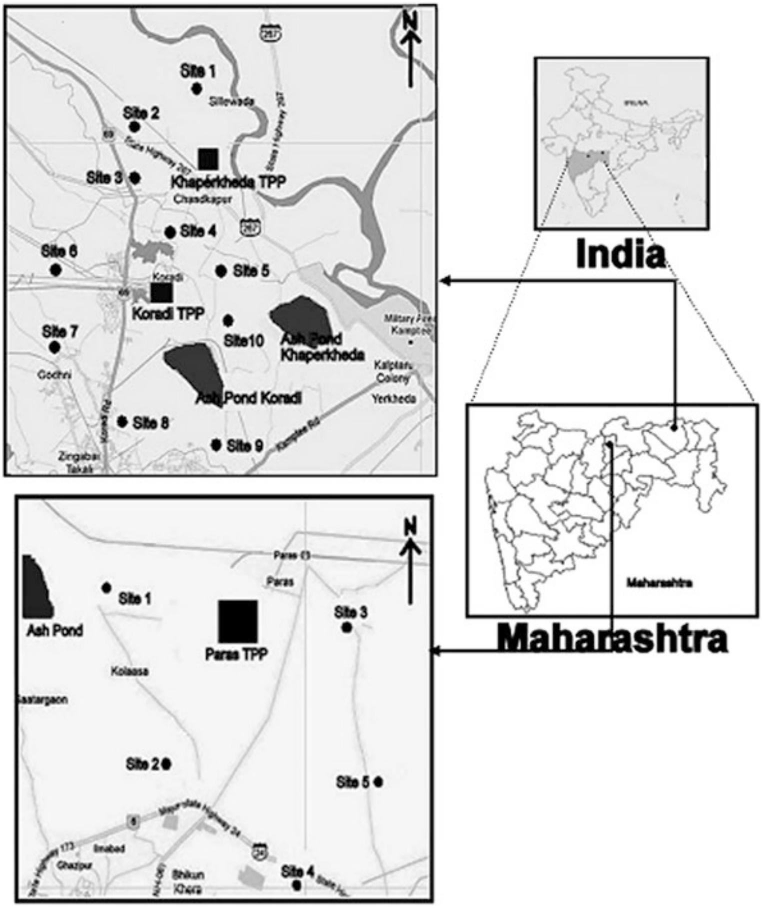



**Fig. 1** Study area of Maharashtra state India. *Source* Google image mapping

## 2.2 Sample Collection

Sample of soil, fly ash, and pond ash was used for the estimation of heavy metals and physicochemical parameters. The sampling strategy was to move away from the pollution sources and determine the dynamics of heavy metals in soil. Topsoil up to 30 cm beneath the soil surface around study site was collected in sterile polythene bags in composite manner and in triplicate. Wet fly ash samples were collected from ash pond and dry fly ash from electrostatic precipitator.

(ESP) of power stations. Samples were air dried at room temperature for 5–7 days, ground and passed through 2 mm sieve, homogenized and stored in sterile plastic containers before analysis.

## 2.3 Sample Analysis

Samples were analyzed for physical and chemical properties as per standard procedure. International pipette method was used to determine the individual soil fraction, i.e., sand, silt, and clay as described by Piper [16]. pH was estimated by pH-meter in the saturation paste as described by McNeal [17] (1:1 suspension). In the same suspension, electrical conductivity was also measured using a conductivity meter (Orion, EA 940 USA). Organic carbon was estimated by Walkley-Black method [18]. Available micronutrients and heavy metals were estimated as per standard procedure described in AOAC [19]. The heavy metals concentrations in the soil were determined using Atomic Absorption Spectrophotometer PerkinElmer Analyst −800. Samples were run in triplicates.

## 2.4 Statistical Analysis

In order to characterize the soil around thermal power plants, the descriptive statistics (mean ± SD) for selected metals were determined. Enrichment of metal concentration above baseline concentrations was calculated using the method proposed by Muller [20] (Table 2), termed as a geo-accumulation index ($I_{geo}$) and given by Eq. (1)

$$I_{geo} = \log\left[C_{m:Sample}/\left(1.5 \times C_{m:Background}\right)\right] \quad (1)$$

The factor 1.5 minimizes the effect of possible variations in the background values, $C_{m:Background}$, which may be attributed to lithogenic variations in soils.

Principal component analysis (PCA) was performed to classify sampling sites according to the metal concentration profiles at the respective sites. The number of significant principal components (PCs) was selected on the basis of varimax orthogonal rotation with Kaiser normalization and with eigenvalue greater than 1.0. Correlations between the metals and the grouping of sites were obtained according

**Table 2** $I_{geo}$ classes with respect to soil quality

| $I_{geo}$ value | $I_{geo}$ class | Designation of soil quality |
|---|---|---|
| >5 | 6 | Extremely contaminated |
| 4–5 | 5 | Strongly to extremely contaminated |
| 3–4 | 4 | Strongly contaminated |
| 2–3 | 3 | Moderately to strongly contaminated |
| 1–2 | 2 | Moderately contaminated |
| 0–1 | 1 | Uncontaminated to moderately contaminated |
| 0 | 0 | Uncontaminated |

*Source* Muller [20]

to the similarity of concentration profiles. The analysis was performed using R-programming language.

# 3 Results and Discussion

## *3.1 Heavy Metals in Samples*

The average values of metal concentrations are given in Table 3a. The statistical significance of difference in the mean concentration of each metal was tested. The metal-wise findings have been presented.

**Copper** (**Cu**): In Maharashtra, at TPP Paras, the minimum average Cu level in soil was observed at site 2 (131.4 ± 5.1 mg/kg), while both site 1 and 3 showed higher levels (Table 3a). The pond ash and fly ash levels were intermediate to the minimum and maximum levels. The mean level at control was 79.43 ± 3.84 mg/kg and was lower than all the sites at this station. At TPP Koradi (TPP Koradi and TPP Khaperkheda), the minimum average Cu concentration was observed at site 6 (46.1 ± 1.92 mg/kg), while maximum was at site 2 (84.53 ± 4.72 mg/kg). The TPP Koradi pond and fly ash mean Cu levels were comparatively lesser than that of TPP Khaparkheda. The soil Cu concentrations at different sites were very close to that of control (40.64 ± 1.49 mg/kg). On the whole, the mean Cu levels in soil samples at TPP Paras, the index values for Cu at different sites ranged between 0–1 in $I_{geo}$ study, indicating marginally low contamination due to Cu as compared to control. Similar results were observed at Koradi.

**Nickel** (**Ni**): At TPP Paras, Ni levels in soil samples were very similar at all the sites and ranged between 82.97 and 87.5 mg/kg. The pond ash level was highest at this station (89 ± 0.7 mg/kg). At TPP Koradi, the minimum Ni level was observed at site 1 (57.87 ± 3.48 mg/kg), while maximum was recorded at site 4 (72.73 ± 1.36 mg/kg). The comparison of Ni levels with control using geo-accumulation index revealed that the index values at TPP Paras were very close to 0 implying hardly any contamination (Fig. 2a).

At TPP Koradi, the index values ranged from 0 to 0.5 (Fig. 2b), revealing that the Ni contamination was marginal as compared to control. Figure 2c shows the highlights of metal analysis.

**Cobalt** (**Co**): At TPP Paras, the least Co level in soil was observed at site 4 (42.17 ± 2.67 mg/kg), while site 3 showed higher level 51.5 ± 1.82 mg/kg. The pond ash level and fly ash level were higher than soil. The mean level at control was 31.77 ± 0.31 mg/kg, which was lower than all the sites at this station. At TPP Koradi sites, the least average Co concentration was observed at site 6 (26 ± 0.36 mg/kg), while maximum was at site 4 (31.8 ± 2.05 mg/kg). The soil Co concentrations at different sites were very close to that of control soil (14.5 ± 1.39 mg/kg).

**Table 3a** Mean and standard deviation for different metal concentrations (mg/kg) at different sites of two sampling stations in Maharashtra state

| Sampling station | Sites | Cu | Ni | Co | Fe | Zn |
|---|---|---|---|---|---|---|
| Paras TPP | Site 1 | 190.07 ± 14.12 | 85.77 ± 2.22 | 50.13 ± 2.29 | 5093 ± 53.84 | 126.17 ± 4.06 |
| | Site 2 | 131.4 ± 5.1 | 83.4 ± 1.84 | 46.3 ± 0.78 | 5048 ± 63 | 104.17 ± 7.44 |
| | Site 3 | 190.83 ± 9.59 | 86.17 ± 0.81 | 51.5 ± 1.82 | 3049.37 ± 44.92 | 126.13 ± 4.1 |
| | Site 4 | 161.7 ± 4.33 | 82.97 ± 1.06 | 42.17 ± 2.67 | 4120.67 ± 84.2 | 108.6 ± 2.54 |
| | Site 5 | 138 ± 2.00 | 87.5 ± 1.04 | 42.83 ± 0.96 | 5018 ± 9.54 | 118.07 ± 3.23 |
| | Site 6[a] | 178.6 ± 2.12 | 93.1 ± 4.49 | 67.43 ± 5.7 | 6906.33 ± 109.71 | 147.63 ± 1.51 |
| | Site 7[b] | 173 ± 6.37 | 89 ± 0.7 | 68.17 ± 1.07 | 5951.67 ± 43.39 | 132.03 ± 3.67 |
| | Control | 79.43 ± 3.84 | 55.53 ± 1.45 | 31.77 ± 0.31 | 4728.33 ± 36.23 | 83.6 ± 1.76 |
| Koradi (Khaperkheda[c] Koradi) | Site 1 | 84.53 ± 4.72 | 64.93 ± 1.19 | 30.2 ± 1.57 | 3053.67 ± 102.19 | 109.97 ± 8.98 |
| | Site 2 | 66.37 ± 2.02 | 57.87 ± 3.48 | 27.6 ± 4.78 | 4041.9 ± 59.34 | 86.63 ± 1.07 |
| | Site 3 | 71.43 ± 1.89 | 60.87 ± 2.69 | 29.83 ± 1.5 | 3171 ± 67.76 | 84 ± 0.98 |
| | Site 4 | 76.2 ± 3.81 | 72.73 ± 1.36 | 31.8 ± 2.05 | 3073.07 ± 65.84 | 95.13 ± 3.93 |
| | Site 5 | 61.2 ± 1.49 | 65.3 ± 2.05 | 27.2 ± 2.6 | 4921.67 ± 41.19 | 73.4 ± 4.58 |
| | Site 6 | 46.1 ± 1.92 | 58.27 ± 2.68 | 26 ± 0.36 | 4041.9 ± 59.34 | 75.3 ± 2.27 |
| | Site 7 | 57.73 ± 8.72 | 66.23 ± 1.3 | 27.9 ± 1.91 | 5056.33 ± 136.26 | 85.63 ± 1.51 |
| | Site 8 | 50.33 ± 4.36 | 65.83 ± 2.63 | 29 ± 2.88 | 6126 ± 3.61 | 76.1 ± 4.33 |
| | Site 9 | 63.4 ± 2.21 | 69.97 ± 3.37 | 28.13 ± 0.57 | 6281.67 ± 122.77 | 82.7 ± 1.66 |
| | Site 10 | 74.2 ± 4.63 | 63.83 ± 3.49 | 28.83 ± 0.38 | 6098.67 ± 405.91 | 82.43 ± 0.64 |
| | Site 11[c] | 93 ± 3.99 | 88.27 ± 1.55 | 36.13 ± 0.59 | 5917 ± 18.33 | 135.3 ± 3.47 |
| | Site 12[d] | 92.47 ± 2.4 | 81.37 ± 2.66 | 29.8 ± 2.01 | 5665.33 ± 27.3 | 99.8 ± 2.26 |

(continued)

**Table 3a** (continued)

| Sampling station | Sites | Cu | Ni | Co | Fe | Zn |
|---|---|---|---|---|---|---|
| | Site 13[e] | 79.9 ± 2.69 | 77.53 ± 4.48 | 37.77 ± 0.93 | 6680.33 ± 131.95 | 123.1 ± 1.13 |
| | Site 14[f] | 72.83 ± 3.55 | 68.67 ± 10.43 | 35.17 ± 0.91 | 6307.33 ± 16.5 | 111.13 ± 2.89 |
| | Control | 40.64 ± 1.49 | 37.03 ± 5.13 | 14.5 ± 1.39 | 3771.67 ± 162.54 | 54.57 ± 4.91 |

[a]Paras pond ash
[b]Paras fly ash
[c]Khaparkheda pond ash
[d]Khaparkheda fly ash
[e]Koradi pond ash
[f]Koradi fly ash

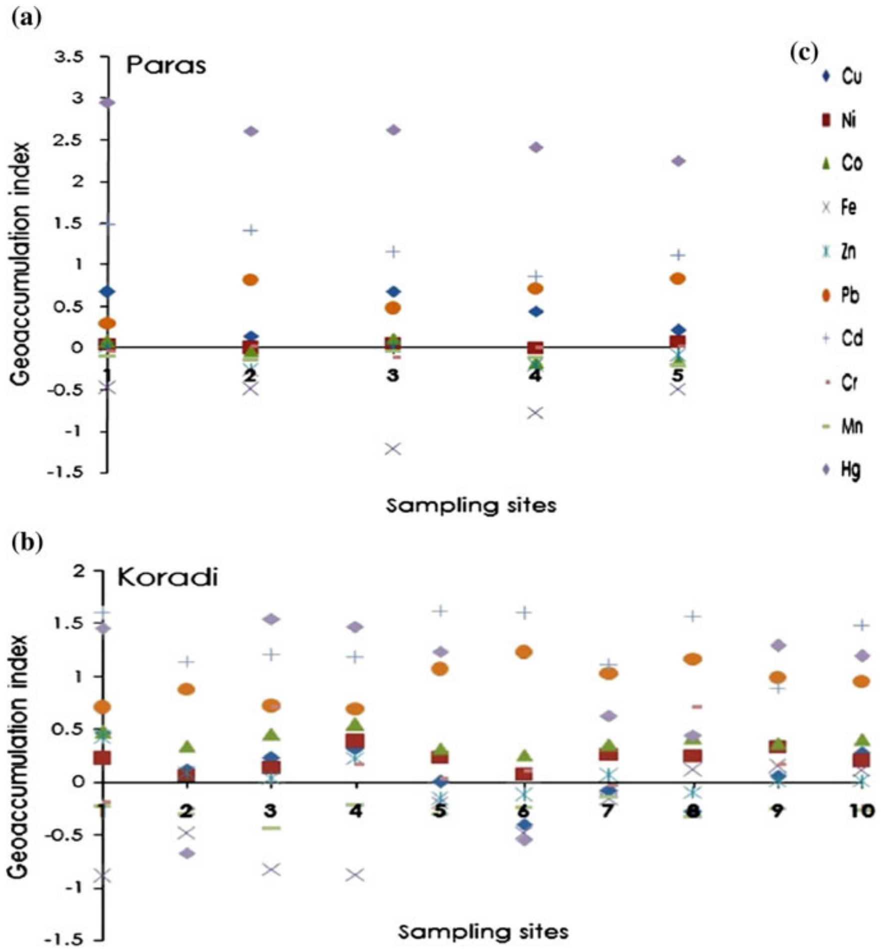



**Fig. 2** **a** $I_{geo}$ plot of heavy metals present in study area (Paras). **b** $I_{geo}$ plot of heavy metals present in study area (Koradi) and **c** metal identification

At Paras sites, the index values for Co at different sites were near 0 indicating uncontaminated soil due to Co as compared to control. At TPP Koradi, the index values at different sites were higher than that of TPP Paras as evident from Fig. 2a, b, but still below contamination levels.

**Iron** (**Fe**): At Paras, mean Fe concentration levels are shown in Table 3a. The pond ash level at this station was very high (6906.33 ± 109.71 mg/kg). According to $I_{geo}$ index, there was hardly any contamination with index values lying below 0 at TPP Paras. At TPP Koradi, the index values were below 0 revealing no contamination by Fe.

**Zinc** (**Zn**): In Maharashtra, at TPP Paras, the mean Zn levels in soil samples are shown in Table 3a. At TPP Koradi, the minimum Zn level was observed at site 5 (73.4 ± 4.58 mg/kg), while maximum was recorded at site 2 (109.97 ± 8.98 mg/kg).

The comparison of Zn levels at different locations with control using geo-accumulation index revealed that the index values at TPP Paras were negative and close to 0 indicating very low contamination. At TPP Koradi also, the index values ranged between either negative or between 0 and 0.5. This reveals that the Zn contamination is very marginal.

**Lead** (**Pb**): At TPP Paras, the minimum average Pb concentration in soil was observed at site 1 (14.1 ± 0.96 mg/kg), while site 5 indicated higher level 20.47 ± 0.31 mg/kg (Table 3b). The pond ash and fly ash levels were higher than soil Pb concentration. The mean concentration in control was 7.67 ± 0.4 mg/kg and was lower than all the sites at this station. At TPP Koradi, the minimum average Pb concentration was observed at site 4 (23.43 ± 0.67 mg/kg), while maximum was at site 6 (34.13 ± 0.67 mg/kg). The soil Pb concentrations at different sites were higher than that of control (9.7 ± 0.17 mg/kg).

On the whole, the mean Pb concentration in soil samples at TPP Paras, the index values for Pb at different sites ranged from 0 to 1, indicating moderate contamination of soil due to Pb. At TPP Koradi, for first four sites, the index values were below 1. At rest of the sites, the values were above 1. This indicates that the sites were moderately contaminated by Pb.

**Cadmium** (**Cd**): At TPP Paras, the pre-monsoon mean Cd levels in soil samples ranged between 2.17 ± 0.23 and 3.37 ± 0.38 mg/kg. The pond ash level at this station was recorded as 5.07 ± 0.15 mg/kg and was higher than soil samples as shown in Table 3b. At TPP Koradi, the minimum average Cd level was observed at site 9 (1.77 ± 0.12 mg/kg), while maximum was recorded at site 5 (2.93 ± 0.23 mg/kg).

The comparison of Cd levels with control using $I_{geo}$ revealed that the index values at TPP Paras were in the range 1–2, indicating moderate contamination at all sites except site 4, which indicated borderline contamination. At TPP Koradi also, the index values were in the range 1–1.5 revealing that the Cd contamination is moderate due to Cd.

**Chromium** (**Cr**): At TPP Paras, the minimum average Cr level in soil was observed at site 3 (29.13 ± 2.85 mg/kg), while site 6 showed highest level 39.03 ± 1.04 mg/kg (Table 3b). The pond ash and fly ash levels were almost similar. The mean level at control was 20.93 ± 1.08 mg/kg, which was lower than all the sites at this station. At Koradi, the minimum average Cr concentration was observed at site 1 (28.23 ± 0.95 mg/kg), while maximum was recorded for both site 3 and 8 (55.43 ± 4.51 mg/kg). As per the results of geochemical analysis, at TPP Paras, the index values for Cr at different sites were closed to 0 and similar observation was recorded at TPP Koradi.

**Manganese** (**Mn**): In Maharashtra, at TPP Paras, the mean Mn levels in soil samples were very similar at all the stations and ranged between 937.33 ± 7.31 and 1051.97 ± 43.08 mg/kg. The pond ash level was recorded as 1232.87 ± 13.38 mg/kg. At TPP Koradi, the minimum Mn level was observed at site 3 (662.6 ± 10.33 mg/kg), while maximum was recorded at site 7

**Table 3b** Mean and standard deviation for different metal concentrations (mg/kg) at different sites of two sampling stations in Maharashtra state

| Sampling station | Sites | Cd | Cr | Mn | Hg | Pb |
|---|---|---|---|---|---|---|
| Paras TPP | Site 1 | 3.37 ± 0.38 | 30.43 ± 1.76 | 1007.93 ± 37.92 | 0.26 ± 0.03 | 14.1 ± 0.96 |
| | Site 2 | 3.2 ± 0.44 | 31.7 ± 1.93 | 979.2 ± 24.86 | 0.2 ± 0.01 | 20.2 ± 0.46 |
| | Site 3 | 2.67 ± 0.81 | 29.13 ± 2.85 | 1051.97 ± 43.08 | 0.2 ± 0.01 | 16 ± 1.08 |
| | Site 4 | 2.17 ± 0.23 | 31.67 ± 1.1 | 1001.57 ± 3.39 | 0.18 ± 0 | 18.77 ± 0.93 |
| | Site 5 | 2.6 ± 0.17 | 31.87 ± 1.06 | 937.33 ± 7.31 | 0.16 ± 0.01 | 20.47 ± 0.31 |
| | Site 6[a] | 5.07 ± 0.15 | 39.03 ± 1.04 | 1232.87 ± 13.38 | 0.81 ± 0.02 | 35.03 ± 0.21 |
| | Site 7[b] | 4.67 ± 0.15 | 36.17 ± 1.27 | 1093.1 ± 51.02 | 0.16 ± 0.02 | 29.27 ± 0.59 |
| | Control | 0.8 ± 0 | 20.93 ± 1.08 | 723.3 ± 3.21 | 0.02 ± 0 | 7.67 ± 0.4 |
| Koradi (Khaperkheda[c] Koradi) | Site 1 | 2.9 ± 0.17 | 29.47 ± 1.68 | 768.23 ± 11.08 | 0.19 ± 0.01 | 23.77 ± 0.15 |
| | Site 2 | 2.1 ± 0.17 | 28.23 ± 0.95 | 726.13 ± 7.7 | 0.04 ± 0.01 | 26.67 ± 2.84 |
| | Site 3 | 2.2 ± 0.56 | 55.43 ± 4.51 | 662.6 ± 10.33 | 0.2 ± 0.01 | 24.03 ± 2.19 |
| | Site 4 | 2.17 ± 0.12 | 37.9 ± 2.82 | 769.67 ± 2.12 | 0.19 ± 0.01 | 23.43 ± 0.67 |
| | Site 5 | 2.93 ± 0.23 | 34.5 ± 1.65 | 726.8 ± 3.82 | 0.16 ± 0.02 | 30.57 ± 1.45 |
| | Site 6 | 2.9 ± 0.17 | 36.23 ± 3.93 | 761.4 ± 2.55 | 0.05 ± 0.02 | 34.13 ± 0.67 |
| | Site 7 | 2.07 ± 0.29 | 33 ± 2.86 | 812.57 ± 2.2 | 0.11 ± 0.01 | 29.63 ± 0.49 |
| | Site 8 | 2.83 ± 0.06 | 55.43 ± 4.51 | 716.37 ± 11.28 | 0.1 ± 0.04 | 32.6 ± 0.44 |
| | Site 9 | 1.77 ± 0.12 | 37.9 ± 2.82 | 749.77 ± 3.61 | 0.17 ± 0.03 | 28.9 ± 0.2 |
| | Site 10 | 2.67 ± 0.23 | 28.77 ± 2.14 | 744 ± 7.1 | 0.16 ± 0.01 | 28.1 ± 0.95 |
| | Site 11[c] | 5.07 ± 0.15 | 65.33 ± 2.43 | 818.73 ± 7.5 | 1.81 ± 0.07 | 54.13 ± 1.07 |
| | Site 12[d] | 4.8 ± 0.17 | 49.83 ± 3.41 | 244.73 ± 31.11 | 0.77 ± 0.03 | 53.1 ± 3.56 |

(continued)

**Table 3b** (continued)

| Sampling station | Sites | Cd | Cr | Mn | Hg | Pb |
|---|---|---|---|---|---|---|
| | Site 13[e] | 5.63 ± 0.29 | 34.27 ± 0.55 | 1004.87 ± 6.77 | 1.27 ± 0.04 | 74 ± 7.67 |
| | Site 14[f] | 4.7 ± 0.62 | 24.7 ± 1.4 | 897.43 ± 3.41 | 1.04 ± 0.19 | 67.53 ± 2.41 |
| | Control | 0.64 ± 0.12 | 22.43 ± 0.55 | 597.67 ± 4.16 | 0.05 ± 0.01 | 9.7 ± 0.17 |

[a]Paras pond ash
[b]Paras fly ash
[c]Khaparkheda pond ash
[d]Khaparkheda fly ash
[e]Koradi pond ash
[f]Koradi fly ash

(812.57 ± 2.2 mg/kg). The comparison of Mn levels with control using $I_{geo}$ index revealed that the index values at TPP Paras sites were very close to 0, indicating hardly any contamination at all sites due to Mn.

**Mercury** (**Hg**): At TPP Paras, the Hg level in soil is shown in Table 3b. The pond ash level was higher, while fly ash level was similar to that of soil. The mean level at control was 0.02 ± 0.01 mg/kg, which was lower than all the sites at this station. At TPP Koradi, the least average Hg concentration was observed at site 1 (0.04 ± 0.01 mg/kg), while maximum was recorded for both site 4 (0.19 ± 0.01 mg/kg). Hg concentration was found to be the highest at TPP Khaparkheda pond ash. At TPP Koradi pond ash, fly ash levels were higher than that of soil samples. The $I_{geo}$ analysis for Hg revealed that at TPP Paras, all the sites were strongly contaminated due to Hg levels when compared to control. At TPP Koradi sites, the levels were in the range of 1–1.5 implying moderate contamination due to Hg.

In $I_{geo}$ studies, the negative values and zero of some metals according to contamination classification by Muller [20] showed that the soil was not polluted by those metals. Interpretations came out after the study of $I_{geo}$ values that soil at TPP Paras revealed that it is moderately to strongly contaminated by Hg and moderately contaminated by Cd. In TPP Koradi, three metals came into focus viz. Hg, Cd, and Pb by which the sites were moderately contaminated, rest of all metals showed uncontaminated to the moderately contaminated soil.

## 3.2 *Physicochemical Characteristics*

The values of physicochemical parameters like pH, electrical conductivity (EC), organic carbon (OC) percentage, sand percentage, silt percentage, clay percentage, and texture class recorded in soil samples at different sampling sites in two states are given in Table 4a. The same parameters in fly ash were analyzed at the study sites and are given in Table 4b. The dry fly ash was collected only once directly from the source of generation to know the basic characteristics of fly ash.

At TPP Paras, maximum mean pH of 7.79 ± 0.07 at site 4 and minimum of 7.03 ± 0.01 at site 3. Pond ash showed highly alkaline pH 10.93 ± 0.23. EC was recorded maximum at site 1 and minimum at site 2. OC showed maximum 1.96 ± 0.02 at site 2 and minimum 0.75 ± 0.03 at site 3, and pond ash OC was recorded 0.64 ± 0.01, and texture class showed loam, clay loam, and sandy clay loam texture of soil. Control soil showed mean pH, EC, and OC of 7.47 ± 0.01, 0.25 ± 0.02, 1.08 ± 0.02, respectively.

At TPP Koradi, the results showed neutral to slight alkaline pH, ranging between 7.32 ± 0.01 at site 1 and maximum 8.1 ± 0.26 at site 5. The pond ash and fly ash of both the plant showed alkaline nature as evident from the tables, while mean pH level at control indicated neutral soil.

EC showed maximum at site 4 (0.27 ± 0.02) and minimum at site 6 (0.18 ± 0.02). Pond ash showed higher EC than in soil. OC was recorded

**Table 4a** Descriptive statistics for various physicochemical parameters at different sites at two sampling locations of Maharashtra

| Sampling station | Sites | pH | EC (ms/cm) | Organic C (%) | Sand (%) | Silt (%) | Clay (%) | Texture class |
|---|---|---|---|---|---|---|---|---|
| | | Pre-monsoon | Pre-monsoon | Pre-monsoon | | | | |
| Paras | Site 1 | 7.13 ± 0.01 | 0.28 ± 0.01 | 1.17 ± 0.02 | 47 | 20 | 33 | Sandy clay loam |
| | Site 2 | 7.39 ± 0.01 | 0.17 ± 0.01 | 1.96 ± 0.02 | 44 | 26 | 30 | Clay loam |
| | Site 3 | 7.03 ± 0.01 | 0.19 ± 0.01 | 0.75 ± 0.03 | 35 | 28 | 37 | Clay loam |
| | Site 4 | 7.79 ± 0.07 | 0.22 ± 0.01 | 1.04 ± 0.02 | 50 | 29 | 21 | Sandy clay loam |
| | Site 5 | 7.27 ± 0.06 | 0.24 ± 0.02 | 0.96 ± 0.02 | 41 | 43 | 16 | Loam |
| | Site 6[a] | 10.93 ± 0.23 | 1.81 ± 0.01 | 0.64 ± 0.01 | 96.69 | 1.33 | 1.98 | Sandy |
| | Control | 7.47 ± 0.01 | 0.25 ± 0.02 | 1.08 ± 0.02 | 43 | 22 | 35 | Clay loam |
| Koradi | Site 1 | 7.32 ± 0.01 | 0.24 ± 0.02 | 1.34 ± 0.01 | 42 | 30 | 28 | Clay loam |
| | Site 2 | 7.82 ± 0.01 | 0.23 ± 0.02 | 1.25 ± 0.03 | 31 | 28 | 41 | Clay |
| | Site 3 | 8.03 ± 0.12 | 0.23 ± 0.02 | 1.16 ± 0.01 | 20 | 37 | 43 | Clay |
| | Site 4 | 7.8 ± 0.02 | 0.27 ± 0.02 | 0.95 ± 0.02 | 38 | 19 | 43 | Clay |
| | Site 5 | 8.1 ± 0.26 | 0.25 ± 0.01 | 1.04 ± 0.01 | 27 | 25 | 48 | Clay |
| | Site 6 | 7.73 ± 0.06 | 0.18 ± 0.02 | 1.36 ± 0.02 | 30 | 28 | 42 | Clay |
| | Site 7 | 7.6 ± 0.17 | 0.2 ± 0.01 | 1.04 ± 0.02 | 25 | 32 | 43 | Clay |
| | Site 8 | 7.73 ± 0.12 | 0.24 ± 0.02 | 1.44 ± 0.02 | 30 | 28 | 42 | Clay |
| | Site 9 | 7.33 ± 0.15 | 0.23 ± 0.02 | 0.96 ± 0.02 | 32 | 26 | 42 | Clay |
| | Site 10 | 7.42 ± 0.08 | 0.23 ± 0.02 | 1.05 ± 0.02 | 36 | 20 | 44 | Clay |
| | Site 11[b] | 11.13 ± 0.4 | 1.25 ± 0.02 | 1.06 ± 0.02 | 96.55 | 1.87 | 1.58 | Sandy |
| | Site 12[c] | 11.03 ± 0.12 | 1.37 ± 0.21 | 0.96 ± 0.02 | 95.97 | 1.98 | 2.05 | Sandy |
| | Control | 7.03 ± 0.12 | 0.24 ± 0.01 | 1.25 ± 0.03 | 42 | 20 | 38 | Clay loam |

[a]Paras pond ash
[b]Khaparkheda pond ash
[c]Koradi pond ash

**Table 4b** Descriptive statistics for various physicochemical parameters in fly ash at two sampling locations of Maharashtra

| Sampling station | Sites | pH | EC (ms/cm) | Organic C (%) | Sand (%) | Silt (%) | Clay (%) | Texture class |
|---|---|---|---|---|---|---|---|---|
| Paras | Site 1[a] | 10.23 ± 0.06 | 1.16 ± 0.01 | 0.75 ± 0.02 | 96.94 | 1.02 | 2.04 | Sandy |
| Koradi | Site 1[b] | 9.87 ± 0.29 | 0.56 ± 0.01 | 0.76 ± 0.03 | 96.5 | 1.2 | 2.3 | Sandy |
| | Site 2[c] | 10.77 ± 0.25 | 0.97 ± 0.21 | 0.25 ± 0.03 | 96.01 | 2.01 | 1.98 | Sandy |

[a]Paras fly ash
[b]Khaparkheda fly ash
[c]Koradi fly ash

maximum at site 8 (1.44 ± 0.02) and minimum at site 4 (0.95 ± 0.02). Soil texture class was observed clay texture. Control soil showed approximately similar range of pH, EC, and OC values like soil.

pH showed neutral to basic in range at TPP Paras and Koradi locations of Maharashtra, which is also revealing that the soil pH might be affected by the fly ash and pond ash deposition.

### *3.3 PCA*

Principal component analysis was performed with metals as variables and sets as objects. The data for each variable were standardized and used for computations. The analysis was performed independently for all the sampling stations, with the results obtained as shown through biplots in Fig. 3. The clustering of sites was obtained on the basis of first two principal components, which accounted for at least 70% variation in the data sets. The component loadings were also obtained indicating the variance of each variable and correlation of variables.

At Paras (Fig. 3), the metal concentration data did not reveal any specific clustering of sites. At site 1 and 3, the concentrations of Cu, Mn, Zn, and Co were higher as compared to other sites. Hg concentration was much higher at site 1. At site 4, the metal concentration levels were close to the respective mean levels. Cr, Pb, and Cd showed high correlation, while Co, Zn, and Mn showed high correlations amongst themselves. Ni and Hg were also highly correlated.

At Koradi, in the pre-monsoon season, sites 2–4 clustered together due to almost similar metal concentration profiles. Sites 6 and 7 and similarly 9 and 10 showed grouping as evident from the figure. Cu, Hg, and Zn showed high concentration at Sites 2–4. Pb concentrations were much higher at Sites 6–8. Site 1 was the least contaminated amongst all. The metals Cu, Zn, and Hg showed high correlation amongst themselves. Also, Cd, Ni, and Cr showed high correlations with each other.

Environmental monitoring and assessment around industries mainly aim to the knowledge of the heavy metal accumulation in soil, the origin of these metals, and their possible interactions with soil properties. Many attempts have been made in this regard around the world as well as in India. Indian scenario regarding the pollution caused by coal-based thermal power stations can be differentiated by locations because there are several types of variations of soil profile which can be seen all over India such as [21] worked the elemental concentrations of Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn in soils around the thermal power stations in Delhi, India, and observed that the distribution of concentrations of pollutants has some relation with the distance and directions from thermal power plants. Praharaj et al. [22] made an attempt to describe the soil contamination around the ash pond of a coal-based thermal power plant in Orissa. The topsoil in the study area was found to be contaminated to varying degrees from ash disposal. The soil drawn from various

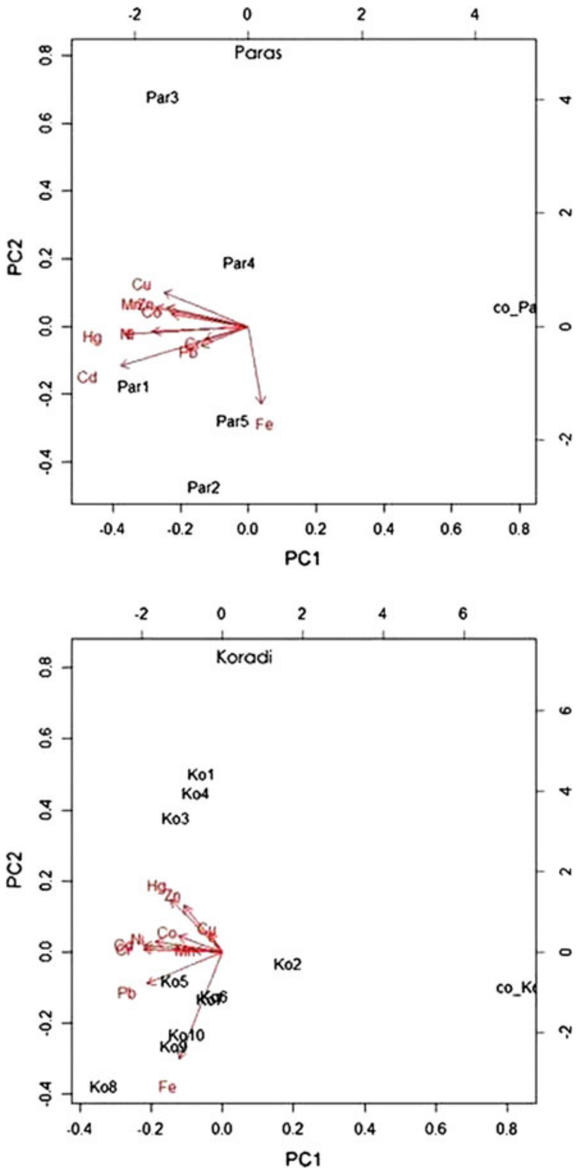



**Fig. 3** PCA plots of heavy metals present in the study area

profiles was predominantly contaminated by ash fall out in the prevalent wind direction.

Sushil and Batra [23] investigated the heavy metal content of fly ash and bottom ash from three major power plants in North India. They studied the presence of Cr, Mn, Pb, Zn, Ni, Cu, and Co on detectable amount in both fly ash bottom ashes. A study has been made to determine the extent of soil contamination around one of the largest thermal power plants of India located at Kolaghat, West Bengal, India, by Mandal and Sengupta [14]. They studied the presence and enrichment of trace metals, i.e., As, Mo, Cr, Mn, Cu, Ni, Co, Pb, Be, V, Zn on the top soils and the soils collected from the different depth profiles surrounding the ash ponds. Agrawal et al. [24] made an attempt to measure contamination of soil around four large coal-based thermal power plants of Singrauli region. The concentration of cadmium, lead, arsenic, and nickel was estimated in all four directions from thermal power plants, and the soil in the study area was found to be contaminated from coal combustion by products. The soil was largely contaminated by metals, predominantly higher within 2–4 km distance from TPP and the mean maximum concentration of Cadmium, Lead, Arsenic, and Nickel was 0.69, 13.69, 17.76, and 3.51 mg/kg, respectively.

## 4 Conclusion

In environmental monitoring and assessment strategies, these methods can be used to estimate the variability of heavy metals and its influence of human activities on heavy metal contents of soils. Therefore, statistical analysis of heavy metals in soil can offer an ideal means through which it can monitor not only the heavy metal accumulation in the soil, but also the quality of the overall environment as reflects in soil. The present work thus shows significant amount of contamination of topsoil due to ash disposal. Total concentration of Cu, Ni, Cd, Zn, Fe, Pb, Co, Hg, Cr, and Mn was evaluated in soil, fly ash, and pond ash of different selected thermal power plants of central India. The contamination is more pronounced in soils within or close to the predominant wind direction. The concentration of all heavy metals in all soil profiles around thermal power plants and ash ponds is higher than the control soil. All elements were present in detectable limits, and soil was found minimal to moderately enriched with Cu, Ni, Zn, Fe, Co, Cr, and Mn. Metals such as Cd, Hg, and Pb were found in considerable enrichment status in soil of studied stations which may cause serious deterioration in soil productivity in near future. Marked differences were observed between metal concentrations of soil as well as fly ash samples of studied two different thermal power plants chosen for study. Fly ash fallout from thermal power plants affects soil quality as well as human health for which a combination of suitable disposal techniques and use of microflora for removal of contaminated metals may be used.

## References

1. Sahu, S.K., Bhangare, R.C., Ajmal, P.Y., Sharma, S., Pandit, G.G., Puranil, V.D.: Characterization and quantification of persistent organic pollutants in fly ash from coal fueled thermal power stations in India. J. Microchem. **92**, 92–96 (2009)
2. Asokan, P., Saxena, M., Asolekar, S.R.: Coal combustion residues—environmental implications and recycling potentials. Resour. Conserv. Recycl. **43**, 239–262 (2005)

3. Parekh, P.P., Husain, L.: Fe/Mg ratio: a signature for local coal-fired power plants. Atmos. Environ. **21**(8), 1707–1712 (1987)
4. Ramachandran, T.V., Lalit, B.Y., Mishra, U.C.: Modifications in natural radioactivity contents of soil samples around thermal power stations in India. Indian J. Environ. Health **32**, 13–19 (1990)
5. Llorens, J.F., Fernandaez-Turiel, J.L., Querol, X.: The fate of trace elements in a large coal fired power plant. Environ. Geol. **40**, 409–416 (2001)
6. Singh, L.P., Siddiqui, Z.A.: Effect of fly ash and Helminthosporium oryzae on growth and yield of three cultivar of rice. Bioresour. Technol. **86**, 73–78 (2003)
7. Carlson, C.L., Adriano, D.C.: Environmental impacts of coal combustion residues. J. Environ. Qual. **22**, 227–247 (1993)
8. Kishor, P., Ghosh, A.K., Kumar, D.: Use of fly ash in agriculture: a way to improve soil fertility and its productivity. Asian J. Agric. Res. **4**, 1–14 (2010)
9. Akoto, O., Ephraim, J.H., Darko, G.: Heavy metal pollution in surface soils in the vicinity of abundant railway servicing workshop in Kumasi, Ghana. Int. J. Environ. Res. **2**(4), 359–364 (2008)
10. Alloway, J.B.: Soil pollution and land contamination, In: Harrison, R.M. (ed.) Pollution: Causes, Effects and Control, p. 318. The Royal Society of Chemistry, Cambridge, UK (1995)
11. Gupta, D.K., Rai, U.N., Tripathi, R.D., Inouhe, M.: Impacts of fly ash on soil and plant responses. J. Plant Res. **115**, 401–409 (2002)
12. Pandey, V.C., Abhilash, P.C., Singh, N.: The Indian perspective of utilizing fly ash in phytoremediation, phytomanagement and biomass production. J. Env. Manag. **90**, 2943–2958 (2009)
13. Shakeri, A., Moore, F., Modabberi, S.: Heavy metal contamination and distribution in the Shiraz Industrial Complex Zone Soil, South Shiraz, Iran. World Appl. Sci. J. **6**(3), 413–425 (2009)
14. Mandal, A., Sengupta, D.: An assessment of soil contamination due to heavy metals around a coal-fired thermal power plant in India. Environ. Geol. **51**, 409–420 (2006)
15. Nyamangara, J., Mzezewa, J.: The effects of environment long-term sewage sludge application on Zn, Cu, Ni and Pb levels in clay loam soil under pasture grass in Zimbabwe. Agri. Ecosys. Environ. **73**, 199–204 (1999)
16. Piper, C.S.: Soil and Plant Analysis. 4th ed., pp. 135–200. University of Acelicide, Adcitada, Australia (1966)
17. McNeal, E.O.: Soil pH and lime requirement. In: Page, A.L., Miller, R.H., Keeney, D.R. (eds.) Methods of Soil Analysis Part 2. Chemical and Microbiological Properties, pp. 199–224. ASA Inc. SSSA Inc. Publishers, NY, USA (1982)
18. Jackson, M.L.: Soil Chemical Analysis. Prentice Hall of India Pub, New Delhi (1967)
19. AOAC: AOAC Official Methods of Analysis. 15th ed., pp. 84–85. Association of Official Analytical Chemists, Arlington, Virginia (1999)
20. Muller, G.: Index of geo accumulation in sediments of the Rhine River. Geol. J. **2**(3), 108–118 (1969)
21. Mehra, A., Farago, M.E., Banerjee, D.K.: (1998) Impact of fly ash from coal fired power stations in Delhi, with particular reference to metal contamination. Environ. Monitor. Assess. **50**:15–35
22. Praharaj, T., Tripathy, S., Powell, M.A., Hart, B.R. Geochemical studies to delineate topsoil contamination around an ash pond of a coal-based thermal power plant in India. Environ. Geol. **45**:86–97 (2003)
23. Sushil, S., Batra, V.S. (2006) Analysis of fly ash heavy metal content and disposal in three thermal power plants in India. Fuel **85**:2676–2679
24. Agrawal, P., Mittal, A., Prakash, R., Kumar, M., Singh, T.B., Tripathi, S.K.: Assessment of contamination of soil due to heavy metals around coal fired thermal power plants at Singrauli Region of India. Bull. Environ. Contam. Toxicol. **85**, 219–223 (2010)

# Generation of Volatile Fatty Acids (VFAs) from Dried and Powdered Ipomoea (*Ipomoea carnea*)

**M. Rafiq Kumar, S. M. Tauseef, Tasneem Abbasi and S. A. Abbasi**

## 1 Introduction

We have shown [1, 2] that energy precursors in the form of volatile fatty acids (VFAs) can be generated in a simple, clean, yet efficient manner from freshly harvested leaves of the weeds like ipomoea (Ipomoea carnea). This process provides a means with which the otherwise very harmful and dominant weed like ipomoea can be gainfully utilized. In the absence of such processes, the weeds grow unchecked, seriously harming biodiversity [3, 4]. Its leaves leach out alkaloids and other toxic chemicals when rain or dew falls on them and trickle down to the underlying soil [5]. Upon its biodegradation, ipomoea gives off carbon dioxide and methane which contribute to global warming [6–9]. For all these reasons, and the fact that no other means of utilization of ipomoea has proved viable, we had explored the possibility of generating VFAs from ipomoea [1]. But in most real-life situations, it may not be possible to set up ipomoea-processing plants very near to the place of ipomoea infestation. Even as the process reported earlier [1] can be very useful to farmers and others in dealing with local ipomoea growth using cottage-scale contraptions, for larger-scale processing of ipomoea it is essential that

M. Rafiq Kumar · T. Abbasi (✉) · S. A. Abbasi
Centre for Pollution Control and Environmental Engineering,
Pondicherry University, Puducherry 605014, India
e-mail: tasneem.abbasi@gmail.com

M. Rafiq Kumar
e-mail: kumarrafiq@gmail.com

S. A. Abbasi
e-mail: abbasi.cpee@gmail.com

S. M. Tauseef
Environmental Research Institute, University of Petroleum
and Energy Studies, Dehradun 248007, India
e-mail: sm.tauseef@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_18

the process uses the weed in its dried form. For such a process, ipomoea can be collected from wherever it is found growing and sun-dried before transporting it to the processing plants. Sun drying would eliminate over 75% of the water contained in fresh ipomoea, thereby reducing the masses of the weed to be transported to less than one-fourth of the masses if undried ipomoea is to be transported. This, in turn, would proportionately reduce transportation costs. It will also dislodge invertebrates and small vertebrates—of whom some may be pathogenic—living in ipomoea plants. Sun drying shall also kill most of possibly harmful microorganism.

Hence, the studies described in this paper were carried out wherein dried and powdered ipomoea was explored for generating energy precursors in the form of volatile fatty acids. The study is distinguished from our previous reports [1, 10] by the fact that use of dried biomass needed a pre-treatment step to open up its matrix for biodegradation. Since such a process is sensitive to particle size, duration of pre-treatment and reuse of the chemical employed in pre-treatment, effect of all those variables were studied.

## 2 Materials and Methods

### *2.1 Preparation of Ipomoea Feedstock*

A stock of dried and powered ipomoea was created by harvesting 200 kg of ipomoea leaves and sun drying the leaves along with soft parts of the stem and side branches for several days to a constant weight. The woody parts were dried separately and studied by other workers for their fuel value and for processing by termites.

The fraction of ipomoea leaves and soft stem was ball-milled to generate fine powder. The powder was then sieved to obtain the following particle sizes: (i) 0.2 mm, (ii) $\geq 0.2$ to $\leq 0.5$ mm, (iii) $\geq 0.5$ to $\leq 1$ mm, (iv) >1 mm.

Pooled samples of the powder were oven dried at 105 °C to constant weights. The resulting 'dry weight' represented the total solid (TS) content of the stock of the ipomoea powder.

### *2.2 Design of Experiment*

The core experiment was similar to the one described earlier [1] with three essential differences:

(i) Instead of fresh ipomoea, four different particle sizes of powder were separately investigated.

(ii) Before feeding to each reactor, the powder was first soaked in 15 g/l of NaOH. Effect of two durations of pre-soaking—24 and 72 h—was investigated.
(iii) After completing each spell of soaking, the NaOH solution was drained off and reused in soaking one more powder feed. After this, the NaOH was reused yet once more to soak one more feed.

The general scheme of reactor operation was otherwise similar to the one described earlier [1]. The reactors used in the present study had the effective capacity of 4 L. Measured quantities of ipomoea powder of chosen particle sizes (Table 1), which had been pre-soaked in 15 g/L NaOH and then brought to pH 6–7.5 after draining off the NaOH-rich slurry, were fed to the reactors containing 4 L of water. Appropriate quantities of fresh cow dung were added to achieve inoculum concentrations as specified in Table 1. The manner of reactor operation, sampling, and VFA determination was as detailed earlier [1].

If all permutations–combinations needed to cover the matrix of Table 1 had been carried out which is the requirement of the classical experimental design method often called full factorial design or 'rotatable central composite design' [11]. It would have needed 48 experiments. In order to reduce consumption of resources without compromising on the accuracy and the precision of the findings, the experiments were designed using Taguchi matrix [12, 13]. It is based on a special design of orthogonal arrays which enable achievement of a fair share of advantages of full factorial design within a much smaller number of experiments. Moreover, in classical methods, mathematical modeling may be required to achieve process optimization (optimal values of process parameters); it is not necessary for the Taguchi method. It is not only possible to obtain optimum process parameters just with a few experiments by the Taguchi method but the method requires only rudimentary computational experience. The graphs it yields are easy to understand and interpret. Due to these attributes, Taguchi method is one of the most widely used methods in the designing of the experiments which require process optimization. Additionally, the Taguchi approach contributes to the appreciation of quality improvement strategies that other methods of design of experiments are not always able to provide.

## 3 Results and Discussion

The VFA yield as a function of time is presented in Tables 2 and 25. It was seen that, in general, the VFA yield fluctuated, reaching a peak during 9th–16th day in most cases, though it also did so earlier in a few cases (Table 26). In all cases, it was seen that once the VFA yield showed a decline on three successive days, it did not recover and kept falling. Hence, all reactors were stopped when they recorded a decline in the VFA yield on three consecutive days. The data of that period of terminal decline has been omitted from calculations so that the average yield can be

**Table 1** Average peak values of VFA yield (g/kg TS) among reactors loaded with 80 g of dry-powdered ipomoea of four different particle sizes ( ≤ 0.2 mm, >0.2 to ≤ 0.5 mm, >0.5 to ≤ 1 mm, and >1 mm) inoculated with 0.5 and 1.5% of fresh CD, at pre-soaking periods of 24 h and 72

| Set | Reactors | Particle size (mm) | Soaking in 15 g/l NaOH (h) | CD (%) | Number of days of reactor operation | Peak values seen on days | VFA yield (g/kg TS) |
|---|---|---|---|---|---|---|---|
| 1 | R0, 1 | ≤ 0.2 | 24 | 0.5 | 8 | 3rd | 16.7 |
| | R1, 1 | ≤ 0.2 | 24 | 0.5 | 7 | 3rd | 28.0 |
| | R2, 1 | ≤ 0.2 | 24 | 0.5 | 12 | 1st | 10.2 |
| | R0, 2 | ≤ 0.2 | 72 | 1.5 | 12 | 4th | 51.6 |
| | R1, 2 | ≤ 0.2 | 72 | 1.5 | 9 | 2nd | 23.9 |
| | R2, 2 | ≤ 0.2 | 72 | 1.5 | 6 | 1st | 22.7 |
| 2 | R0, 3 | ≥ 0.2 to ≤ 0.5 | 24 | 0.5 | 18 | 16th | 12.9 |
| | R1, 3 | ≥ 0.2 to ≤ 0.5 | 24 | 0.5 | 17 | 15th | 10.9 |
| | R2, 3 | ≥ 0.2 to ≤ 0.5 | 24 | 0.5 | 16 | 12th | 7.3 |
| | R0, 4 | ≥ 0.2 to ≤ 0.5 | 72 | 1.5 | 16 | 11th | 8.9 |
| | R1, 4 | ≥ 0.2 to ≤ 0.5 | 72 | 1.5 | 14 | 11th | 9.3 |
| | R2, 4 | ≥ 0.2 to ≤ 0.5 | 72 | 1.5 | 11 | 8th | 8.3 |
| 3 | R0, 5 | ≥ 0.5 to ≤ 1 | 24 | 1.5 | 19 | 16th | 8.4 |
| | R1, 5 | ≥ 0.5 to ≤ 1 | 24 | 1.5 | 18 | 11th | 9.1 |
| | R2, 5 | ≥ 0.5 to ≤ 1 | 24 | 1.5 | 16 | 5th | 5.8 |
| | R0, 6 | ≥ 0.5 to ≤ 1 | 72 | 0.5 | 16 | 11th | 6.7 |
| | R1, 6 | ≥ 0.5 to ≤ 1 | 72 | 0.5 | 12 | 5th | 6.6 |
| | R2, 6 | ≥ 0.5 to ≤ 1 | 72 | 0.5 | 11 | 1st | 5.3 |
| 4 | R0, 7 | >1 | 24 | 1.5 | 15 | 10th | 46.0 |
| | R1, 7 | >1 | 24 | 1.5 | 14 | 9th | 34.7 |
| | R2, 7 | >1 | 24 | 1.5 | 15 | 9th | 34.8 |
| | R0, 8 | >1 | 72 | 0.5 | 15 | 12th | 35.6 |
| | R1, 8 | >1 | 72 | 0.5 | 12 | 9th | 35.6 |
| | R2, 8 | >1 | 72 | 0.5 | 12 | 6th | 36.0 |

linked to the days of most productive reactor operation. The findings, presented in Tables 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, and 25, also indicate that no clear pattern, except that VFA yields fluctuate in a fairly wide range, is discernible.

When NaOH was reused to pre-soak the substrate, the VFA yield per unit total solid (TS) was, in general, close to or even higher than the VFA yield when fresh NaOH solution is used. This shows that the NaOH solution can be reused at least twice, possibly more times.

We had used four different particle sizes, spanning diameters differing by five orders of magnitude: from less than 0.2 mm to greater than 1 mm. But no trend of their effect on VFA yield is discernible. The maximum VFA yield recorded, 51.6 g/kg of TS, (or 5.1% of TS) came from a reactor which had substrate in particle size $\leq 0.2$ mm (pre-soaked for 72 h and with cow dung inoculum of 1.5%) but similar advantage of particle size was not generally seen and it may be deduced

**Table 2** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size 0.2 mm

| Number of days from the start of the reactor (R0, 1) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 12.1 |
| 2 | 16.7 |
| 3 | 11.4 |
| 4 | 6.6 |
| 5 | 7.5 |
| 6 | 5.9 |
| 7 | 8.5 |
| Average | 9.8 ± 3.8 |

The powder, 80 g was pre-soaked for 24 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 0.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to 7 ± 0.5 units

**Table 3** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size 0.2 mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 2

| Number of days from the start of the reactor (R1, 1) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 16.0 |
| 2 | 20.3 |
| 3 | 28.0 |
| 4 | 16.0 |
| 5 | 15.5 |
| 6 | 5.6 |
| 7 | 7.1 |
| Average | 15.5 ± 7.6 |

Rest of the steps were same as in Table 2

**Table 4** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size 0.2 mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 3

| Number of days from the start of the reactor (R2, 1) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 10.2 |
| 2 | 9.5 |
| 3 | 9.1 |
| 4 | 6.9 |
| 5 | 7.2 |
| 6 | 5.5 |
| 7 | 6.6 |
| 8 | 7.8 |
| 9 | 5.4 |
| 10 | 5.9 |
| 11 | 3.9 |
| 12 | 2.1 |
| Average | 6.7 ± 2.3 |

Rest of the steps were same as in Table 3

**Table 5** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size 0.2 mm

| Number of days from the start of the reactor (R0, 2) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 5.3 |
| 2 | 12.6 |
| 3 | 10.4 |
| 4 | 51 |
| 5 | 51.6 |
| 6 | 7.6 |
| 7 | 8.1 |
| 8 | 7 |
| 9 | 3.3 |
| 10 | 8.5 |
| 11 | 4.6 |
| 12 | 2.7 |
| Average | 14.4 ± 17.4 |

The powder, 80 g was pre-soaked for 72 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 1.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to 7 ± 0.5 units

that grinding the substrate to particle sizes below 1 mm did not provide any significant advantage. It is possible that particles of size below 1 mm get substantially aggregated, thus negating the advantage of larger net surface area of the powder that might have otherwise been achieved.

**Table 6** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size 0.2 mm pre-soaked for 72 h with the NaOH slurry obtained from the experiment referred in Table 5

| Number of days from the start of the reactor (R1, 2) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 15.2 |
| 2 | 23.9 |
| 3 | 9.2 |
| 4 | 9.8 |
| 5 | 6.5 |
| 6 | 10.5 |
| 7 | 20.8 |
| 8 | 12.6 |
| 9 | 5.3 |
| Average | 12.6 ± 6.3 |

Rest of the steps were same as in Table 5

**Table 7** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size 0.2 mm pre-soaked for 72 h with the NaOH slurry obtained from the experiment referred in Table 6

| Number of days from the start of the reactor (R2, 2) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 22.7 |
| 2 | 15.8 |
| 3 | 12.5 |
| 4 | 11.3 |
| 5 | 5.9 |
| 6 | 3.8 |
| Average | 12.0 ± 6.8 |

Rest of the steps were same as in Table 6

Likewise, pre-soaking for 72 h had no consistent advantage over shorter duration pre-soaking (24 h) nor inoculation with 1.5% cow dung was always beneficial over 0.5% cow dung. As may be seen from the Table 26, the VFA yield was more in the reactors with 72 h of the pre-soaking period for particle sizes 0.2 mm and >1 mm. NaOH reuse has resulted reduction in the time at which peak values in VFA concentration has been achieved, this may be due to the presence of microorganisms drained with the NaOH slurry obtained from the soaking of ipomoea in the previous runs.

**Table 8** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size $\geq 0.2$ to $\leq 0.5$ mm

| Number of days from the start of the reactor (R0, 3) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 3.6 |
| 2 | 3.0 |
| 3 | 12.5 |
| 4 | 5.5 |
| 5 | 4.1 |
| 6 | 4.6 |
| 7 | 3.2 |
| 8 | 4.4 |
| 9 | 3.5 |
| 10 | 4.1 |
| 11 | 9.3 |
| 12 | 9.0 |
| 13 | 9.3 |
| 14 | 3.2 |
| 15 | 8.4 |
| 16 | 12.9 |
| 17 | 8.6 |
| Average | $6.4 \pm 3.3$ |

The powder, 80 g was pre-soaked for 24 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 0.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to $7 \pm 0.5$ units

## *3.1 Analysis of Results Using Taguchi Method*

As stated earlier, Taguchi's parameter design offers a systematic approach for optimization of various parameters with regards to performance, quality, and cost. Taguchi method stresses the importance of studying the response variation using the signal-to-noise (S/N) ratio, resulting in minimization of quality characteristic variation due to the uncontrollable parameters. The volatile fatty acids (VFAs) production was considered as the desired goal with the motto of 'The larger the better.' The effect of variation in soaking time, particle size of powdered weeds, amount of cow dung used to inoculate the reactor, and the amount of NaOH used to facilitate release of cellulose/hemicellulose were studied on the VFA production.

The VFA yields, for the various combination of particle sizes of powered weed (A), pre-soaking time in NaOH (B), and % cow dung (CD) used as inoculum (C), are summarized below in Tables 27, 28, and 29. The average response (VFA yield) for each combination of control factors (A, B, and C) is plotted in Figs. 1a, 2a, and 3a.

**Table 9** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size $\geq 0.2$ to $\leq 0.5$ mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 8

| Number of days from the start of the reactor (R1, 3) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 4 |
| 2 | 2.27 |
| 3 | 3.73 |
| 4 | 4.67 |
| 5 | 3.73 |
| 6 | 3.6 |
| 7 | 4 |
| 8 | 4.8 |
| 9 | 6.3 |
| 10 | 6.7 |
| 11 | 3.5 |
| 12 | 3.2 |
| 13 | 8.8 |
| 14 | 5.3 |
| 15 | 10.9 |
| 16 | 7.5 |
| Average | 5.1 ± 2.1 |

Rest of the steps were same as in Table 8

The signal/noise (S/N) ratio—with the objective, The larger the better, so as to maximize VFA yields for various combinations of control factors—are shown in Figs. 1b, 2b, and 3b.

As seen in Tables, following factors were studied on the basis of the tests done earlier by others in the author's laboratory to study the influence of various factors on volatile fatty acids (VFAs) production/extraction from date palm waste (DPW) [10, 11]:

(i) Amount of NaOH used for pre-treatment: it was fixed in the current experiment but had been varied in the previous experiments.
(ii) Duration of soaking (2 levels: 1 and 2).
(iii) Particle size (4 levels: 1, 2, 3, and 4).
(iv) Amount of cow dung used to inoculate the reactors (2 levels: 1 and 2).

For the data pertaining to soaking in fresh NaOH (Table 27), the Taguchi outputs for S/N ratios and mean VFA yield at various levels are as in Table 30. This data can be fitted into a linear regression model and can be used to forecast the results for other levels of input parameters. The same treatment is possible for the data of Tables 28 and 29. As per this analysis, the mean VFA yield for particle

**Table 10** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size $\geq 0.2$ to $\leq 0.5$ mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 9

| Number of days from the start of the reactor (R2, 3) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 3.0 |
| 2 | 3.5 |
| 3 | 6.0 |
| 4 | 5.4 |
| 5 | 4.9 |
| 6 | 6.2 |
| 7 | 3.1 |
| 8 | 3.3 |
| 9 | 5.0 |
| 10 | 3.0 |
| 11 | 6.0 |
| 12 | 7.3 |
| 13 | 4.9 |
| 14 | 6.6 |
| 15 | 5.6 |
| 16 | 5.3 |
| Average | 4.9 ± 1.3 |

Rest of the steps were same as in Table 9

size >1 mm, soaking time of 24 h, and % CD of 1.5 are close to the mean VFA yield for particle size >1 mm, soaking time 72 h, and % CD of 1.5. Therefore, using 24 h soaking in combination of >1 mm particle size and 1.5% CD will give close to maximum VFA yield. This finding notwithstanding, and given the inherent variability in the characteristics of ipomoea growing in different regions, it is prudent to conclude that these results are only broadly indicative.

For precise design of ipomoea-processing units in different locations, lead up studies similar to the ones described in this paper ought to be done. The VFA, can be converted to methane [14–16] and the spent weed can be vermicomposted into an organic fertilizer [17, 18].

**Table 11** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size ≥ 0.2 to ≤ 0.5 mm

| Number of days from the start of the reactor (R0, 4) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 4.0 |
| 2 | 6.3 |
| 3 | 3.6 |
| 4 | 4.7 |
| 5 | 3.1 |
| 6 | 7.9 |
| 7 | 5.2 |
| 8 | 4.4 |
| 9 | 7.7 |
| 10 | 8.2 |
| 11 | 8.9 |
| 12 | 8.0 |
| 13 | 3.7 |
| 14 | 5.7 |
| 15 | 6.0 |
| 16 | 5.9 |
| Average | 5.8 ± 1.8 |

The powder, 80 g was pre-soaked for 72 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 1.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to 7 ± 0.5 units

**Table 12** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size ≥ 0.2 to ≤ 0.5 mm pre-soaked for 72 h with the NaOH slurry obtained from the experiment referred in Table 11

| Number of days from the start of the reactor (R1, 4) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 8.3 |
| 2 | 3.6 |
| 3 | 4.6 |
| 4 | 5.4 |
| 5 | 7.0 |
| 6 | 5.9 |
| 7 | 3.2 |
| 8 | 5.5 |
| 9 | 4.8 |
| 10 | 5.6 |
| 11 | 9.3 |
| 12 | 7.0 |
| 13 | 5.9 |
| 14 | 5.0 |
| Average | 5.8 ± 1.6 |

Rest of the steps were same as in Table 11

**Table 13** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size $\geq 0.2$ to $\leq 0.5$ mm pre-soaked for 72 h with the NaOH slurry obtained from the experiment referred in Table 12

| Number of days from the start of the reactor (R2, 4) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 6.8 |
| 2 | 3.3 |
| 3 | 4.3 |
| 4 | 5.8 |
| 5 | 5.6 |
| 6 | 4.6 |
| 7 | 5.3 |
| 8 | 8.3 |
| 9 | 6.9 |
| 10 | 3.1 |
| Average | 5.4 ± 1.6 |

Rest of the steps were same as in Table 12

**Table 14** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size >0.5 to $\leq 1$ mm

| Number of days from the start of the reactor (R0, 5) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 5.0 |
| 2 | 4.0 |
| 3 | 3.1 |
| 4 | 3.7 |
| 5 | 4.0 |
| 6 | 4.7 |
| 7 | 4.3 |
| 8 | 6.3 |
| 9 | 2.7 |
| 10 | 2.4 |
| 11 | 6.0 |
| 12 | 5.1 |
| 13 | 7.1 |
| 14 | 4.6 |
| 15 | 3.4 |
| 16 | 8.4 |
| 17 | 7.4 |
| 18 | 7.0 |
| Average | 5.0 ± 1.7 |

The powder, 80 g was pre-soaked for 24 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 1.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to 7 ± 0.5 units

**Table 15** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >0.5 to ≤ 1 mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 14

| Number of days from the start of the reactor (R1, 5) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 3.4 |
| 2 | 2.3 |
| 3 | 4.1 |
| 4 | 3.8 |
| 5 | 6.0 |
| 6 | 4.6 |
| 7 | 4.9 |
| 8 | 4.3 |
| 9 | 2.8 |
| 10 | 6.4 |
| 11 | 9.1 |
| 12 | 2.3 |
| 13 | 2.4 |
| 14 | 3.1 |
| 15 | 1.8 |
| 16 | 6.4 |
| 17 | 8.0 |
| 18 | 8.8 |
| Average | 4.7 ± 2.2 |

Rest of the steps were same as in Table 14

**Table 16** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >0.5 to $\leq 1$ mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 15

| Number of days from the start of the reactor (R2, 5) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 3.2 |
| 2 | 2.0 |
| 3 | 3.5 |
| 4 | 3.2 |
| 5 | 5.8 |
| 6 | 2.8 |
| 7 | 4.3 |
| 8 | 4.6 |
| 9 | 4.2 |
| 10 | 3.9 |
| 11 | 3.5 |
| 12 | 4.3 |
| 13 | 3.0 |
| 14 | 4.6 |
| 15 | 3.2 |
| Average | $3.74 \pm 0.9$ |

Rest of the steps were same as in Table 15

**Table 17** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size >0.5 to $\leq 1$ mm

| Number of days from the start of the reactor (R0, 6) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 3.0 |
| 2 | 3.4 |
| 3 | 3.4 |
| 4 | 3.3 |
| 5 | 6.4 |
| 6 | 4.7 |
| 7 | 4.9 |
| 8 | 4.3 |
| 9 | 4.9 |
| 10 | 4.0 |
| 11 | 6.7 |
| 12 | 5.7 |
| 13 | 5.9 |
| 14 | 4.7 |
| 15 | 2.6 |
| Average | $4.5 \pm 1.2$ |

The powder, 80 g was pre-soaked for 72 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 0.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to $7 \pm 0.5$ units

**Table 18** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >0.5 to $\leq 1$ mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 17

| Number of days from the start of the reactor (R1, 6) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 4.3 |
| 2 | 3.3 |
| 3 | 5.6 |
| 4 | 5.7 |
| 5 | 6.6 |
| 6 | 5.4 |
| 7 | 4.9 |
| 8 | 5.4 |
| 9 | 6.6 |
| 10 | 2.4 |
| Average | 5.0 ± 1.3 |

Rest of the steps were same as in Table 17

**Table 19** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >0.5 to $\leq 1$ mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 18

| Number of days from the start of the reactor (R2, 6) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 4.9 |
| 2 | 4.9 |
| 3 | 4.7 |
| 4 | 4.3 |
| 5 | 4.3 |
| 6 | 4.3 |
| 7 | 2.8 |
| 8 | 1.8 |
| 9 | 5.3 |
| 10 | 5.3 |
| 11 | 3.5 |
| Average | 4.2 ± 1.9 |

Rest of the steps were same as in Table 18

**Table 20** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size >1 mm

| Number of days from the start of the reactor (R0, 7) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 2.7 |
| 2 | 9.0 |
| 3 | 3.3 |
| 4 | 5.9 |
| 5 | 15.9 |
| 6 | 12.0 |
| 7 | 11.7 |
| 8 | 8.9 |
| 9 | 9.7 |
| 10 | 46.0 |
| 11 | 29.3 |
| 12 | 25.1 |
| 13 | 17.6 |
| 14 | 8.3 |
| 15 | 6.9 |
| Average | 14.1 ± 11.5 |

The powder, 80 g was pre-soaked for 24 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 1.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to 7 ± 0.5 units

**Table 21** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >1 mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 20

| Number of days from the start of the reactor (R1, 7) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 4.3 |
| 2 | 5.3 |
| 3 | 8.0 |
| 4 | 16.6 |
| 5 | 8.5 |
| 6 | 20.2 |
| 7 | 12.4 |
| 8 | 11.5 |
| 9 | 34.7 |
| 10 | 29.4 |
| 11 | 24.3 |
| 12 | 18.8 |
| 13 | 5.9 |
| 14 | 7.6 |
| Average | 14.8 ± 9.5 |

Rest of the steps were same as in Table 20

**Table 22** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >1 mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 21

| Number of days from the start of the reactor (R2, 7) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 5.4 |
| 2 | 2.6 |
| 3 | 11.1 |
| 4 | 6.5 |
| 5 | 13.6 |
| 6 | 11.3 |
| 7 | 9.7 |
| 8 | 33.0 |
| 9 | 34.8 |
| 10 | 26.4 |
| 11 | 18.1 |
| 12 | 13.1 |
| 13 | 10.7 |
| 14 | 7.0 |
| 15 | 8.1 |
| Average | 14.1 ± 9.8 |

Rest of the steps were same as in Table 21

**Table 23** Generation of volatile fatty acids (VFAs) from dry-powdered ipomoea of particle size >1 mm

| Number of days from the start of the reactor (R0, 8) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 5.8 |
| 2 | 6.9 |
| 3 | 6.9 |
| 4 | 9.1 |
| 5 | 12.1 |
| 6 | 10.7 |
| 7 | 14.8 |
| 8 | 19.5 |
| 9 | 21.4 |
| 10 | 23.3 |
| 11 | 14.3 |
| 12 | 35.6 |
| 13 | 31.8 |
| 14 | 8.4 |
| 15 | 6.4 |
| Average | 15.1 ± 9.3 |

The powder, 80 g was pre-soaked for 24 h in 1 L of water containing 15 g NaOH and was introduced in the reactors containing 4 L of 1.5% cow dung slurry after the NaOH had been drained off and the pH of the soaked powder was raised to 7 ± 0.5 units

**Table 24** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >1 mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 23

| Number of days from the start of the reactor (R1, 8) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 3.1 |
| 2 | 9.7 |
| 3 | 11.8 |
| 4 | 13.4 |
| 5 | 11.2 |
| 6 | 16.3 |
| 7 | 30.6 |
| 8 | 33.9 |
| 9 | 36.0 |
| 10 | 11.2 |
| 11 | 9.0 |
| 12 | 13.4 |
| Average | 16.6 ± 10.0 |

Rest of the steps were same as in Table 23

**Table 25** Generation of VFAs from 80 g of dry-powdered ipomoea of particle size >1 mm pre-soaked for 24 h with the NaOH slurry obtained from the experiment referred in Table 24

| Number of days from the start of the reactor (R2, 8) | VFA yield (g/kg of ipomoea) |
|---|---|
| 1 | 8.0 |
| 2 | 11.4 |
| 3 | 32.6 |
| 4 | 35.6 |
| 5 | 27.7 |
| 6 | 36.9 |
| 7 | 29.4 |
| 8 | 13.2 |
| 9 | 22.7 |
| 10 | 19.2 |
| 11 | 12.0 |
| 12 | 8.8 |
| Average | 21.5 ± 10.7 |

Rest of the steps were same as in Table 24

**Table 26** VFA yield on two different pre-soaking periods (24 h and 72 h) with fresh NaOH sol, NaOH sol from 1st run, and NaOH sol from 2nd run

| Pre-soaking period 24 h | | | | | | Pre-soaking period 72 h | | |
|---|---|---|---|---|---|---|---|---|
| Set | Days | Particle size (mm) | VFA yield (g/kg) from fresh NaOH sol. | VFA yield (g/kg) NaOH from 1st run | VFA yield (g/kg) NaOH from 2nd run | VFA yield (g/kg) from fresh NaOH sol. | VFA yield (g/kg) NaOH from 1st run | VFA yield (g/kg) NaOH from 2nd run |
| 1. | 1 | 0.2 | 12.1 | 16.0 | **10.2** | 5.3 | 15.2 | **22.7** |
| | 2 | | **16.7** | 20.3 | 9.5 | 12.6 | **23.9** | 15.8 |
| | 3 | | 11.4 | **28.0** | 9.1 | 10.4 | 9.2 | 12.5 |
| | 4 | | 6.6 | 16.0 | 6.9 | 51.0 | 9.8 | 11.3 |
| | 5 | | 7.5 | 15.5 | 7.2 | **51.6** | 6.5 | 5.9 |
| | 6 | | 5.9 | 5.6 | 5.5 | 7.6 | 10.5 | 3.8 |
| | 7 | | 8.5 | 7.1 | 6.6 | 8.1 | 20.8 | |
| | 8 | | | | 7.8 | 7.0 | 12.6 | |
| | 9 | | | | 5.4 | 3.3 | 5.3 | |
| | 10 | | | | 5.9 | 8.5 | | |
| | 11 | | | | 3.9 | 4.6 | | |
| | 12 | | | | 2.1 | 2.7 | | |
| 2. | 1 | | 3.6 | 4 | 3.0 | 4.0 | 8.3 | 6.8 |
| | 2 | >0.2 to ≤ 0.5 | 3.0 | 2.27 | 3.5 | 6.3 | 3.6 | 3.3 |
| | 3 | | 12.5 | 3.73 | 6.0 | 3.6 | 4.6 | 4.3 |
| | 4 | | 5.5 | 4.67 | 5.4 | 4.7 | 5.4 | 5.8 |
| | 5 | | 4.1 | 3.73 | 4.9 | 3.1 | 7.0 | 5.6 |
| | 6 | | 4.6 | 3.6 | 6.2 | 7.9 | 5.9 | 4.6 |
| | 7 | | 3.2 | 4 | 3.1 | 5.2 | 3.2 | 5.3 |
| | 8 | | 4.4 | 4.8 | 3.3 | 4.4 | 5.5 | **8.3** |
| | 9 | | 3.5 | 6.3 | 5.0 | 7.7 | 4.8 | 6.9 |
| | 10 | | 4.1 | 6.7 | 3.0 | 8.2 | 5.6 | 3.1 |
| | 11 | | 9.3 | 3.5 | 6.0 | **8.9** | **9.3** | |
| | 12 | | 9.0 | 3.2 | **7.3** | 8.0 | 7.0 | |
| | 13 | | 9.3 | 8.8 | 4.9 | 3.7 | 5.9 | |
| | 14 | | 3.2 | 5.3 | 6.6 | 5.7 | 5.0 | |
| | 15 | | 8.4 | **10.9** | 5.6 | 6.0 | | |
| | 16 | | **12.9** | 7.5 | 5.3 | 5.9 | | |
| | 17 | | 8.6 | | | | | |

(continued)

**Table 26** (continued)

| Pre-soaking period 24 h | | | | | | Pre-soaking period 72 h | | |
|---|---|---|---|---|---|---|---|---|
| Set | Days | Particle size (mm) | VFA yield (g/kg) from fresh NaOH sol. | VFA yield (g/kg) NaOH from 1st run | VFA yield (g/kg) NaOH from 2nd run | VFA yield (g/kg) from fresh NaOH sol. | VFA yield (g/kg) NaOH from 1st run | VFA yield (g/kg) NaOH from 2nd run |
| 3. | 1 | >5 to ≤1 | 5.0 | 3.4 | 3.2 | 3.0 | 4.3 | 4.9 |
| | 2 | | 4.0 | 2.3 | 2.0 | 3.4 | 3.3 | 4.9 |
| | 3 | | 3.1 | 4.1 | 3.5 | 3.4 | 5.6 | 4.7 |
| | 4 | | 3.7 | 3.8 | 3.2 | 3.3 | 5.7 | 4.3 |
| | 5 | | 4.0 | 6.0 | **5.8** | 6.4 | 6.6 | 4.3 |
| | 6 | | 4.7 | 4.6 | 2.8 | 4.7 | 5.4 | 4.3 |
| | 7 | | 4.3 | 4.9 | 4.3 | 4.9 | 4.9 | 2.8 |
| | 8 | | 6.3 | 4.3 | 4.6 | 4.3 | 5.4 | 1.8 |
| | 9 | | 2.7 | 2.8 | 4.2 | 4.9 | **6.6** | **5.3** |
| | 10 | | 2.4 | 6.4 | 3.9 | 4.0 | 2.4 | 5.3 |
| | 11 | | 6.0 | **9.1** | 3.5 | **6.7** | | 3.5 |
| | 12 | | 5.1 | 2.3 | 4.3 | 5.7 | | |
| | 13 | | 7.1 | 2.4 | 3.0 | 5.9 | | |
| | 14 | | 4.6 | 3.1 | 4.6 | 4.7 | | |
| | 15 | | 3.4 | 1.8 | 3.2 | 2.6 | | |
| | 16 | | **8.4** | 6.4 | | | | |
| | 17 | | 7.4 | 8.0 | | | | |
| | 18 | | 7.0 | 8.8 | | | | |
| 4. | 1 | >1 | 2.7 | 4.3 | 5.4 | 5.8 | 3.1 | 8.0 |
| | 2 | | 9.0 | 5.3 | 2.6 | 6.9 | 9.7 | 11.4 |
| | 3 | | 3.3 | 8.0 | 11.1 | 6.9 | 11.8 | 32.6 |
| | 4 | | 5.9 | 16.6 | 6.5 | 9.1 | 13.4 | 35.6 |
| | 5 | | 15.9 | 8.5 | 13.6 | 12.1 | 11.2 | 27.7 |
| | 6 | | 12.0 | 20.2 | 11.3 | 10.7 | 16.3 | **36.9** |
| | 7 | | 11.7 | 12.4 | 9.7 | 14.8 | 30.6 | 29.4 |
| | 8 | | 8.9 | 11.5 | 33.0 | 19.5 | 33.9 | 13.2 |
| | 9 | | 9.7 | **34.7** | **34.8** | 21.4 | **36.0** | 22.7 |
| | 10 | | **46.0** | 29.4 | 26.4 | 23.3 | 11.2 | 19.2 |
| | 11 | | 29.3 | 24.3 | 18.1 | 14.3 | 9.0 | 12.0 |
| | 12 | | 25.1 | 18.8 | 13.1 | **35.6** | 13.4 | 8.8 |
| | 13 | | 17.6 | 5.9 | 10.7 | 31.8 | | |
| | 14 | | 8.3 | 7.6 | 7.0 | 8.4 | | |
| | 15 | | 6.9 | | 8.1 | 6.4 | | |

The maximum value recorded has been highlighted in bold

**Table 27** Results for fresh NaOH

| Reactors | Particle size (mm) (A) | Soaking in 15 g/l NaOH (h) (B) | CD (%) (C) | Number of days of reactor operation | Peak values seen on days | VFA yield (g/kg TS) |
|---|---|---|---|---|---|---|
| R0, 1 | ≤ 0.2 | 24 | 0.5 | 8 | 3rd | 16.7 |
| R0, 2 | ≤ 0.2 | 72 | 1.5 | 12 | 4th | 51.6 |
| R0, 3 | ≥ 0.2 to ≤ 0.5 | 24 | 0.5 | 18 | 16th | 12.9 |
| R0, 4 | ≥ 0.2 to ≤ 0.5 | 72 | 1.5 | 16 | 11th | 8.9 |
| R0, 5 | ≥ 0.5 to ≤ 1 | 24 | 1.5 | 19 | 16th | 8.4 |
| R0, 6 | ≥ 0.5 to ≤ 1 | 72 | 0.5 | 16 | 11th | 6.7 |
| R0, 7 | >1 | 24 | 1.5 | 15 | 10th | 46 |
| R0, 8 | >1 | 72 | 0.5 | 15 | 12th | 35.6 |

**Table 28** Results for first cycle of reuse of NaOH

| Reactors | Particle size (mm) (A) | Soaking in 15 g/l NaOH (h) (B) | CD (%) (C) | Number of days of reactor operation | Peak values seen on days | VFA yield (g/kg TS) |
|---|---|---|---|---|---|---|
| R1, 1 | ≤ 0.2 | 24 | 0.5 | 7 | 3rd | 28 |
| R1, 2 | ≤ 0.2 | 72 | 1.5 | 9 | 2nd | 23.9 |
| R1, 3 | ≥ 0.2 to ≤ 0.5 | 24 | 0.5 | 17 | 15th | 10.9 |
| R1, 4 | ≥ 0.2 to ≤ 0.5 | 72 | 1.5 | 14 | 11th | 9.3 |
| R1, 5 | ≥ 0.5 to ≤ 1 | 24 | 1.5 | 18 | 11th | 9.1 |
| R1, 6 | ≥ 0.5 to ≤ 1 | 72 | 0.5 | 12 | 5th | 6.6 |
| R1, 7 | >1 | 24 | 1.5 | 14 | 9th | 34.7 |
| R1, 8 | >1 | 72 | 0.5 | 12 | 9th | 35.6 |

**Table 29** Results for second cycle of reuse of NaOH

| Reactors | Particle size (mm) (A) | Soaking in 15 g/l NaOH (h) (B) | CD (%) (C) | Number of days of reactor operation | Peak values seen on days | VFA yield (g/kg TS) |
|---|---|---|---|---|---|---|
| R2, 1 | $\leq 0.2$ | 24 | 0.5 | 12 | 1st | 10.2 |
| R2, 2 | $\leq 0.2$ | 72 | 1.5 | 6 | 1st | 22.7 |
| R2, 3 | $\geq 0.2$ to $\leq 0.5$ | 24 | 0.5 | 16 | 12th | 7.3 |
| R2, 4 | $\geq 0.2$ to $\leq 0.5$ | 72 | 1.5 | 11 | 8th | 8.3 |
| R2, 5 | $\geq 0.5$ to $\leq 1$ | 24 | 1.5 | 16 | 5th | 5.8 |
| R2, 6 | $\geq 0.5$ to $\leq 1$ | 72 | 0.5 | 11 | 1st | 5.3 |
| R2, 7 | >1 | 24 | 1.5 | 15 | 9th | 34.8 |
| R2, 8 | >1 | 72 | 0.5 | 12 | 6th | 36 |

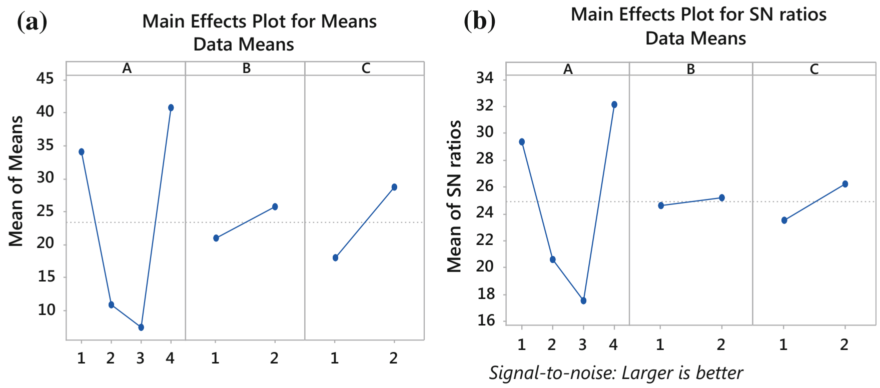



**Fig. 1** Taguchi plots for pre-soaking of powdered weed in fresh NaOH, **a** plot of the mean versus the control factors (A, B, and C); **b** plot of the signal-to-noise ratio versus control factors (A, B, and C)

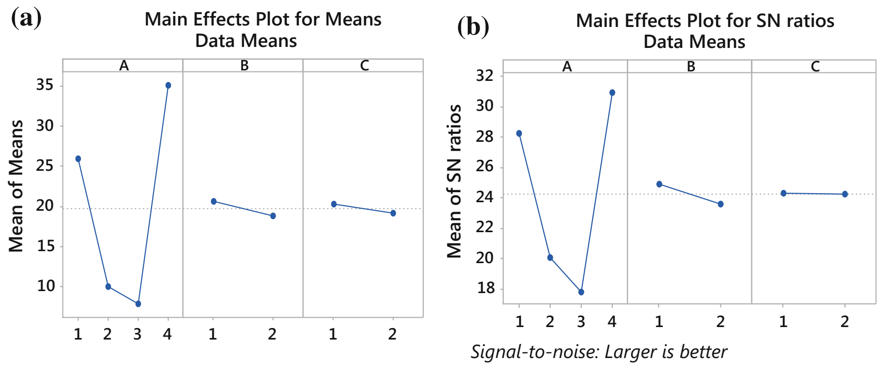



**Fig. 2** Taguchi plots for pre-soaking of powdered weed in NaOH, for the first cycle of its reuse, **a** plants of the mean versus the control factors (A, B, and C); **b** plots of the signal-to-noise ratio versus the control factors (A, B, and C)

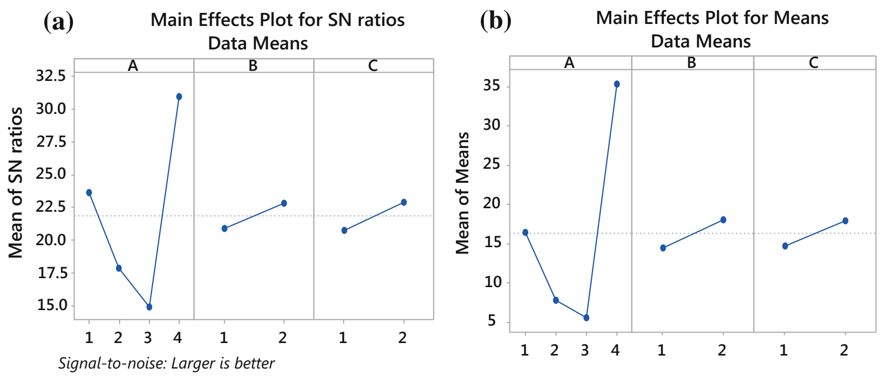



**Fig. 3** Taguchi plots, **a** for the mean versus the control factors (A, B, and C); **b** for the signal-to-noise ratio versus control factors (A, B, and C), for pre-soaking of powdered weed in NaOH, for the second cycle of its reuse

**Table 30** Taguchi output for different levels of particle size, soaking, and % cow dung

| Particle size | Soaking | %CD | S/N ratio | Mean (VFA yield, g/kg TS) |
|---|---|---|---|---|
| 4 | 2 | 2 | 33.7857 | 48.525 |
| 4 | 1 | 2 | 33.1896 | 43.825 |
| 4 | 1 | 1 | 30.4984 | 33.075 |

**Acknowledgements** SAA thanks the Council Scientific and Industrial Research (CSIR), New Delhi for Emeritus Scientist Grant (21(1034)/16/EMR-II. MRK expresses gratitude to the UGC for Maulana Azad National Fellowship.

## References

1. Rafiq Kumar, M., Tauseef, S.M., Abbasi, T., Abbasi, S.A.: Control of amphibious weed ipomoea (*ipomoea carnea*) by utilizing it for the extraction of volatile fatty acids as energy precursors. J. Adv. Res. **6**, 73–78 (2015)
2. Ganesh, P.S., Ramasamy, E.V., Gajalakshmi, S., Abbasi, S.A.: Extraction of volatile fatty acids (VFAs) from water hyacinth using inexpensive contraptions, and the use of the VFAs as feed supplement in conventional digesters. Biochem. Eng. J. **27**, 17–23 (2005)
3. Khan F.I., Abbasi S.A.: Techniques and methodologies for Risk Analysis in Chemical Process Industries. Discovery Publishing House New Delhi; ix + 364 Pages, (1998)
4. Abbasi, S.A., Nipaney, P.C.: Infestation by aquatic weeds of the fern genus salvinia—its status and control. Environ. Conserv. **13**(3), 235–241 (1986)
5. Abbasi, T., Abbasi, S.A.: Sources of pollution in rooftop rainwater harvesting systems and their control. Crit. Rev. Environ. Sci. Technol. **41**, 2097–2167 (2011)
6. Abbasi, S.A., Nipaney, P.C., Schaumberg, G.D.: Bioenergy potential of 8 common aquatic weeds. Biol. Wastes. **34**, 359–366 (1990)
7. Abbasi, T., Tauseef, S.M., Abbasi, S.A.: Biogas Energy. Springer, New York & Londan; xiv +169 Pages; ISBN 978-1-4614-1039-3 (2012)
8. Abbasi, T., Abbasi, S.A.: Production of clean energy by anaerobic digestion of phytomass—new prospects for a global warming amelioration technology. Renew. Sustain. Energy. Rev. **14**, 1653–1659 (2010)
9. Abbasi, T., Abbasi, S.A.: Is the use of renewable energy sources an answer to the problems of global warming and pollution? Crit. Rev. Environ. Sci. Technol. **42**, 99–154 (2012)
10. Patnaik, P., Abbasi, T., Abbasi, S.A.: Extraction of energy precursors in the form of volatile fatty acids (VFAs) from the xerophyte prosopis (Prosopis juliflora), in Siddiqui, N.A., Tauseef, S. M., and Bansal, K., (Eds), Advances in Health and Environment Safety, https://doi.org/10.1007/978-981-10-7122-5, Springer, New York, Chapter 26, pages 1–8
11. Cukor, G., Jurković, Z., Sekulić, M.: Rotatable central composite design of experiments versus Taguchimethod in the optimization of turning. Metalurgija, **50**(1), 17–20 (2011)
12. Tanco, M., Viles, E., Ilzarbe, L., Alvarez, M.J.: Implementation of design of experiments projects in industry. Appl. Stochast. Models. Bus. Ind. **25**(4), 478–505 (2009)
13. Asghar, A., Abdul Raman, A.A. Daud, W.M.A.W.: A comparison of central composite design and Taguchi method for optimizing Fenton process. The Scientific World Journal, (2014)
14. Tasneem Abbasi., Premalatha, M., Tauseef, S.M., Tabassum Abbasi, and Abbasi, S.A.: A Process and a system for eco-friendly and total disposal of date palm waste (DPW). Official J. Pat. Off. **17**, 2412 (2014)
15. Tauseef, S.M., Premalatha, M., Abbasi, T., Abbasi, S.A.: Methane capture from livestock manure. J. Environ. Manag. **117**, 187–207 (2013)
16. Ramasamy, E.V., Abbasi, S.A.: Energy recovery from dairy waste–waters; impacts of biofilm support system on anaerobic CST reactors. Appl. Energy. **65**, 91–98 (2000)
17. Hussain, N., Abbasi, T., Abbasi, S.A.: Vermicomposting-mediated conversion of the toxic and allelopathic weed ipomoea into a potent fertilizer. Process. Saf. Environ. Prot. **103**, 97–106 (2016)
18. Hussain, N., Abbasi, T., Abbasi, S.A.: Toxic and allelopathic ipomoea yields plant-friendly organic fertilizer. J. Cleaner. Prod. **148**, 826–835 (2017)

# Risk and Environmental Assessment of an Indian Industry Through Active Monitoring—Case Study

**Sabari Bhaumik, Santosh Vani, Sarath Chandra and Abhishek Nandan**

## 1 Introduction

The steel fabrication industry deals with fabricating and installing large, small, and various other steelworks relating to the construction industry, process equipment's such as pressure vessels, heat exchangers, storage tanks and piping pertaining to petrochemical industry, oil and gas plants, power plants, cement plants, water treatment plants, material handling equipment's like elevators, conveyors, hoppers, EOT cranes, silos, legged cranes, piping's, handrails, stainless steel tanks, architectural works. Fabrication of steel involves various machineries including shearing, milling, drilling, sand blasting, and painting. The industry as a whole also delivers a significant contribution to the economy. Since the process involves certain risky operations, injury rate is more to the workers and is also considered as the third highest risky industry [1]. The fabricated metal products industry recorded 9.8 injuries and illnesses per 100 workers. The hazards are the results of excessive noise, welding fumes, sandblasting vapors, painting fumes, fall from height, manual material handling, injuries due to handheld tools and injuries due to lack of guards [2]. The aim of any industry is to maintain a safety system and standard that protects both the human and financial sources in the industry. The objective of the recent study is to identify, analyze, and control the potential hazards to people and environment by means of risk assessment and EIA.

S. Bhaumik (✉) · S. Vani · S. Chandra · A. Nandan
Department of Health Safety and Environmental Engineering,
University of Petroleum and Energy Studies, Dehradun, India
e-mail: sabari.1si12cv050@gmail.com

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_19

## 1.1 Raw Material Unloading

Unloading involves manual handling and mechanical handling. Manual handling process has hazards that have potential to cause danger to worker life [3]. The steel fabrication industry involves many different activities that cause danger to the worker. The major health effect due to manual handling is musculoskeletal disorder (MSD) [4]. The various processes contributing to these hazards include raw material handling, packaging, dye handling, and material handling for transportation [5]. Some of the causes of MSD are due to repetitive movement, awkward posture, and lifting undesired load [6]. Workers, who are inadequately trained, unload the materials using manual lever to lift the steel material from the truck or storage area. Safe lifting load to be fixed in mechanical handling to prevent fall of objects or toppling of vehicles. Accidents and injuries can be minimized by using forklifts and mobile cranes inside the premises. Other controls are changing the workplace design and providing proper job rotation and rest [7] (Fig. 1).

## 1.2 Powdered Machinery

Powdered machinery includes grinding, drilling, flame cutting and bending activities. Among the discussed processes, drilling and grinding pose major risk to worker [8]. This occurs when the scrap particles fly as projectiles and affect eyesight, and when the worker is subjected to noise-induced hearing loss due to noisy equipments used for processing [9]. Day-long exposure and continuous exposure to vibrating tools in the machinery result in MSD [10] while flame cutting causes arcing, volatile fumes, and fire. Improving the welding process minimizes the need of grinding. This can be controlled by proper atmospheric monitoring, ensure proper flashback arrestor is fit, enrollment of trained personnel, and appropriate protective clothing.

## 1.3 Welding

The welding process is one of the vital activities for a steel fabrication unit. The process can never be avoided and hence, worker is subjected to health hazards due to inhalation of metal fumes, vapors, and particulate dust. It is necessary to ensure that there is appropriate ventilation [11]. Welding also involves exposure to UV radiation; thus, it is mandatory to use appropriate PPE and face shield. Insufficient ventilation allows hazardous gases to flow through and hence causes health risks. Using auto-darkening helmets, extraction system stops exposure to fumes. Welding booths to separate welding from other activities and the presence of flashback arrestors ensure fire does not occur. Safe system of work should be followed for all high-risk activities.

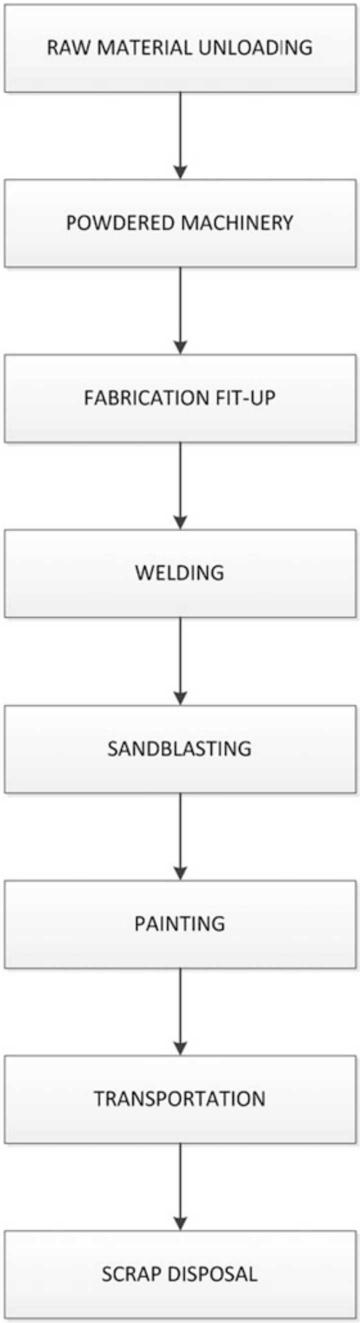



**Fig. 1** Sequence of operations being carried out in a fabrication industry

## 1.4 Sandblasting

Sandblasting or bead blasting is the process of smoothing, shaping, and cleaning a hard surface by forcing solid particles across that surface at high speeds [12]. The effect is similar to that of using sandpaper but provides a finish with no problems at corners. Sandblasting occurs artificially using compressed air. The operation involves high noise and dust emissions which lead to damage to worker performing the activity as well as environmental pollution. The dust emitted from blasting causes lung cancer and asphyxiation if proper control measures are not put in place [13]. Typical safety equipment for blasting operators in a blast room or open air blasting includes helmet or positive pressure blast hood. The helmet should be designed in such a way where it should have a window to see through, a hose with air feeder, and a spring system for easy movement of operator's head. It also includes an air filtrate [14], pressure regulator, and an alarm that detects harmful gases such as hydrogen sulfide and carbon monoxide. Workers are exposed to excessive noise; hence, appropriate ear protection should be worn to control the potential damage. Recommended protections include ear plugs and ear defenders [15]. In order to prevent damage to worker body, suitable body aprons or coveralls should be worn.

## 1.5 Painting

Painting operations include serious concerns such as environmental pollution, i.e., to air, water, and soil, affects worker's health, disposal of expired paint and solvent, contamination [16]. The painting operation carried out at high buildings involves high velocity of wind and hence, there is a possibility of any excess paint spray called as "overspray" [16]. Fumes, vapors coming from paint cause serious health hazards and also causes fire if there is any spillage. Containment of overspray requires screenings. If the conventional methods of painting by means of brushes are carried out, then there is a possibility of potential spillage on nearby workers and vehicles. Safe temperature to paint steel structures is below 40 °F. Storage of hazardous substances like paints and solvents should be according to the manufacturer's information or municipal guidelines [17]. Ensure proper ventilation at the storage premises so that fire hazards can be neglected to a greater extent. There should be proper labeling of paints to provide information to the worker about the expiry date of the substance, its safe use and its potential health effects. Deteriorated paints during storage should be disposed.

### 1.6 Transportation

Steels from high weight to low weight are being moved and transported in the workplace through all the processes mentioned in the process flowchart. Transportation is done using EOT cranes and forklifts [18]. Major hazards in mechanical transportation include failure of any load-carrying equipment and improper slings and clamps leading to fall of material which eventually causes injury to people nearby. This can be controlled by carrying load under safe working limit, use of trained personnel, and appointment of banksman for proper assistance. Usage of trolleys and overhead cranes is an added advantage [19].

### 1.7 Scrap Disposal

The last step for fabrication of steel is scrap disposal which should be disposed as per the guidelines of government. Major hazards of scrap include contamination, slips, fire, etc., thus requires the management to segregate the storage of hazardous waste from normal waste. Even storage area should be away from working area in order to avoid collision with workers and vehicles. Non-biodegradable scraps should be used for recycling [20]. Maintain a separate color code for individual wastes in order to ensure that different scrap materials are not mixed together.

## 2 Methodology

The above processes are to be analyzed for the hazards they may pose and the risk and danger that might occur due to the hazards. The methodology used here to identify them is as follows:

### 2.1 Risk Assessment

Detailed risk assessment is carried out for individual activities. The hazards are first identified, then the people who might be at risk are identified, and then the existing controls in compliance with the local government are identified. Based on the findings, the risk matrix is drawn considering the severity and probability of occurrence for each hazards. The risk matrix is ranked from 1 to 10 for both severity and occurrence.

$$\text{Risk} = \text{Severity} \times \text{Probability of occurrence}$$

Risk matrix is always described in semiquantitative format with severity being denoted as low, medium, high, and extreme. Based on the findings, risk priority number is calculated and priority is given first to the activities that possess extreme danger or high risk along with additional controls given in order to reduce the risk to considerable level. The resultant risk is termed as residual risk. If the risk still remains high, then the entire process has to be changed. Raw material handling involves both manual handling and mechanical handling like load falling from height, entanglement of person between loads, and vehicle toppling over due to improper lifting load. On calculating the risk priority number, this activity posed extreme risk ($9 \times 8 = 72$) which means these hazards result in fatality or lost time accidents; hence, the controls were to be of highest standard to minimize the impact. Controls like providing outriggers for firm support of vehicle, proper lighting, training on safe lifting, proper job rotation, and employment of competent person are implemented. On implementing the controls, the risk was reduced to low ($3 \times 3 = 9$). Powdered machinery involves various activities like shearing, cutting, milling with all posing the risk of fire/explosion, noise, fumes, and projectiles of cut particles pose risk that were extreme ($9 \times 6 = 54$) which might cause huge property damage or fatality. The potential control measures were to wear eye guard, enclosure the machine partially to reduce noise, and store the combustibles separately. The residual risk thus obtained was medium ($2 \times 9 = 18$) which meant continuous supervision was mandatory. Fabrication fit-up involves manual bending of steel structures excluding that there was no such serious risk posed to workers; hence, the risk was medium ($6 \times 5 = 30$) with continuous supervision and training being the most effective controls bringing the risk to low ($3 \times 3 = 9$). Welding involves emission of fumes, fire/explosion due to damaged flash back arrestors, electrocution, and arcing. Since welding happens daily, the risk associated was found to be extreme ($9 \times 7 = 63$). The efficient control measures include using double-insulated cables, atmospheric monitoring to be carried out daily, ensure proper ventilation, and replacement of good quality flashback arrestors thus reducing the risk to medium ($9 \times 4 = 36$). This is true because in high-risk activities, only the probability of occurrence can be minimized not the severity. Sandblasting involves inhalation of huge amount of dust, hazardous waste, health and fire hazards; thus, risk rating was found to be medium ($5 \times 5 = 25$). The effective control measures include testing of pressure vessels and safety valves, blasting carried out in confined area, barricade the area, and ensure appropriate safety equipment are worn thus reducing the risk rating to low ($2 \times 3 = 6$). Painting poses serious health hazards like cancer and asthma due to inhalation of fumes and vapors. The risk rating was calculated to be high ($7 \times 6 = 42$), and controls required were employment of competent person to carry out the activity, appropriate PPE, good housekeeping, and training on safe working methods helped to reduce the risk rating to low ($2 \times 6 = 12$). Transportation involves movement of heavy load out of the workshop for delivery which causes collision of vehicles and vehicles colliding with the workers. The risk was calculated to be medium (6 × 6 = 36) thus controls recommended were sending an escort vehicle, proper communication facility, and pre-startup check to all vehicles to ensure it is in proper condition thus reducing the risk to be low (2 × 3 = 6). The last activity in the steel fabrication industry is disposal of waste which includes spilling of hazardous substance, contamination, fire, and explosion. The subsequent risk rating for the activity was calculated to be high (6 × 7 = 42) and recommended controls, include recycling of waste, segregation of hazardous, and non-hazardous material, follow spill control procedure, wearing appropriate protective equipment and information, instruction and training workers on safe disposal of waste as per municipal guidelines. The residual risk was then calculated to be low (2 × 3 = 6).

| | 1-2 | 3-4 | 5-6 | 7-8 | 9-10 |
|---|---|---|---|---|---|
| **9-10** | | | **H** | | |
| **7-8** | | **M** | | **E** | |
| **5-6** | | | | | |
| **3-4** | **L** | | | | |
| **1-2** | | | | | |

## 2.2 *Environment Aspect Impact Assessment*

The components of activities that interact with the environment are termed as aspect. Any subsequent change to the environmental condition due to the aspect is termed as the impact. The assessment includes separate assessment of each minor activity to analyze if it poses any environmental degradation. The various environmental degradation examples include water pollution, air pollution, noise pollution, land pollution, and natural resource depletion. If the activity poses any of the above risk, i.e., noncompliance of legal regulations, then quantity of polluted substance, probability of occurrence, severity of the hazard, and the necessary control measures are calculated based on the ranking given to them on a scale of 1–5 from very effective to ineffective to find out what other additional controls are required.

The formula used is

$$\text{Risk Rating} = (\text{LC} \times \text{Q} \times \text{P} \times \text{S}) - (\text{C} + \text{M})$$

where

LC is legal compliance,
Q is quantity,
P is probability of occurrence,
S is severity,

C is control measures, and
M is monitoring.

If the rating is positive and is under legal considerations, then a management program should be organized to control the environmental degradation. Legal compliance varies depending on the industry. Quantity is the amount of substance that pollutes the environment due to the activities carried out. Probability of occurrence denotes the likelihood that the environmental degradation occurs and the extent to which it poses danger is termed as severity. Environmental aspect and impact assessment were carried at various locations including office area, raw materials storage area, vehicles operations area, and maintenance area. Each area is divided into sub-activities such as working on computer, using electrical equipment in the kitchen, housekeeping, and clinical waste disposal, movement of trucks, polishing process, painting process, and welding and gas cutting. Sub-activities are analyzed based on the formula mentioned above to find out the necessary actions to be taken. On final observations, it was found that.

## 3 Conclusion

The detailed risk assessment and environmental aspect impact assessment for a steel fabrication industry was being carried out and checked if they were complying with legal regulations. Based on the study, it has been observed and recommended that appropriate corrective actions like hydraulic maintenance of machines, welding and gas cutting, storage of materials, and use of electrical equipment which requires management program as a control method must be taken including management program which includes training to workers on safe working methods, continuous supervision and monitoring, changes to process, and safe disposal methods should be an integral part of safety management system.

## References

1. Choudhry, R.M., Fang, D.: Why operatives engage in unsafe work behavior: investigating factors on construction sites. Saf. Sci. **46**, 566–584 (2008)
2. Smith, L., Deivanayagam, S.: Workspace, equipment and tool design. Work Space Equip. Tool Des. **15**, 113 (2014)
3. Trethewy, R.W., Atkinson, M., Falls, B.: Improved hazard identification for contractors in the construction industry. J. Constr. Res. **4**, 71–85 (2003)
4. Punnett, L., Wegman, D.H.: Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J. Electromyogr. Kinesiol. **14**, 13–23 (2004)
5. Polprasert, C., Liyanage, L.: Hazardous waste generation and processing. Resour. Conserv. Recycl. **16**, 213–226 (1996)
6. Keyserling, W.M., Chaffin, D.B.: Occupational ergonomics-methods to evaluate physical stress on the job. Annu. Rev. Public Health **7**, 77–104 (1986)

7. Spellman, F.R., Bieber, R.M.: Physical Hazard Control: Preventing Injuries in the Workplace. Government Institutes (2011)
8. Forastieri, V.: Children at Work: Health and Safety Risks. International Labour Organization (2002)
9. Speegle, M.: Safety, Health, and Environmental Concepts for the Process Industry. Cengage Learning (2012)
10. Ali, A., Qutubuddin, S., Hebbal, S., Kumar, A.: An ergonomic study of work related musculoskeletal disorders among the workers working in typical Indian saw mills. Int. J. Eng. Res. Dev. **3**, 38–45 (2012)
11. Wisner, B., Gaillard, J.C., Kelman, I.: Handbook of Hazards and Disaster Risk Reduction and Management. Routledge (2012)
12. Moriarty, B.: Occupational Health Hazards: Are You at Risk. ASSE Professional Development Conference and Exposition. American Society of Safety Engineers (2016)
13. World Health Organization.: Environmental and occupational health hazards associated with artisanal and small-scale gold mining (2016)
14. Nishigawa, G., Maruo, Y., Irie, M., Maeda, N., Yoshihara, K., Nagaoka, N., Matsumoto, T., Minagi, S.: Various effects of sandblasting of dental restorative materials. PLoS ONE **11**, e0147077 (2016)
15. Rokni, M., Mohammadyan, M., Hashemi, S.T., Asadi, S.M., Boogaard, P.J., Heibati, B., Yetilmezsoy, K., Abdul-Wahab, S.A.: Risk assessment of workers exposed to crystalline silica aerosols. Human Ecol. Risk Assess.: Int. J. **22**, 1678–1686 (2016)
16. Silcox, S.: Impact of work on health. Occup. Health Wellbeing **68**, 22 (2016)
17. Carson, P.A.: Hazardous Chemicals Handbook. Butterworth-Heinemann (2002)
18. Gumus, A.T.: Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. Expert Syst. Appl. **36**, 4067–4074 (2009)
19. Fischhoff, B., Hohenemser, C., Kasperson, R.E., Kates, R.W.: Handling hazards: can hazard management be improved? Environ.: Sci. Policy Sustain Dev. **20**, 16–37 (1978)
20. Misra, V., Pandey, S.: Hazardous waste, impact on health and environment for development of better waste management strategies in future in India. Environ. Int. **31**, 417–431 (2005)

# Air Pollutant Dispersion Models: A Review

**Shweta Sachdeva and Soumyadeep Baksi**

## 1 Introduction

To predict the behaviour of the pollutants in the air, dispersion modelling plays a crucial role. Air pollution modelling is the term used to describe using mathematical theory to understand or predict the way pollutants behave in the atmosphere. Modelling enables to develop scenarios, test theories and understand the impact under different emission rates. Data such as emission factors, emission rates, sources enable studies to propagate [1].

Primarily, air pollution modelling aids to assess the complete imaginary situation, for instance, the impact of certain modifications in an industrial operation will result in how much changes in air pollution levels, etc. These emission rates can be fed into models, which can simulate real-life scenarios, thus quantifying the levels of pollution and hence what necessary precautionary measures to be adopted [2].

## 2 Mesoscale Air Pollution Dispersion Model

The mesoscale dispersion modelling system was originally developed at the Warsaw University of Technology, Poland. The prime aim of this model was aimed at simulation for the numerical analysis of air pollution dispersion of mesoscale over complex terrain [3]. The land surface is of utmost importance while discussing this form of air pollution dispersion modelling system. The mentioned assumptions are taken into consideration while formulating such dispersion models:

S. Sachdeva (✉) · S. Baksi
University of Petroleum and Energy Studies, Dehradun, India
e-mail: shweta@ddn.upes.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_20

a. Dry thermodynamics.
b. Components of horizontal wind velocity.
c. Virtual potential temperature.
d. Specific humidity.
e. Lateral boundary conditions.

Mesoscale air pollution dispersion modelling emphasizes on soil hydrology established in the Noilhan and Fanton [4].

## 3 Lagrangian Particle Dispersion (LPD) Model

Simulation of atmospheric dispersion can be obtained by tracking a large set of particles. Each particle represents a discrete mass of pollutants [5]. Particles are assumed to be released from multiple emission sources characterized by random geometry [6]. Particles are perturbed by resolvable-scale turbulent velocity components, which can be derived under assumptions in coherence with second-order turbulence applicable for second-order turbulence closure [7].

The Markov chain structures the turbulence of particles, steeply depending on the turbulent velocity at the previous time step and on a random component. The definite time lag utilized to mobilize the particles is determined by the small fraction of the Lagrangian time typically ranging between ($1\ \text{s} < t < 15\ \text{s}$) [6]. The more the value of the time step or an increase in the Lagrangian timescale increases, the particles lose its momentary turbulent velocity and hence the randomness of the particles increases. During the consideration of full random walk scheme, the time step is considered to be constant ($t = 180$ s [6]).

The dispersion phenomenon of heavy particles with an increase in settling velocity will cross the trajectory, thus resulting in autocorrelation with vertical or upward movement. The inertial effect needs to be neglected in that case as discussed in [8].

While discussing the interaction of pollutants with the ground surface, perfect reflection of particles and the trends of disposition of particles, with the consequent absorbing probability, have been studied in Monin [9] and Boughton et al. [10].

## 4 Euler Grid Dispersion Model

The set formulated the K-Theory advection–diffusion equations inclusive of dry deposition or a linear or nonlinear chemical reaction of pollutants [11]. Short-lived species are simulated utilizing pseudo-steady approximation, thus leading to an algebraic equation [12–14].

Equations extrapolated backwards in time with a receptor functions as a source term to calculate influence functions. Specifically, volume or area emission sources are generally simulated using the EGD model [15].

## 5 Source-Oriented and Receptor-Oriented Dispersion Modelling

The source-oriented and receptor-oriented dispersion model emphasizes on complimentary air quality studies. The equation is given by

$$(\varphi C) = \iint RCdtdx = \iint C * Qdtdx \tag{1}$$

The source and the receptor approach are being designated by the first and the second integral, respectively [16, 17]. It is identified as the final goal of dispersion modelling as to be able to calculate the certain concentration of a given receptor [18]. **R** is defined as the receptor geometry.

In the case of the traditional source-oriented approach, this circumscribes around the fact of solving model equations, forward in time for a given source of pollution [19]. This specific model aids in calculation of various air pollution characteristics for given receptors $\varphi$ within a domain. For all practical application, air pollution's receptor is of prime concern. In certain cases too the emission field can be denoted as

$$Q = \sum_i \varepsilon i \delta(X - X1)\delta(Y - Y1)\delta(Z - Z1) \tag{2}$$

Where $X, Y, Z$ denotes the coordinates, and **ei** denotes the emission rates. The average concentration at the receptor may also be denoted as

$$\phi(C) = \sum_i^n ei \int C * [Xi, Yi, Zi(t)]dt \tag{3}$$

## 6 Hybrid Dispersion Model

The hybrid Eulerian–Lagrangian model has been proposed to simulate subgrid scale dispersion close to point-line emission sources [20]. After travelling sufficiently for a long time, the particles are assumed to contribute a volume emission and field and consequently disappear. Hence, the pollution dispersion close to point emission source is simultaneously simulated by Lagrangian model, and for large distances when the plume size is larger, the numerical solution providing vertical diffusion equation is applied.

The condition determining the particle contribution to volume emission field is related to horizontal sigma coefficient since the plume is resolved much faster by vertical grid than in comparison with horizontal grid. The HDM is more efficient than the Lagrangian dispersion model (LDM), as it does not require too many particles to be tracked down.

## 7 Conclusion

Atmospheric dispersion modelling is the scientific recreation of how air contaminations scatter in the surrounding environment. It is performed with programs that understand the numerical conditions and calculations which reproduce the contamination scattering. The scattering models are utilized to appraise the downwind encompassing grouping of air poisons or poisons radiated from sources, for example modern plants, vehicular activity or incidental concoction discharges. They can likewise be utilized to foresee future focuses under particular situations (i.e. changes in discharge sources). Along these lines, they are the predominant kind of model utilized as a part of air quality arrangement making. They are most helpful for poisons that are scattered over expensive separations and that may respond to the climate. For poisons that have a high spatial-transient changeability (i.e. have exceptionally soak separation to source rot, for example, dark carbon) and for epidemiological studies, factual land-utilized relapse models are likewise utilized.

## References

1. Baldasano, J.M., et al.: An annual assessment of air quality with the CALIOPE modeling system over Spain. Sci. Total Environ. **409**(11), 2163–2178 (2011)
2. Abdel-Rahman, R.G.: Group classification of the dispersion equation of gaseous pollutants in presence of a temperature inversion. J. Quant. Spectrosc. Radiat. Transfer **98**(1), 1–17 (2006)
3. Moradpour, M., Afshin, H., Farhanieh, B.: A numerical investigation of reactive air pollutant dispersion in urban street canyons with tree planting. Atmos. Pollut. Res.
4. Lateb, M., et al.: On the use of numerical modelling for near-field pollutant dispersion in urban environments—a review. Environ. Pollut. **208, Part A**, 271–283 (2016)
5. Cécé, R., et al.: Microscale anthropogenic pollution modelling in a small tropical island during weak trade winds: Lagrangian particle dispersion simulations using real nested LES meteorological fields. Atmos. Environ. **139**, 98–112 (2016)
6. Inthavong, K., Tian, L., Tu, J.: Lagrangian particle modelling of spherical nanoparticle dispersion and deposition in confined flows. J. Aerosol Sci. **96**, 56–68 (2016)
7. Vitali, L., et al.: A Lagrangian modelling approach to assess the representativeness area of an industrial air quality monitoring station. Atmos. Pollut. Res.
8. Walklate, P.J.: A random-walk model for dispersion of heavy particles in turbulent air flow. Bound.Layer Meteorol. **39**(1), 175–190 (1987)
9. Monin, A.S.: Smoke propagation in the surface layer of the atmosphere. Adv. Geophys. **6**, 331–343 (1959)
10. Boughton, B.A., Delaurentis, J.M., Dunn, W.E.: A stochastic model of particle dispersion in the atmosphere. Bound.Layer Meteorol. **40**(1-2), 147–163 (1987)
11. Ničeno, B., Dhotre, M.T., Deen, N.G.: One-equation sub-grid scale (SGS) modelling for Euler-Euler large eddy simulation (EELES) of dispersed bubbly flow. Chem. Eng. Sci. **63**(15), 3923–3931 (2008)

12. Arya, S.P.: Air pollution meteorology and dispersion (1999)
13. Stohl, A., et al.: Technical note: The Lagrangian particle dispersion model FLEXPART version 6.2. Atmos. Chem. Phys. **5**(9), 2461–2474 (2005)
14. Zannetti, P.: Air Pollution Modeling: Theories, Computational Methods and Available Software. Springer Science & Business Media (2013)
15. Stohl, A., Hittenberger, M., Wotawa, G.: Validation of the Lagrangian particle dispersion model FLEXPART against large-scale tracer experiment data. Atmos. Environ. **32**(24), 4245–4264 (1998)
16. Uliasz, M., Pielke, R.A.: Application of the receptor oriented approach in mesoscale dispersion modeling. In: Air Pollution Modeling and Its Application VIII, pp. 399–407. Springer (1991)
17. Hopke, P.K.: Recent developments in receptor modeling. J. Chemom. **17**(5), 255–265 (2003)
18. Vardoulakis, S., et al.: Modelling air quality in street canyons: a review. Atmos. Environ. **37**(2), 155–182 (2003)
19. Nehrkorn, T., et al.: Coupled weather research and forecasting–stochastic time-inverted lagrangian transport (WRF–STILT) model. Meteorol. Atmos. Phys. **107**(1–2), 51–64 (2010)
20. Andrén, A.: A meso-scale plume dispersion model. Preliminary evaluation in a heterogeneous area. Atmos. Environ. Part A. Gen. Top. **24**(4), 883–896 (1990)

# Application of Sustainable Solar Energy Solutions for Rural Development—A Concept for Remote Villages of India

**Shivakshi Jasrotia, Arun Kansal, Madhuben Sharma and Swati Gupta**

## 1 Introduction

Approximately 50% of the world's population lives in rural areas. Another fact also brings about the information that the rural population exceeds 70% of the country's population, especially in low- and middle-income countries. In many countries, the share of rural GDP is much more than that of urban GDP; however, in terms of quality of life, the rural population is far behind than that of the urban population and lacks access to basic services such as electricity, water supply, transport, sanitation [1]. Water is a basic necessity of life, and the provision of potable drinking water is a prime priority for improving health of rural and poor sectors of Indian society. As per the report of UNICEF in 2001, nonavailability to potable drinking water resulted in nearly 1.5 million losses of lives of children with 37.7 million yet affected [2]. In rural areas, the groundwater or earmarked surface water

S. Jasrotia (✉)
Centre for Global Environmental Research, Earth Science and Climate Change Division, The Energy and Resources Institute (TERI), IHC Complex, Lodhi Road, New Delhi 110003, India
e-mail: shivakshi_jasrotia@yahoo.com

A. Kansal
Coca-Cola Department of Regional Water Studies, TERI University, Vasant Kunj, New Delhi 110070, India
e-mail: akansal37@gmail.com

M. Sharma
Department of Environment Sciences, University of Petroleum and Energy Studies (UPES), Dehradun, India
e-mail: madhubensharma06@gmail.com

S. Gupta
TERI University, New Delhi 110070, New Delhi, India
e-mail: swatiboond71@yahoo.co.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*, Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_21

has been considered to be safe for public water supplies. But recent times, enough evidences have brought out the fact that present groundwater is becoming increasingly contaminated with elevated concentrations of heavy metals. Also, it is a known fact that worldwide, nearly 1.0 billion people remain without access to electricity and 2.9 billion are still cooking on harmful and inefficient stoves. Easy management and disposal of domestic wastewater is another key issue for rural residents. Many rural residents still live in the remote rural locations, and until they have access to energy services, little progress can be made to develop and improve their lives.

In India, one such village which lacks all the above-mentioned basic amenities is Kaudikasa. Figure 1a shows the location of the village located in Rajnandgaon, a district of Chhattisgarh, India. Figure 1b shows the dry location where there exists some local, seasonal ponds for fishing, bathing and washing, etc. The other common practices for using local water are for both cooking and drinking. As per the 2011 census, 400 households (HH) are present where the population count was 1970 [3]. The average shows around 5–6 members lived together in each household. The village does not have a very high literacy rate with nearly one primary and one secondary school opened a few years ago.

The housing style included both "*Kacha* and *Pakka*" houses. Locally available bricks and mud tiles were used for construction of *Pakka* houses. *Kacha* houses were constructed using mud, grass and bamboo. The figures reflect the real situation where ample space is present on both house roof and on the ground area. Figures 2a and 2b show the roof structures and village drainage system which are not that well maintained. Nearly 6.1 mg/L arsenic has been found in the village. The numbers of groundwater hand pumps, open dug wells, pond in the village were 6, 2 and 1, respectively [4]. About 110 people are currently suffering from arsenic-related diseases such as keratosis (skin burning and irritation blackening of skin) paralytic attacks and early greying of the hair due to drinking this unsafe water [4]. Very recently a piped water supply scheme has been implemented by PHED, Rajnandgaon. Also, four neighbouring houses share a common tap.

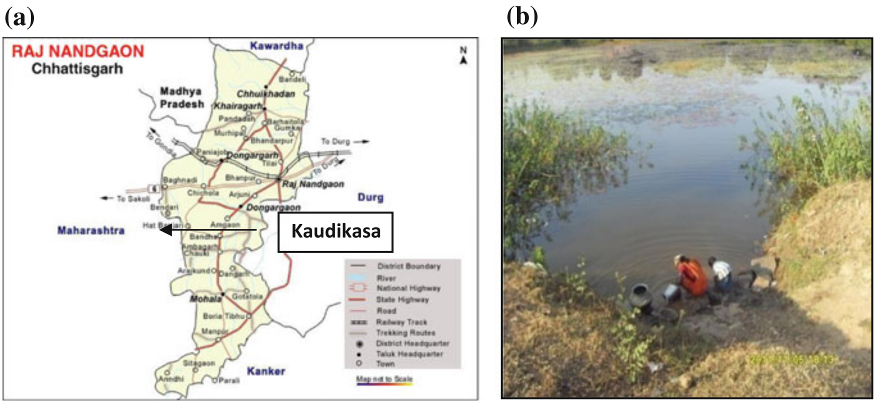



**Fig. 1** **a** Map of Rajnandgaon (Kaudikasa location) and **b** local usage of pond for cleaning

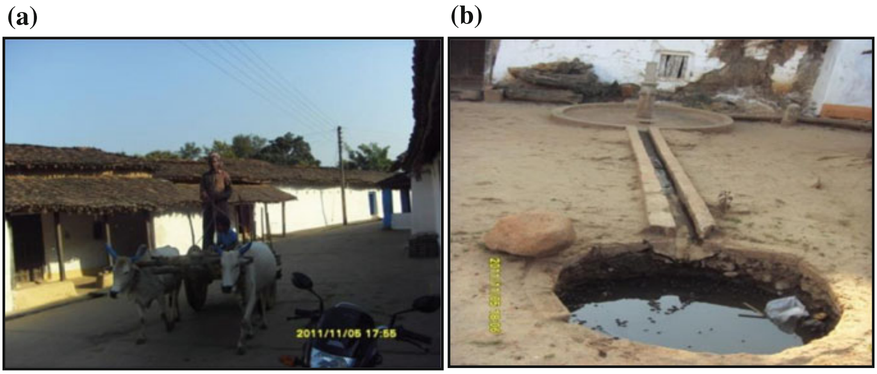



**Fig. 2** **a** Kacha–pakka house (Kaudikasa village) and **b** common drainage of hand pump water

There exists a wide range of available solutions for above-mentioned drinking water and sanitation issues, but with their own set of limitations on the front of long-term sustainability. For instance, like water treatment methods applied today for the purpose of drinking water supplies conventionally require energy-intensive technologies such as coagulation, filtration and flocculation. The treatment technologies include ion exchange, electro dialysis, ultra-filtration, which are not only dependent on a reliable supply of grid electricity supply but are also expensive and require skilled operators. But such technologies are not economically viable in rural areas and are found to be deficit in terms of reliable power supply as well as per capita income. Another health impact issue is the using the conventional cook stoves. Many rural household females still rely on conventional cook stoves for cooking, which risking their health in many forms [5].

Therefore, innovative approach for sustainable management of water, sanitation and other important issues like alterative safe and healthy cooking practices is required in rural areas. The innovative approach should also consider the local custom and environmental conditions so as to provide a long-term and reliable solution. One such approach is harnessing solar energy for this purpose. For a country like India, which is blessed with ample amount of sunshine, i.e. about 5000 trillion kWh of solar energy annually, relying on solar energy is upcoming frontline of research as new initiatives. Not only does it uses the naturally present solar flux, but also promotes the independency of local villagers to smarter green technologies. These technologies and systems that are more cost-effective, natural, grid free, sustainable, bear less operation and maintenance cost and can be used by both males and females of the family [6]. The solar energy on earth is most efficiently tapped in two forms which solar energy as heat (thermal capturing) and solar capturing through biomass production (photon or radiation capturing).

The following study brings forth the application of solar energy as an alternative for producing safe drinking for per capita basis, as per the set drinking water standards of BIS and WHO. This paper presents the results obtained by using solar energy in the form of solar still for water treatment. Also, the study concludes the smart rural household concept, schematic with various solar-energy-dependent solutions such as solar cooker, solar panels for generating power and solar lanterns. The study also relates solar-flux-dependant phyto-pond for remediation of wastewater for rural sanitation and further irrigation usage.

# 2 Methodology for Drinking Water Quality Evaluation

## 2.1 *Experimental Set-up for Drinking Water Treatment by Solar Distillation Unit*

Performance evaluation was done on a plastic-type solar distillation unit (Fig. 3) for a period of one year in 2011. The dimensions of the solar still were 1 $m^2$ (length = 1 m, width = 1 m,) and have a glass top of thickness 4 mm with tray capacity of 40 L. The basin was made of black fibre with inlet and outlet ports made of stainless steel to avoid corrosion and rust. East-to-west direction is the most stable direction for unit alignment with the glass cover panel in the north-to-south direction which produces a maximum yield of distillate. The still was operated on batch mode where spiked water samples were loaded /introduced into the unit on every 10th-day basis. This system was placed at 8.6° tilt angle, and a daily yield of 1.5–3.5 L approximately was collected in the collector box positioned at bottom of still. A total of six batch run for three different samples were conducted where in each batch, water remains in the tray for 10 days. Evaluation efficiency was based on various types of input waters used.

**Fig. 3** Single basin-type solar still with distillate collector

**Table 1** Sample preparation

| S. No. | Sample | Source | Location | Additional information |
|---|---|---|---|---|
| 1 | S1/GW | TERI university | New Delhi | Used for preliminary trials |
| 2 | S2 | Simulated sample | Prepared in TERI university laboratory | Rich in arsenite salts |
| 3 | S3 | Simulated sample | Prepared in TERI university laboratory | Rich in arsenate salts |
| 4 | S4 | Simulated sample | Prepared in TERI university laboratory | Rich in arsenate + arsenite |
| 5 | S3 + 5 | Simulated sample | Prepared in TERI university laboratory | Rich in Arsenite + Arsenate +Fluoride + Fe + Nitrate and coliforms |

The experiments pertaining to the study were conducted in a research laboratory in New Delhi, India. Five different inlet samples were simulated in the laboratory which resembled the groundwater conditions found in arsenic- and fluoride-affected Kaudikasa village (Table 1). Samples 2, 3 and 4 consisted of arsenite and arsenate. Sample 5 consisted an elevated % of salts such as total arsenic, iron, fluoride and nitrate as per the ranges found across affected locations. Different samples that were used in the still are listed below:

Spiked samples with variable concentrations were loaded in the basin for a 10-day study and further evaluation. Distillate was recovered from unit on a daily basis, and various water quality parameters were checked. Nearly 50 samples of distillate have been analysed for parameters such as TDS, arsenic, pH, iron, fluorides, nitrates, sulphates, total coliform. Standard method references have been used for analysis of parameters [7].

## 3 Results for Solar Still Investigations for Rural Domestic Water Supply

Figure 4 represents the results of study and in comparison to the limits of WHO standards the quality of outlet—treated water. It shows comparisons between initial values of TDS and hardness to their distillate qualities. The TDS which ranges from 1200–1300 mg/l was lowered down to nearly 30–60 mg/l. The residual had only 2.5% of the initial TDS load remaining in the basin, with no odour emissions. Similarly, initial chlorides with a range of 270–500 mg/l were lowered to 9–13 mg/l in distillate, i.e. 2.6% was found in brine residue. Similar, a decrease was also found in the initial concentration of sulphates, arsenic, pH, nitrates and iron. Throughout the experiment, pH of distillate was between 7 and 7.3.

Based on drinking water guidelines by WHO for drinking water quality, the level of nitrates should be below 50 mg/l, arsenic should be below 0.01 mg/l, and

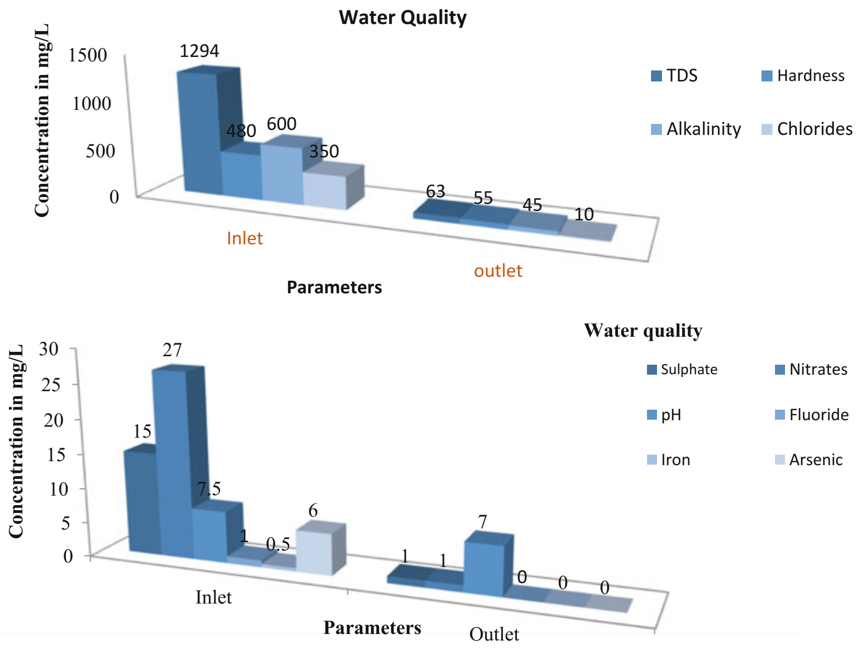



**Fig. 4** Comparison between inlet and outlet water quality parameters

fluoride should be below 1.5 mg/l. The values for all the health-based parameters for distillate fall well as per the listed WHO standards. In terms of drinking, some fluoride salts may be added to the distillate as the distillate water is deficient in fluoride concentration. Another important health-related concern is the presence of *coliforms* in the drinking water. As per the WHO standard, safe drinking water should not have coliform in any 100 ml of sample. This was not found in any of the samples of distillate water analysed (Table 2).

## 3.1 *Feasibility Study for Adoption of Solar Distillation Technology for Kaudikasa Village, Rajnandgaon*

The benefits of the usage of the solar still distillation unit were discussed with the community people. It was found that the technology was found to have high acceptance as it would help provide safe drinking and cooking water, and the solar distillation can be easily installed on the rooftop or above the ground [4]. This system for treatment of brine and kitchen waste could further be attached to phyto-pond with hyperaccumulator plant species [8]. The Public Health Engineering Department (PHED) also found that the concept and the implementation are highly acceptable and were ready to extend support for the same. It is

**Table 2** Comparison of distillate water quality with drinking water standards (Jasrotia et al. 2015)

| S. No | **Parameter** | **Outlet average** | **WHO limits** (mg/L) | **Remarks** |
|---|---|---|---|---|
| 1 | pH | 7.14 | 6.5–8.0 | No post-treatment polishing is required |
| 2 | TDS | 45 | 600 | No post-treatment polishing is required |
| 3 | Arsenic | <0.01 | 0.01 | No post-treatment polishing is required |
| 4 | Alkalinity | 38.3 | Not defined | No post-treatment polishing is required |
| 5 | Hardness | 33.8 | 200 | No post-treatment polishing is required |
| 6 | Sulphate | 0.72 | 250 | No post-treatment polishing is required |
| 7 | Fluoride | 0.02 | 1–1.5 | Requires addition of fluoride salts |
| 8 | Chlorides | 10.8 | 251 | Requires addition of fluoride salts |
| 9 | *T.coli* | NA | Should not be detectable in any 100 mL of sample | No post-treatment polishing is required |
| 10 | Iron | 0.00 | 0.3 | No post-treatment polishing is required |
| 11 | Nitrates | 0.74 | 51 | No post-treatment polishing is required |

estimated that the daily drinking water and wastewater treatment using the proposed unit would require a capital investment of Rs 68,795 (Jasrotia et al. 2013). Therefore, it is estimated that a total cost of INR 2,75,18,000 will be required for setting up the solar distillation technology for the village which has approximately 400 households.

For a village in Chhattisgarh (Kaudikasa) where approximately 5–6% of the total population is suffering from arsenic- and/or fluoride-related medical conditions, such a treatment system would be a good and easily affordable initiative. Replicability in other affected regions also could be aimed once this is implemented. It is expected that access to clean drinking water and better sanitation will result in improved health of many rural residents. The initiative will significantly improve the lives of women and children who have to travel 3−5 km daily to bring water. The time saved by the women and children will give them the opportunity to engage in educational activities and especially women can engage in some employment [4].

Figure 5 shows a schematic for the final set-up of the system, which can be installed at household level and can be easily scaled to community level. Other than

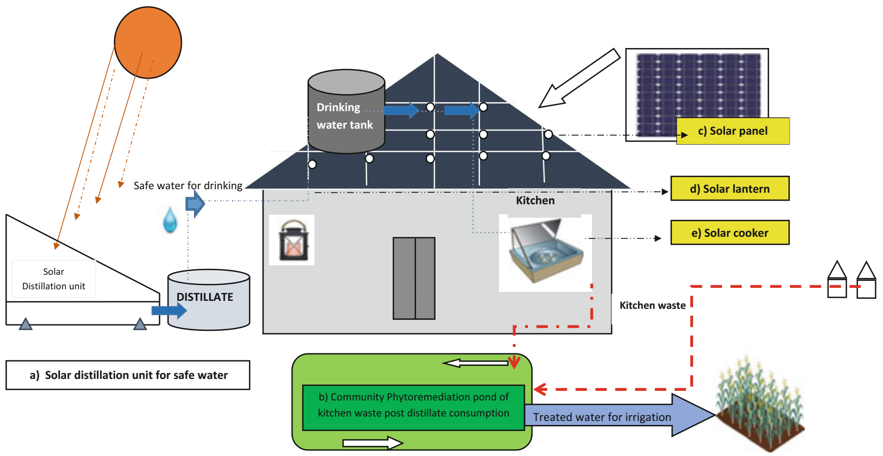



**Fig. 5** Schematic for utilization of solar energy solutions for rural household

solar distillation unit, more renewable energy concepts such as the addition of solar cookers, solar lanterns and solar panel could also promote the development of rural front.

## 4 Conclusion

### *4.1 Application of Solar Distillation and Phyto-pond for Domestic Water Supply*

Various controlling parameters such as depth of water in the still, input water quality, solar radiation intensity were studied to optimize the performance of a solar still. The performance of the system was studied by varying the parameters such as nitrates, fluorides and arsenic using stock solutions. Other parameters such as pH, alkalinity, hardness, chlorides and sulphates which have an influence on the solubility of various metals including were also simultaneously studied. Sewage water was added to the feed water to gauge the pathogen removal potential of solar still. A number of trials were run over a period of two years.

It was found that the solar still has very high treatment potential. The removal efficacy for the pollutant (arsenic) is more than 97%. The treated water was free from pathogens. Coliforms and the other remaining parameters meet the drinking water standards set by WHO [8]. The treated water was found deficient in essential salts, and therefore, some salts have to be added to the distillate for drinking purpose. The added salts were in accordance with the current requirements as per drinking water quality standards—1.5 mg/L of fluoride, 240 mg/L of chlorides, etc. [9].

This study was aimed towards the global efforts in addressing the problem of heavy metal and pathogen-free clean water supply which is a major concern in many parts of the world. This study and its results do strive to make a contribution. This could be termed as a novel approach against other arsenic treatment as it is a simple concept which is easy to operate and does not need skilled labour. This does not need any electrical power and it majorly runs on direct sunlight.

As rural locations have ample sunlight and space, this could be a safe solution in upcoming time.

## References


1. Food Consumption and Nutrition Division: Rural and Urban Dynamics and Poverty: Evidence from China and India discussion paper 196, (electronic resource). http://www.ifpri.org/sites/default/files/pubs/divs/fcnd/dp/papers/fcndp196.pdf (2005). Accessed 14 Oct 2012
2. United Nations International Children's Emergency Funds. Report on safe drinking water. Electronic resource. http://www.unicef.org/specialsession/about/sgreportpdf/03_SafeDrinkingWater_D7341Insert_English.pdf (2001). Accessed 14 Oct 2012
3. Census available at http://www.census2011.co.in/data/village/441650-kaudikasa-chhattisgarh.html (2011). Accessed 13 June 2012
4. Jasrotia, S., Kansal, A., Kishore, V.V.N.: Application of solar energy for water supply and sanitation in arsenic affected rural areas a study for Kaudikasa village, India. J. Clean Prod. **37**, 389–393 (2012)
5. Arora P., Jain S., Sachdeva K.: Physical characterization of particulate matter emitted from wood combustion in improved and traditional cookstoves. Energy for Sustain Dev. 497–503 (2013)
6. Arjunan TV., Aybar HS., Nedunchezhian N.: Status of solar desalination in India. Renew Sustain Energy Rev. **13**, 2408–2418 (2009)
7. APHA, AWWA, WEF.: Standard Methods for Examination of Water and Wastewater, 20th edn. New York (1998)
8. Jasrotia, S., Kansal, A., Mehra, A.: Performance of aquatic plant species for phytoremediation of arsenic-contaminated water J. Appl. Water. Sci. (2015). doi:10.1007/s13201-015-0300-4
9. World Health Organization: Guidelines for Drinking—Water Quality (electronic resource): Incorporating 1st and 2nd addenda. vol 1. Recommendations—3rd edn. (2008)

# Biological Monitoring of Water Quality Before and After Completion of the Hydroelectric Project on the River Alaknanda at Srinagar

**Prakash Nautiyal, Mansi, Neetika Sharma, Pankaj Kumar and Deepak Singh**

## 1 Introduction

Dam building is acknowledged as to cause the most substantial human impact on riverine ecosystems [1]. The ecological effects of river regulation are scarcely known in India. The EIA studies only assess the impacts, but none has bothered to verify these claims and to document the actual changes. A recent cumulative impact assessment is one such document that assesses the impacts of existing, under construction and proposed hydro-projects in the Alaknanda and Bhagirathi Basins [2]. In view of the paucity of such information, a short-term study was carried out to see the impact of R–O–R hydro-project on the River Alaknanda. There are two major hydroelectric projects on the River Alaknanda: at Vishnuprayag in the headwaters and at Srinagar in the lower stretch, ca 30 km upstream of its confluence with the Bhagirathi at Devprayag.

The 330 MW AHPCL hydroelectric project at Srinagar was commissioned in 2014. Since then, the section between dam and power house is characterized by sparse discharge, which has led to disappearance of the riffles and occurrence of algal blooms in certain riffles and pools. This stretch of the river now witnesses some large-scale mining. Motor bridge construction near earlier incomplete structure is also a source of direct interference with river. In view of the above facts, the modified section of the Alaknanda between dam and the power house was subjected to biological monitoring using epilithic diatoms and macroinvertebrates.

**Electronic supplementary material** The online version of this chapter (doi:10.1007/978-981-10-7122-5_22) contains supplementary material, which is available to authorized users.

P. Nautiyal (✉) · Mansi · N. Sharma · P. Kumar · D. Singh
Department of Zoology & Biotechnology, Hemvati Nandan Bahuguna Garhwal University, Srinagar 246 174, India
e-mail: lotic.biodiversity@gmail.com

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_22

Continuous sampling of water chemistry is usually too expensive to be practical, and periodic sampling may not detect episodic pollution. Benthic communities are continuously exposed to water quality, and their responses to pollutants are often cumulative over the life of a cohort. Benthic assemblages can be widely used in place of or to complement chemical monitoring of water quality [3]. Thus, diatoms and invertebrate-based indices are able to detect both episodic and cumulative releases of chemicals [4, 5]. Community structure used to assess biological conditions in streams because it is the result of both long-term environmental factors and short-duration conditions [6]. Diatoms and benthic macroinvertebrates have been used widely for bio-monitoring of aquatic ecosystems [7] and seem to be more suitable for indicating organic pollutions [8, 9].

The present state of the River Alaknanda has been compared with past physicochemical features and benthic diatom and macroinvertebrate assemblages to know the kind of change that has occurred due to reduced discharge in the river. The proposed study will contribute to our knowledge of communities found in modified discharge and help in enhancing the use of diatoms and macroinvertebrates as indicators of HEP impacts.

## 2 Study Area

The stretch between the dam (near Sweith) and the power house (Kilkileshwar before Naithana bridge) extends from 30°13′36.61″ to 30°13′41.01″N latitude, 78°47′11″ to 78°49′04″E longitude bordering Srinagar along NH 58 (Fig. 1). Two sampling stations were selected in this stretch, Station S1 (541–544 m asl) near the Srikot and Station S2 (535–537 m asl) near the Chauras pedestrian bridge. Each station was sampled in pool and riffle habitats. A reference riffle located little before S2 was also sampled because of its riffle-like appearance, despite less discharge. It was sampled to compare its community composition with zones that were riffle in the unregulated river. S1 is located on the left bank of River Alaknanda close to Shiva temple. Human interference occurs in the form of cremation rituals, discarded worship material. Large-scale mining of building material is done in this segment of the river. The substrate is largely sandy with large boulders, gravel, and pebbles. In pool habitat, riverbed was dominated by silt followed by gravel. The vegetation is comprised of trees, shrubs, and *Lantana*. S2 is located on the right bank. Silt is dominant in pool followed by rocks. In riffle, the riverbed was dominated by boulders, gravel, and pebble, respectively, in order of decreasing abundance. Algal blooms occurred in this area. This site is heavily disturbed due to extensive large-scale mining post-2013 flood and motor bridge construction since last many years. Vegetation is primarily a plantation. Flow was sluggish at both stations.


**Fig. 1** Terrain map showing sampling locations in the stretch of River Alaknanda between dam and power house (PH). Acronyms used in the figure; S1P—Station 1 Pool; S1R—Station 1 Riffle; S2RR—Station 2 Reference Riffle; S2R—Station 2 Riffle; S2P—Station 2 Pool

## 3 Materials and Methods

The present investigations on the physicochemical features, benthic diatom, and macroinvertebrate assemblages were carried out at monthly intervals in the months of November, December, January, February, March, and April during 2015–2016. Care was taken to compare past data on these aspects for same months. Samples of benthic communities were collected from pool and riffle habitats at each location. The following physicochemical characteristics of surface water were analyzed and recorded according to standard method outlined in [10] and [11]: water temperature, current velocity, pH, free carbon dioxide, total alkalinity, dissolved oxygen, phosphate, and nitrate (mg $l^{-1}$).

**Benthic Assemblages**

**Diatoms:** The diatoms were collected from sand at pools and cobbles at riffle by scraping 3 × 3 $cm^2$ area with the help of razor and brush. Samples were treated with HCl and $H_2O_2$. The processed material was mounted in Naphrax. Each slide was examined under a BX-40 Trinocular Olympus microscope to perform species count till 250 taxa were counted and recorded. Species were identified according to the standard literature [12–15]. Counts were used to obtain relative abundance (as %) to determine the dominants of the assemblages.

**Van Dam ecologic values**: These were computed from species count to determine the water quality and ecological state of the diatom community in the perturbed section of the river. OMNIDIA software was used to analyze the water quality through Van Dam ecologic values along with Louis Leclercq index.

**Benthic macroinvertebrates**: Five quadrats were laid in different substrates and flow conditions in this stretch. Sampling procedure involved lifting stones (boulder, cobble, pebble, gravel) and sieving clay and silt from 0.09 $m^2$ area. Only those organisms visible to the naked eye were collected. These were transferred to a plastic container and preserved in 5% formalin solution and taken to the laboratory. Identification and counts were carried out to the family level, in the laboratory with the help of keys [16]. Counts were used to obtain relative abundance (as %) to determine the dominants of the assemblages.

**Biological monitoring working party (BMWP):** BMWP scores were calculated for each month using families of macroinvertebrates as biological indicators. A BMWP score >100 indicates good water quality and <10 heavily impacted [17].

## 4 Observations

Comparison with past physicochemical data of the Alaknanda River reveals increase in water temperature while decrease in current velocity and DO; past WT 9–16.5 °C, CV 55–80 cm $sec^{-1}$, DO 11–14 mg $l^{-1}$ present WT 12–18 °C, CV 1.67–82 cm $sec^{-1}$, DO 7–10.4 mg $l^{-1}$ (Appendix 1a, 1b[1]).

**Diatom Assemblages:** *C. laevis*—*A. linearis* assemblages recorded earlier were replaced by *A. minutissimum*-dominated assemblages occurred intermittently in most of the riffle and pool habitats in the impacted section. Other dominants not recorded earlier also formed assemblages.

The Van Dam ecological value shows that the diatom community of the River Alaknanda comprised of alkaliphilus (pH) taxa at both stations but circumneutral in the reference riffle and pool at S2. In respect of salinity, fresh brackish conditions prevailed. The N-autotrophic taxa tolerating very small concentrations of organically bound nitrogen occurred at all riffles and pools except elevated concentrations of organically bound nitrogen dominated the assemblages which were maximum at S1P. The $O_2$ high conditions occurred at all the stations being maximum at S1R. The β-mesosaprobic state at all stations except oligosaprobic at S2RR and S2P shows increased saprobity and hence organic pollution. The trophic state varied from indifferent state at S1P and S2R; eutraphentic condition at S2RR, while mesotrophic condition at S1R, an indication of deterioration in the trophic state. Moisture conditions at most locations were ‘mainly occurring in water bodies, also rather regularly on wet and moist places.’ Moisture state, ‘never or rarely occurring outside water bodies’ was recorded only at S2RR (Appendix 2[2]). The Leclercq index shows degradation and organic pollution at S1, which declined at S2.

**Benthic macroinvertebrate assemblages:** In past, the invertebrate assemblages were primarily dominated by *Simuliidae* (December, February, April),

[1]supplementary data for online viewing only

[2]supplementary data for online viewing only

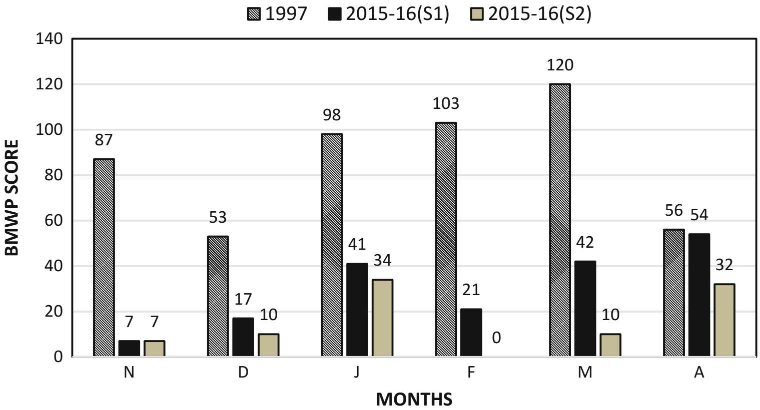



**Fig. 2** BMWP scores for the period before (1997) and after the completion (2015–2016) of the hydroelectric project at Srinagar on the River Alaknanda. Acronyms N—November, D—December, J—January, F—February, M—March, A—April

*Ephemeridae* during November, *Psephenidae* during January, and *Chironomidae* during March. In contrast, the present assemblages at S1 were dominated by Chironomidae continuously (November–January, April), Tipulidae in February while Chironomidae and Limnephilidae during March. At S2, Chironomidae dominated during December, January, and March, Tipulidae during November, none during February while Heptageniidae during April.

The monthly BMWP score in past varies, indicating moderately impacted during December and April (53, 56), slightly impacted during November and January (87, 98), and unimpacted water quality during February and March (103, 120). The present scores were much lower than past (Fig. 2). At S1, score shows heavily impacted quality in November (7), impacted during December and February (17, 21), and moderately impacted in January, March, and April (41, 42, 54). At S2, highly impacted state occurs during November, December, February, and March (7, 0, 10), while impacted during January and April (34, 32). Pooled BMWP score in past indicated unimpacted water quality (126) while in present a moderately impacted quality (69 at S1, 43 at S2).

## 5 Discussion

Among the freshwater bodies, rivers are highly interactive systems, the ecological integrity of which depends on events occurring beyond the channel boundaries and human activities disrupt the natural pattern of temperature, discharge, water chemistry, organic resources, and habitat heterogeneity along longitudinal profiles [18]. Human activity has caused a wide range of impacts upon river ecosystems with, perhaps the most far reaching being the modification of river channel form and discharge, resulting in loss of lateral diversity and channel-riparian connectivity [19]. Construction of dams is considered to be one of the greatest stresses affecting the integrity of running waters [20], because it can interfere or even stop the transport of sediment and nutrients along waterways and eventually disturb ecological connectivity, which underpins the transfer of materials and products of ecological functions and processes [21]. An impoundment, a barrage or a dam impacts the river ecosystem by altering the flow regime. Flow is a major determinant of physical habitat and in turn biotic composition [22]. Complex interaction between flow and the physical habitat governs the distribution, abundance and diversity of the stream and river organisms [23]. Areas below dams are subjected to both daily and seasonal fluctuation as a result of dam operation [24], which can change the natural conditions, as visible in the river stretch impacted by this dam. Changes in the physical, chemical, and biological conditions may result in changes of species composition, species richness, and trophic structure, number of top carnivores and omnivores, and shifts from specialized to generalized behaviors.

**Physicochemical environment of the regulated river:** The WT has increased, while CV and DO have declined due to decreased discharge below the dam. Due to negative relationship between DO and WT [25], increase in WT has resulted in lower DO concentrations. During present study, the pH was acidic (6–6.9) in the pools while neutral to alkaline (7–7.6) in most of the riffles. The free $CO_2$ and total alkalinity levels were not affected. The phosphate and nitrate content was low in this stretch, but comparatively higher in pools and riffles at S1 and S2 than the reference riffle, which correlates with algal blooms observed in these habitats.

**Biological monitoring:** The diatom assemblages demonstrate unstable river ecosystem as the epilithic diatom assemblages varied from month to month. This is in contrast to the earlier observations as *Cymbella laevis* Naegeli in Kützing—*Achnanthidium linearis* (W. Smith) Grunow assemblages (epilithic) were recorded from November to February and *A. linearis*—*Cocconeis placentula* var. *euglypta* (Ehrenberg) Cleve during March and only *A. linearis* in April. The epiphytic diatom community assemblage comprised *D. anceps* (Ehrenberg) Kirchner—*A. linearis* and *C. placentula* var. *euglypta* [26, 27].

The Van Dam ecological value shows that the diatom assemblage of the River Alaknanda generally comprised of circumneutral/ alkaliphilus, fresh brackish, N-autotrophic-sensitive/tolerant, $O_2$ continuously high, oligosaprobic to β-mesosaprobic taxa. There was more variation in trophic and moisture state. The trophic state relates well with intermittent supply of nutrients attributed to variations in the flow. The moisture state is also related to the increase and decrease in the water levels as a result of regulation. Thus, the substrate that was submerged sometime back and exposed during sampling will harbor an assemblage comprising diatom taxa that can live in both conditions in contrast to RR where continuously submerged substrate will mostly harbor taxa that are strictly aquatic. The Leclercq index ranged from non-existent to presence of degradation and organic pollution. The lack of uniformity vis-à-vis variability in the stretch under examination points to an unstable ecosystem in contrast to an unregulated Mandakini River that contains alkaliphilus, fresh brackish, N-autotrophic-tolerant, $O_2$ continuously high, and oligosaprobic taxa, reflecting a more stable ecosystem except variability in moisture and trophic state. Organic pollution was non-existent all along the River Mandakini. Degradation was low at all stations [28].

The macroinvertebrate assemblages have also changed as Simuliidae dominated even though intermittently in 3 months while Ephemeridae, Psephenidae, and Chironomidae in other 3 months. In contrast, the assemblages between dam and powerhouse were largely dominated by Chironomidae. Heptageniidae, a rheophilic form dominated during April only. The BMWP score is used to categorize water bodies [29] according to the sensitivity of taxa to oxygen depletion as such it is widely used in running water to assess water quality—the premise being that pollution increases BOD (biological oxygen demand) and therefore reduces available oxygen and so eliminates the more sensitive taxa progressively. The higher the score for each family, the greater its sensitivity to oxygen depletion and so higher the site score, the 'better' the water quality. The BMWP scores clearly reveal a decline in water quality from moderately/slightly impacted/unimpacted in past to heavily/ impacted/moderately impacted after the completion of the hydroelectric project.

The hydroelectric project has certainly altered the benthic diatom and macroinvertebrate assemblages as more tolerant taxa have replaced the sensitive dominants. The diatom communities in the impacted section indicate deterioration in trophic state, increased saprobity, more organic pollution, and hence degradation, which correlates with the dominance of *Chironomidae* and impacted water quality indicated by macroinvertebrates. The diatom assemblages were dominated by *A. minutissimum*, as also observed in the regulated section of the Ganga below Bheemgoda barrage [30] attributed to its tolerance to variety of stressors (hydrologic disturbance, low pH, heavy metals) [31], which explains its dominance in downstream sections of dam/barrage. However, the macroinvertebrate assemblages downstream of the Bheemgoda barrage were dominated by sensitive taxa *Heptageniidae* in the regulated section of the River Ganga [32], suggesting that the macroinvertebrate community was not badly affected by regulation. The benthic macroinvertebrate assemblages may have been badly affected in early phase of barrage's existence. Possibly these sensitive taxa adapted to the altered conditions as this barrage is ca 100 years old. Besides, diatoms by virtue of being at the base of trophic structure of the ecosystem are more sensitive to changes in the water chemistry, especially the nutrients, the availability of which gets inhibited by the diminished quantum and hindrance to the flow in a river. Beyene et al [33] opine that diatoms by virtue of their immobility and ubiquity (i.e., at least a few can be found under almost any condition) are powerful bio-indicators for monitoring urban-impacted and seriously stressed rivers and to examine pollution gradients and impacts of specific pollution sources where macroinvertebrates are completely absent or less diverse.

**Acknowledgements** The authors are thankful to the Head, Department of Zoology & Biotechnology, H.N.B. Garhwal University, Srinagar, for extending all facilities during the present study.

## References

1. Dynesius, M., Nilsson, C.: Fragmentation and flow regulation of river systems in the northern third of the world. Science **266**, 753 (1994)
2. Rajvanshi, A., Roshni, A., Mathur, V.B., Sivakumar, K., Sathyakumar, S., Rawat, G.S., Johnson, J., Ramesh, K., Dimri, N.K., Maletha, A.: Assessment of Cumulative Impacts of Hydroelectric Projects on Aquatic and Terrestrial Biodiversity in Alaknanda and Bhagirathi Basins. Wildlife Institute of India Technical Report plus Appendices, Uttarakhand (2012)
3. Rosenberg, D.M., Resh, V.H.: Freshwater Biomonitoring and Benthic macroinvertebrates. Routledge, Chapman and Hall, New York (1993)
4. Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., Hughes, R.M.: Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA/440/4-89-001. Office of Water, US Environmental Protection Agency, Washington D.C. (1989)
5. Battegazzore, M.: Diatoms used for the evaluation of the effects of experimental water releases from hydroelectric power plants in alpine river systems, the case of the Cairasca–Devero basins (NW Italy). 7th CE-Diatom Meeting, pp. 108–110 (2013)
6. Lenat, D.R.: A biotic index for the southern united states: derivation and list of tolerance values, with criteria for assigning water-quality ratings. J. North Am. Benthol. Soc. **12**, 290–297 (1993)
7. Whitton, B.A., Kelly, M.G.: Use of algae and other plant for monitoring rivers. Aus J Ecol (1995)
8. Wu, J.A.: Generic index of diatom assemblages as bioindicator of pollution in the Keelung River of Taiwan, 79–87 (1999)
9. Karr, J.R., Chu, E.W.: Restoring Life in Running Waters: Better Biological Monitoring, Springer (1999)
10. Welch, P.S.: Limnology, 2nd edn. McGraw Hill Book Co. Inc., New York (1948)
11. APHA.: Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington D.C. (1995)
12. Hustedt, F.: The Pennate Diatoms. Koeltz Scientific Books, Koenigstein, 981 (1985)
13. Krammer, K., Lange-Bertalot, H.: *Bacillariophyceae*. 2/1 *Naviculaceae*, Spektrum Akademischer, Stuttgart and Heidelberg, pp. 1–876 (1986)
14. Krammer, K.: Diatoms of Europe, Vol 3. The genus *Cymbella*, A. R. G. Gantner Verlag Komanditgesellschaft, FL 9491 Ruggell, p. 584, 194 plates (2002)
15. Krammer, K.: Diatoms of Europe, vol. 4, The genus *Cymbopleura*, *Delicata, Navicymbula, Gomphocymbellopsis, Afrocymbella*, A. R. G. GantnerVerlag Komanditgesellschaft, FL 9491 Ruggell, p. 520, 164 plates (2003)
16. Ward, H.B., Whipple, G.C.: Freshwater Biology, 2nd edn. Wiley, New York, pp. 1248 (1959)
17. Gibson, K.: http://lists.lib.plymouth.ac.uk/lists/FCC7BDB5
18. Ward, J.V., Stanford, J.A.: Riverine ecosystems: the influence of man on catchment dynamics and fish ecology. In: Dodge, D.P. (ed.) Proceedings of the Inter Large River Symposium. Can. Sp. Publ. Fish Aquat. Sci. **106**, 56–64 (1989)
19. Zalewski, M., Puchalski, W., Nowak, M., Frankiewicz, P., Bis, B.: Riparian ecotones and fish communities in rivers–intermediate complexity hypothesis. In: Cowx, I. (ed.) Rehabilitation of freshwater Fisheries. Blackwell Scientific Publications, Oxford (1994)
20. de Garcia Leaniz, C.: Weir removal in salmonid streams implications, challenges and practicalities. Hydrobiologia **609**, 83–96 (2008)
21. Jenkins, K.M., Boulton, A.J.: Connectivity in a dry land river short term aquatic micro invertebrate recruitment following floodplain inundation. Ecology **84**, 2708–2723 (2003)
22. Sparks, R.E.: Risks of altering the hydrologic regime of large rivers. In: Cairns, J., Niederlehner, B.R., Orvos, D.R. (eds.) Predicting Ecosystem Risk 20, Advances in Modern Environmental Toxicology Princeton, pp. 119–152. Princeton Scientific Publishing Co. (1992)

23. Nilsson, C., Svedmark, M.: Basic principles and ecological consequences of changing water regimes: Riparian plant communities. Environ. Manage. **30**, 468–480 (2002)
24. Stanford, J.A., Ward, J.V.: Insect species diversity as a function of environmental variability and disturbance in stream systems. In: Barnes, J.R., Minshall, G.W. (eds.) Stream Ecology: Application and Testing of General Ecological Theory, pp. 265–278. Plenum Press, New York (1983)
25. Nautiyal, P.: Studies on the riverine ecology of the torrential waters in Indian uplands of Garhwal region. 2. Seasonal fluctuations in diatom density. Proc. Indian Acad. Sci. (Anim. Sci.) **93**, 671–674 (1984)
26. Nautiyal, R., Nautiyal, P., Singh, H.R.: Impact of sewage on the diatom communities of the river Alaknanda (Srinagar Garhwal). Int. J. Ecol. Environ. Sci. **22**(3), 289–296 (1996)
27. Nautiyal, R., Nautiyal, P., Singh, H.R.: Community structure of cold water epiphytic diatoms in relation to substrate and flow conditions of a Himalayan river Alaknanda. J. Freshw. Biol. **8**, 1–5 (1996)
28. Nautiyal, P., Mishra, A.S., Verma, J.: The health of benthic diatom assemblages in lower stretch of a lesser Himalayan glacier-fed river, Mandakini. J. Earth Syst. Sci. **124**(2), 383–394 (2015)
29. Aquilina, R.: Pre-restoration assessment of the Hogsmill and river Wandle. http://www.aquilina-environmental.co.uk (2013)
30. Badoni, K., Nautiyal, R., Bhatt, J.P., Kishor, B., Nautiyal, P.: Variations in the Epilithic diatom community structure due to River valley projects on the Ganga between Rishikesh and Haridwar. Proc. Indian natn. Sci. Acad. **63**(6), 523–536 (1997)
31. Ponader, K.C., Potapova, M.G.: Diatoms from the genus *Achnanthidium* in flowing waters of the Appalachian Mountains (North America): ecology, distribution and taxonomic notes. Limnologica **37**, 227–241 (2007)
32. Migratory phenomenon of the endangered Himalayan Mahseer *Tor putitora* in relation to the Ecology of the river Ganga (14/28/92—MAB/RE/01.06.94, 01.09.94 to 30.8.97) MOEn& F, New Delhi (1997)
33. Beyene, A., Addis, T., Kifle, D., Legesse, W., Kloos, H., Triest, L.: Comparative study of diatoms and macroinvertebrates as indicators of severe water pollution: case study of the Kebena and Akaki rivers in Addis Ababa, Ethiopia. Ecol. Ind. **9**, 381–392 (2009)

# Evaluating the Effectiveness of Administrative Controls in a Food Processing Industry

**K. R. Manoj Prabakar, Nihal Anwar Siddiqui and S. M. Tauseef**

## 1 Introduction

Administrative controls are used by the management to reduce the exposure of hazards by implementing some rules and regulations to the workers. In the hierarchy of controls triangle, administrative controls are in the bottom because it does not reduce the exposure of hazard and injuries completely. Safe operating procedures, safety trainings and education, work permit system, job rotation, safety campaigns to create awareness are some ways to reduce the hazards and injuries.

### *1.1 Evaluating Safety trainings, Safety Campaigns and Work Permit System*

It is necessary to evaluate the safety trainings, safety campaigns and the work permit system. Safety training which is efficient can prevent accidents, injuries and also develop a safe system of work. Safety training can enhance the employee's skills and allows them to do the work in a safe manner. It is important that all the employees in an organization receive proper safety training.

Safety campaigns are conducted to create awareness among employees. It can make clear messages to the employees, so that they can understand the safety-related issues in a more efficient way. These will bring changes in behavior and action in a positive way and also helps to develop a positive safety culture. Safety campaigns should be evaluated so that we could know if it delivers the message in a right way to the employees.

K. R. Manoj Prabakar (✉) · N. A. Siddiqui · S. M. Tauseef
Department of HSE, University of Petroleum and Energy Studies, Dehradun, India
e-mail: manoj.prabakar1993@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_23

It is important that the employees know and understand the hazards to which they are exposed to in their workplace. Work permit system also helps to reduce the hazards, injuries, etc. It is also a part of safe system of work. So, it is important to evaluate it and improve the existing system.

## 2 Literature Review

The study was aimed at evaluating the effectiveness of administrative controls. There are various methods to evaluate the effectiveness of administrative controls, [1] paper data collecting tools such as interviews and questionnaires which are used for survey and researches were examined. Both the interviews and questionnaires were compared in terms of various aspects. Comparisons were made regarding cost, time, schedule, sample size and sampling, access to information, bias, confidentiality, response rate, validity, reliability, and data analysis. Finally, the advantages and disadvantages of both the techniques were outlaid, so that one knows which method suits the best for a particular industry.

Elliott [2] describes a cross-sectional, descriptive study to estimate the probability of human errors in PTW in a chemical plant in Iran. In the first stage, through interviewing the personnel and studying the procedure in the plant, PTW process was analyzed by hierarchical task analysis (HTA) technique. In doing so, PTW was considered as a goal and detailed tasks to achieve the goal were analyzed. The mean probability of human error in PTW system was estimated to be 0.11. The highest probability of human error in the PTW process was related to flammable gas testing (50.7%).

Regarding the work permit surveys, as discussed in [3], it is important to investigate the practicalities and realities of operating PTW systems in the onshore chemical industry, in order to inform future guidance to the industry on how to design and implement effective PTW systems. Particular reference was made to small- to medium-sized plant, where only limited resources are available for developing and operating permit systems. These companies might, therefore, be expected to experience more problems with their permit systems than larger companies and be in greater need for guidance. Existing sources of information on the operation of permit systems were reviewed.

Hosseini et al. [4] have done a study which shows that contractors are sensitive to organizational, feedback, content, process, and worker issues. Whenever they encounter language problems, they use visual aids and provide translators and safety guidelines written in workers' own language. Very few statistically significant differences are observed when the findings are analyzed from the point of view of the demographic characteristics of the respondents. The contribution of this study is that it conveys the views of safety personnel about how safety learning can be achieved, sustained, and improved by addressing organizational, feedback, content, process, and worker issues in training sessions. It provides project managers with best practices in safety training sessions.

In his work regarding improving the road safety campaigns, [5] has stated that the pros and cons of some of the more common campaign strategies and introduces a number of new methods that show a great deal of promise for the purpose of road safety campaigns. In order to infuse the field of road safety campaigning with such new insights into road user behavior and behavioral modification, one should look beyond the confines of road safety campaign standards and learn from the knowledge gained in other disciplines such as economics and social psychology. These new insights are discussed in terms of their implications for the future of road safety campaigns [6]. A study showing the effects of training content consisting of examples and/or non-examples was studied on the acquisition of safety-related skills. Participants were randomly assigned to first receive computer-based training on office ergonomics that included either no examples of safe or at-risk postures, safe examples only, at-risk examples only, or both safe and at-risk examples. Participants then attempted to classify as safe or at-risk various postures depicted in short video clips and demonstrate with their own posture the range of safe postures. Training with only safe or at-risk examples resulted in a moderate amount of error and a consistent underestimation of risk. Training content consisting of both examples and non-examples improved acquisition of safety-related skills.

## 3 Methodology

The survey in the form of a questionnaire was prepared and conducted for a target sample size of the company workforce. Ten percent of the total workforce was targeted which included the management staffs, direct workers, and the contractors. Separate questionnaires were prepared for evaluating the safety trainings, safety campaigns, and the work permit system. The questionnaires were prepared in English and also in the regional language so that the regional people could understand the questions asked in the survey. The survey was conducted and each employee was approached individually to collect the responses. All the responses from the respondents were recorded in the excel tool and analyzed. The suggestions given by the respondents were recorded. Further recommendations were given to improve the existing system (Fig. 1).

## 4 Results and Discussion

The survey on safety campaigns through questionnaire was conducted targeting 10% of the total workforce. Various questions regarding the safety campaigns were asked in the questionnaire to get genuine responses from the workers. There were yes or no questions, multiple choice questions, and subjective type questions to make the survey more efficient. The respondents were approached individually and the questionnaire was collected from them. Most of the people took time to

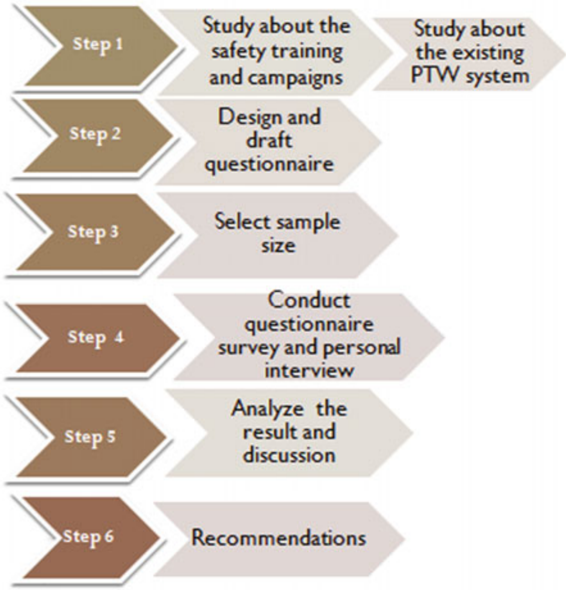



**Fig. 1** Step-by-step process of evaluating

understand and respond to all the questions. The survey was carried out successfully and the responses were recorded in excel tool.

Almost 98% of the people think safety campaigns are necessary and safety campaigns create more awareness among workers. Most of them have participated in the campaign but some did not. Hundred percent of the people believe that safety campaigns benefitted them in a way.

Lot of campaigns such as chemical safety campaign, work at height campaign, road safety campaign, confined space campaign, near miss campaign, electrical safety campaign, off the job safety campaign, PPE campaign were conducted by the company in the year 2016–2017. Most of the campaign involved setting up banners, internal and external training, workshops, etc. Nearly half of the survey respondents believe that trainings given have more impact in a campaign. However, 22% of the people feel that field audits and mock drills would be more appealing. Eighteen percent of the people think that putting up lot of banners may convey the message more efficiently in a campaign. Before conducting the campaign, the organizers should put themselves in the place of the target people and think whether the campaign would benefit them. This has to be kept in mind before starting the campaign, only then the safety campaigns would be effective. Except 2% of the respondents, others feel that conducting safety campaigns should continue.

The questionnaire had a question which asked the respondents to name any four safety campaigns which were conducted in the plant to which 32% of the people did not answer. Thirty-four percent of the people named four safety campaigns and 20% of the people managed to name two or three. Another question which asked the respondents to name the best safety campaign was not received well. Nearly half of the respondents did not answer the question. Fourteen percent of the people said that the road safety campaign was best followed by height work campaign (12%) and off the job safety campaign (10%). There were some difficulties while conducting the questionnaire survey. Most of the people did not understand English so I had to draft the questionnaire in the regional local language. Many respondents did not want to answer the subjective questions and ignored them. Many suggestions were given by the respondents to improve the safety campaigns. All the suggestions were recorded. Some of them were, displaying more banners at different locations apart from the regular spots, encourage the workers for participating in safety campaigns, conducting more competitions as a part of safety campaigns.

## *4.1 Work Permit Survey Analysis*

The survey questionnaire based on work permit was drafted carefully to evaluate the respondent's knowledge on the work permit, understanding of the permit system, work permit training, and the existing permit to work system. The respondents were approached individually, and the questionnaire was collected from them. The survey was useful in identifying the gaps in the work permit system and also provides scope for improvement. All the respondents believe that the work permit system is necessary in the plant. When asked whether they had a personal experience of dangerous event occurring due to failure of the permit, 24% of the respondent's answer was positive. In the plant, eight types of work permits are used. They are General work permit, hot work permit, confined space permit, hazardous chemical permit, Electrical work permit, Excavation permit, Height work and permit.

The respondents were asked to name any five work permits, in which 61% of the people answered it right and the other respondents could name only three or four. Seventy-two percent of the respondents knew who raises and authorizes the permit while 14% of people did not answer to the question and another 14% gave an incorrect answer. Seventy-two percent of the respondents have attended work permit training and 38% people feel that the work permit training which they have received is not sufficient. Most of the respondents knew when to use the work permit.

Ninety-eight percent of the respondents agree that they receive safety talk by the permit requestor before carrying out a work with a permit. When asked about the deviations which happen in the work permit, 38% of the respondents tell that the risk is not identified properly, 18% of the respondents feel that permit rules are violated and other 18% say that the PPE use is the deviation that happens often. Eighty-two percent of the people deny that they sign for themselves in the permit and their co-workers after receiving safety talk. Ten percent of the people agree that they sign sometimes for themselves and their co-workers after receiving safety talk. All the respondents agree that they take safety precaution before carrying out a work. Fifty-eight percent of the respondents answered right on what should be done in an emergency while doing a work with permit. Suggestions on how to improve the work permit and work permit system were recorded. More effective training on work permit system is needed for the employees who use work permit. Refresher trainings must be given frequently. Work permit audit should be done in an effective manner and on a regular basis.

## 4.2 Safety Training Survey Analysis

In the company, basic safety induction training is given to all the management staffs, direct workers, contractors of the company. The training register and the training need analysis are done to decide what trainings should be given to the employees. Trainings, such as BBS-STOP, HSE induction, Electrical safety, Basic firefighting techniques, Incident investigation techniques, First aid, Emergency evacuation, are given to all the employees of the company. Apart from that, task-specific safety trainings are given to the workers based on their jobs.

The Training survey questionnaire was drafted in such a way to identify any gaps in safety trainings and to improve the safety trainings in the company. All the respondents agree that:

- Safety training is necessary for all employees.
- All have attended the basic safety induction training.
- Safety training is taken seriously the company.
- Safety training received is relevant and useful.
- Safety training needs are properly identified by the Management.
- Safety training program was helpful in their personal growth.
- Supervisors support the use of techniques learned in training program to apply on the job.

Ninety percent of the respondents say that they would discuss about the training with others even after it is over. When asked to rate the methodology of the safety trainings given (e.g., role plays, games, case studies, video, audio), 16% of the respondents feel it is excellent, 30% of them feel it is average, and 54% of them feel it is good. Safety trainings must be conducted in a convenient day and time so that it is easy for the most of the people to attend safety trainings. When asked about this, 64% of the respondents want the safety trainings to be conducted in the mornings while 20% of the people want it to be conducted in the evening. Thirty percent of the respondents want the safety trainings to be conducted on Wednesday, 28% of them want the trainings on Monday, and 22% of them want the trainings on Saturday. When asked whether they face any difficulties during training, 82% of respondents say that they do not face any difficulties. Some of the respondents say that they are called for urgent work; some say that there is no proper ventilation in the refinery area where trainings are conducted occasionally. Eighty-six percent of the respondents feel that they would like to have additional trainings and other 14%

are content with the trainings that they receive. Eighty-two percent of the respondents feel that their expectations are fulfilled after the safety training is completed. Valuable suggestions from the respondents were recorded to improve the safety trainings. More external safety trainings, interaction sessions, plant visits, increasing the duration of safety training, more task-specific trainings can be provided to employees to enhance and improve the existing safety training system.

## 5 Further Recommendations

- Work permit training and refresher training should be given to employees and contractors who use the permit regularly.
- Work permit must be audited in a regular basis.
- Do not authorize the permit if the job description is not clearly written.
- The permit must identify the hazards properly, it should be rechecked.
- There must not be any violation of permit rules. If so, stop the work immediately.
- It must be ensured that the appropriate PPE is being provided to or used by the workers for the appropriate job.
- Along with basic induction training, the new contractors, supervisors should be given work permit training also.
- Safety trainings are given to all employees. There are violations done by the lorry drivers and people who work at height. They are not using safety harness. A safety meeting or small training regarding this can be given.
- If there are change of work to certain employees, safety trainings and task-specific trainings needed for them should be identified and given by the management.
- Trainings given to the workers should involve practical sessions and the effectiveness of the training should be evaluated after the training.
- Safety campaigns are well organized here in the company. However, more participation of workers should be encouraged especially the employees and the contractors.
- Every campaign should be different and innovative from other. The main aim of the campaign is to create awareness and deliver a clear important message regarding safety.
- Competitions can be incorporated as a part of campaign, as it would kindle the desire of the employees and contractors to participate.
- Any plant visit would cheer the employees as it can be used as a teaching method to engage the heart and minds of the employees towards safety.
- Any information regarding safety should be effectively communicated. Everyone must be able to know.
- Most of the employees and contractors did not want to answer some of the subjective questions in the survey. This attitude of people must be changed.

A meeting can be organized to tell the importance of those surveys and some small gifts can be given if they genuinely complete the survey. People should get motivated. More surveys should be regularly conducted.

## 6 Summary and Conclusion

The survey was completed successfully and the people showed good participation. They took time to complete their survey and provided various suggestions to improve the existing safety system. The contractors also had sound knowledge on safety-related issues and awareness toward safety. This really shows how much importance is being given to safety in the company. Based on the survey results, one can infer that there is positive safety culture and the existing administrative controls work fine. To be the best, continual improvement is necessary.

Some changes can be done to make the present system even more effective. Certain changes like putting safety banners in different places apart from regular spots can be more effective, more contractors and employees participation should be encouraged in safety campaigns and trainings, work permit refresher training should be given to the direct workers and contractors. I kindly request the management to review the suggestions given by the workers and to take necessary action to make the safety trainings, safety campaigns, and the work permit system even more effective. An effective safety management with the proper training and education for the workers may prevent the accidents considerably. Also, top management commitment to prevent accidents will be the important one.

## References

1. Adamos, G., Nathanail, E.: An experimental approach towards the evaluation of mass media safety campaigns—A comparative analysis of two case studies. Transportation Research Board 90th Annual Meeting, Washington DC, 23–27 Jan 2011
2. Elliott, B.: Effective Road Safety Campaigns: A Practical Handbook. Report prepared for Federal Office of Road Safety, Elliott & Shanahan Research, Sydney (1989)
3. Jahangiri, M., Derisi, F.Z., Hobobi, N.: Predictive human error analysis in permit to worksystem in a petrochemical plant. In: Safety and Reliability: Methodology and Applications, pp. 1007–1110. CRC Press (2014)
4. Hosseini, A.H., Jafari, M., Mehrabi, Y., Halwani, G., Ahmadi, A.: Factors influencing human errors during work permit issuance by the electric power transmission network operators. Ind. J. Sci. Technol. **5**(8), 3169–3173 (2012)
5. Akbaryak, B.: A comparison of two data collecting methods: interviews and questionnaires. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi **18**, 1–10 (2000)
6. Jahangiri, M., Hosseini, A.A., et al.: Human error analysis in permit to work system: a case study in a chemical plant. Saf. Health Work (2015), PII: S2093-7911(15)00053-0. doi: 10.1016/j.shaw.2015.06.002, Reference: SHAW 102

# A Review of Vehicular Pollution and Control Measures in India

**Aayush Rastogi, Albert V. Rajan and Mainak Mukherjee**

## 1 Introduction

Air contamination is one of the genuine ecological issues of the metropolitan areas where greater part of the populace is exposed to poor air quality. Today a large portion of the Indian cities are encountering fast unplanned urbanization due to which there is a colossal increment in the quantity of vehicles. Vehicular emissions and smouldering of fossil fuels are the root cause of air contamination. About 70% of the nation's air contamination is caused by vehicular emissions only. As indicated by research led by the World Health Organization, 2.4 million individuals die each year due to air contamination. Air contamination from vehicle exhausts is a crucial issue for India as the air quality of Indian cities is degrading at an alarming rate.

In present, there are 53 cities in India which have million plus population. In many cities, air quality is observed not to meet the standards recommended by the Legislature of India. The cities like Ahmedabad, Kolkata, Lucknow and Hyderabad are recognized as hotspots as far as air pollution level is concerned. The main reasons of air contamination are rapid growth in registered vehicles leading to traffic congestion, predominance of older vehicles, poor inspection and maintenance, avoidance of public transport and car pooling, poor fuel quality, improper traffic management and poor road conditions, lack of awareness among people and inefficiency of the pollution control boards [1, 2].

A. Rastogi · A. V. Rajan
Energy Systems, University of Petroleum and Energy Studies, Dehradun, India

M. Mukherjee (✉)
Department of Electrical Power and Energy, University of Petroleum and Energy Studies, Dehradun, India
e-mail: mmukherjee@ddn.upes.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*, Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_24

## 2 Development of Vehicles Sector in India

According to the **Society of Indian Automobile Manufacturers**, the sales of passenger vehicles marked a growth of 7.24% in April–March 2016 compared to last year. There is a gain of 7.87, 6.25 and 3.58% in the sales of passenger cars, utility vehicles and vans, respectively, during April–March 2016 over the same time frame a year ago [3]. Vehicles domestic sales trends are shown in Fig. 1.

India has shown a significant economic growth in recent years, and buying power of population has also increased drastically due to which there is a significant increment in sales of vehicles sector in last five years. This gain is a meaningful indicator of the pollution of major cities of India. The domestic market share of vehicles for 2015–2016 shows that the 80% of total market is comprised of two-wheelers, 14% by passenger vehicles, commercial and three-wheelers comprise of 3% each [3]. The impact on the ambient air pollution due to increasing vehicular population is illustrated in Figs. 2 and 3.

## 3 Vehicular Pollution in India

The total commercial vehicles marked a growth of 11.51% compared to the last year, and the aggregate vehicle population is 32.03 million including four-wheelers, two-wheelers, three-wheelers and engines. The total $CO_2$ emission was estimated to be 391 million tonnes in the year 2015, and it is expected to reach up to 1212

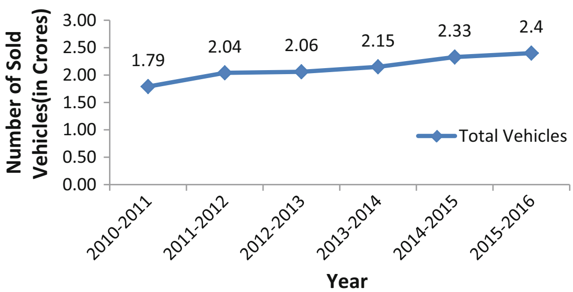



**Fig. 1** Vehicular sales growth in India [3]

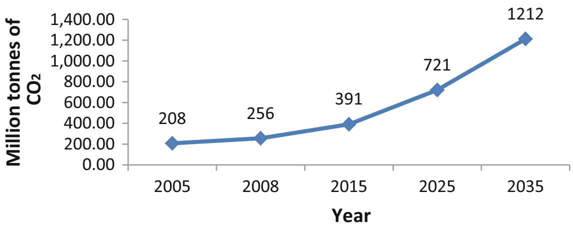



**Fig. 2** Total $CO_2$ emissions on Indian roads [1]

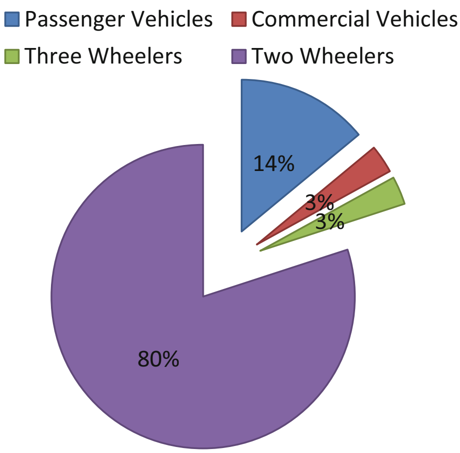



**Fig. 3** Domestic market share of vehicles for 2015–2016 [3]

million tonnes by 2035 [4]. Bigger centralization of vehicles is seen in the metropolitan areas, especially the four main metros Delhi, Kolkata, Chennai and Mumbai, accounting 15% of the aggregate automobile population of India, while 40 other metros account for 35% of the total automobile populace of the country. These vehicles are accounted for the emission of following gases: 70% of CO, 50% of HC, 30–40% of NO*x*, 30% of SPM and 10% of $SO_2$. The critical levels of pollutants in these metros are the reasons for ailments and life-threatening diseases like asthma and lung cancer [1]. The vehicular pollution in major cities is illustrated in Fig. 4 and Table 1.

The transport sector is accounted for the consumption of more than 50% of the petroleum products. The high critical values of these toxic gases especially in the urban metros are the clear indication of high vehicular population.

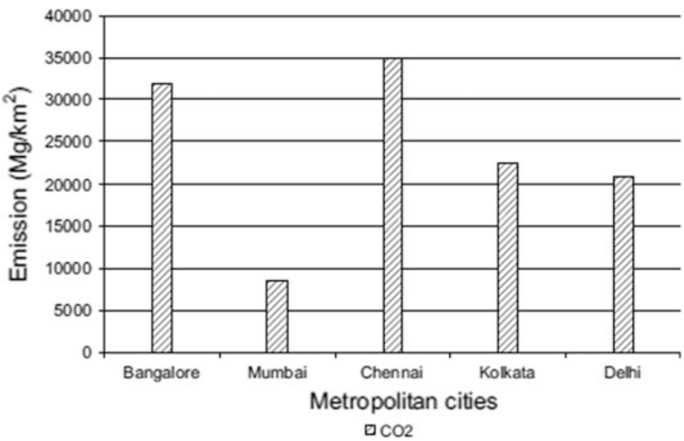



**Fig. 4** Vehicular pollution in major Indian cities [5]

**Table 1** Vehicular pollution in major Indian cities [5]

| Metropolitan cities | Number of road vehicles | Geographical area ($km^2$) | $CO_2$ ($mg/km^2$) | CO ($mg/km^2$) | $SO_2$ ($mg/km^2$) | $NO_X$ ($mg/km^2$) | $CH_4$ ($mg/km^2$) | HC ($mg/km^2$) | PM ($mg/km^2$) |
|---|---|---|---|---|---|---|---|---|---|
| Bangalore | 18,90,692 | 226.24 | 32,013.25 | 405.25 | 93.29 | 323.75 | 16.14 | 86.03 | 22.18 |
| Mumbai | 11,99,416 | 438 | 8,562.01 | 118.91 | 23.67 | 67.8 | 4.95 | 24.69 | 5.41 |
| Chennai | 20,14,776 | 174 | 34,903.50 | 429.13 | 108.04 | 353.67 | 18.99 | 118.95 | 23.01 |
| Kolkata | 8,75,156 | 186.23 | 22,402.15 | 213.94 | 72.07 | 273.55 | 9.1 | 59.66 | 14.23 |
| Delhi | 42,36,675 | 431.09 | 20,843.82 | 284.43 | 42.38 | 129.99 | 15.56 | 87.74 | 9.13 |

## 4 Health Issues Due to Vehicular Pollution

Air contamination is one of the main ten executioners on the planet and is the fifth driving reasons for death in India. It brings about around 620,000 premature deaths which are brought about by stroke, lung cancer, severe infections and pulmonary diseases. Vehicular contamination is leading to complex blend of different gases mainly oxides of carbon, nitrogen, sulphur, hydrocarbons and particulates. Health risks are more severe for susceptible groups such as children, senior citizens and those with prior cardiovascular and pulmonary ailments. More cases of skin diseases are also found in urban areas [4, 8]. The effects of vehicular emissions on human health are summarized in Tables 2 and 3.

**Table 2** Adverse effects of pollutants on human health [1]

| Pollutant | Effects |
|---|---|
| Carbon monoxide (CO) | Damages the cardiovascular system, aggravates cardiovascular illness, particularly angina; also affects foetuses, sick, anaemic and young infants, influences the nervous system, poor vision and judgments, causes cerebral pains and queasiness, less productivity and increasing personal uneasiness |
| Nitrogen oxides ($NO_x$) | Decreased immunity, lung diseases, impairment of nose, eye and throat irritations |
| Sulphur dioxide ($SO_2$) | Severe lung impairment |
| Particulate matter and respirable particulate matter | Affects respiration system and causes poor lung functioning |
| Lead | Damages kidney and liver, causes cerebrum harm in infants leading to lower I.Q., hyperactivity and decreased concentration |
| Benzene | Both poisonous and carcinogenic. Excessive exposure can lead to blood cancer |
| Hydrocarbons (HC) | Carcinogenic |

**Table 3** Effects of vehicular emission [1]

| Pollutant | Health effects | | | | | Climate change | |
|---|---|---|---|---|---|---|---|
| | Direct | Indirect | Acid rain | Eutrophication | Visibility | Direct | Indirect |
| CO | A | | | | | | A |
| HC | A | A[a] | | | | | A |
| $NO_x$ | A | A[a] | A | A | A | A | |
| PM | A | | | | A | A | |
| $SO_x$ | A | | A | | A | | A |

[a]Ozone does not release from the vehicles directly but it is formed due to chemical reactions of NOx and volatile compound in the presence of heat and sunlight which causes various lung diseases

# 5 Control Measures

The motor vehicle rules developed by Ministry of Road Transport and Highways (MRTHs) are the principal tools for motor vehicle pollution control throughout the country. Bharat Stage IV an equivalent to European Standard Euro IV was a huge step for improving the air quality, introduced in 2010, and was implemented in 13 megacities and currently applicable in 33 cities. BS IV gives a standard for fuel quality and tailpipe emission. BS IV standard depicts fuel specification having sulphur content maximum of 50 PPM in both petrol and diesel [6]. The BS IV emission standards up to six seaters and vehicles weighing up to 2500 kg are as follows: CO—1 g/km, HC—0.1 g/km and $NO_x$—0.08 g/km. For vehicles with GVW up to 3500 kg, the limits are as follows: CO—2.27 g/km, HC—0.16 g/km and $NO_x$—0.11 g/km [1, 9].

For controlling the vehicular pollution and improving the air quality in India, following are the suitable control measures based on our study.

## 5.1 *Road Infrastructure Development*

Transport sector plays a vital role in the advancement of any country. It provides access to individuals to markets, vocation, entertainment, health care, education and other services. But nowadays traffic congestion is the most visible challenge for India as it creates a significant effect on national GDP. The numbers of private-owned automobiles are continuously increasing day by day. Therefore, the transportation sector is vigorously responsible for public health issues. Thus, proper maintenance of roads, setting up different lanes for different vehicles, construction of flyovers, intelligent transportation system (ITS) such as proper synchronised real-time traffic monitoring with timers, cameras, traffic density sensors and traffic lights are some of the control measures for proper traffic management. India faces a loss of around sixty thousand crores annually due to traffic congestion, slow-moving freight vehicles and waiting at toll booths. Recent study has shown that trucks in India can cover maximum 325–350 km in a day, but in case of the most BRICS countries, trucks can cover up to 500 km a day [11–14].

## 5.2 *Mass Public Transport*

It is one of the most effective measures which can reduce individual's carbon footprint, reduce fuel consumption and traffic congestion while meeting the public mobility needs efficiently. A fully occupied transport system is more efficient than average commuter's single occupant auto. Local commuter rail system is currently functional in seven metros Hyderabad, Bangalore, Delhi, Mumbai, Chennai, Kolkata and Pune. Organised bus services are also functional in 65 cities.

### 5.3 Alternate Fuels

Various research agencies, auto sectors, CPCB, oil companies and planning commission have shown their interest towards the use of alternate fuels. The most suitable biofuels are ethanol and biodiesel (B-20). It is observed that liquefied petroleum gas (LPG)- and compressed natural gas (CNG)-based vehicles produce less GHG emission compared to other conventional fuels. Electrical vehicles have gained popularity in recent years. Several automobile manufacturers have commercialized battery-driven two-wheelers and three-wheelers [7, 9].

### 5.4 Other Measures

Government initiatives for research and development in the field of alternate fuels and automobile technologies for reduced GHG emissions, ensuring better fuel quality standards throughout the country, stringent emission regulation and policies, periodic maintenance of vehicles, awareness campaigns, encouraging car pooling, scrapping old polluting vehicles out of the existing vehicular pollution, imposing parking charges and fines, emission warranty, development of green belts, thrust on public transport system such as bus rapid transit (BRT), use of non-motorized transport and transportation demand management are some of the measures to control air pollution [7, 11, 12].

## 6 Conclusion

Vehicular pollution is a serious environmental concern all around the world. Data have shown that numbers of vehicles are increasing drastically resulting in significant deterioration in ambient air quality. In many urban cities of India, the air quality is found to be below standards. Various researches and study have shown that there is a continuous rise in the pollution level of urban cities which has adversely affected human life. The poor air quality in urban areas leads to reduced lifespan and comfort of people residing in these areas. The emission load coming out from vehicles is prime reasons behind the climate and ecological imbalance, causing irreversible climate change and other phenomenon like acid rain, smog, noise pollution and loss of biodiversity. Irreversible damage has been already seen in urban metros due to the heavy vehicle population. Air contamination has caused six lakhs premature deaths in India and is the fifth main reason of death. It was recently found that Delhi is having pollution levels 12 times greater than World Health Organizations (WHOs) recommendation [10]. Ahmadabad, Agra, Lucknow, Faridabad, Kanpur and Varanasi are other six cities with air contamination levels at about ten times more than the recommended levels. The rate at which air is getting polluted is alarming. Therefore, it is proposed that successful vehicular emanation control activity plan ought to be created and executed.

Government initiatives have been already taken for the betterment of air quality in urban metros. BS IV standards (2010) and Auto Fuel Policy (2003) are some of the examples, but implementations of these standards are still ineffective. Thus, adaptation of BS IV standards throughout the country and subsequently introduction of BS V regulations are the necessary pollution control measures. Apart from it, there is an essential need to develop good public transport system and better road infrastructure in urban areas. Mass public transportation facilities and intelligent transportation systems are still absent in many metropolitan cities. Kolkata is an example of implementing a well-connected and organised public transportation system which discourages people reliance on private vehicles. There is a significant reduction in Kolkata's private-owned vehicles in recent years because of the efficient public transport system including suburban railways, metros, trams and buses [2, 6, 9].

Emphasis should be given in research and development of alternate fuel. Periodical inspection of vehicles, scrapping out of old vehicles, use of better fuel quality, follow emission standard norms should be made compulsory. Establishing a sustainable urban transport system is necessary to mitigate the adverse effects of air contamination.

## References

1. Central Pollution Control Board, (CPCB): Status of the vehicular pollution Control Program in India Program objective series PROBES/136/2010 (2010)
2. Central Pollution Control Board, (CPCB): Status of Pollution Generated From Road Transport in Six Mega Cities (March 2015)
3. Society of Indian Automobile Manufacturers
4. Center for Science and Environment (CSE), New Delhi, India
5. Ramachandra, T.V., Shwetmala: Emissions from India's transport sector: state wise synthesis
6. Auto Fuel Vision and Policy 2025, Goverment of India (May 2014)
7. Vehicular Pollution Control in India, Technical & Non-Technical Measure Policy, Dr. B. Sengupta, Member Secretary, CPCB: Paper presented at regional workshop on transport sector inspection & maintenance policy in Asia, organized by ESCAP/UN (DESA) in Bangkok, 10–12 Dec 2001
8. Khandar C., Kosankar, S.: A Review of Vehicular Pollution in Urban INDIA and its Effects on Human Health, vol. V, issue no. III. National Environmental Engineering Research Institute, Nagpur (2014)
9. Kathuria, V.: Vehicular Pollution Control—Concept Note. Madras School of Economics, Chennai
10. Study on Ambient Air Quality, Respiratory Symptoms and Lung Function of Children in Delhi, CPCB, Environmental Health Series (EHS/2/2008), Aug 2008
11. Air Pollution Control in the Transportation Sector: Third Phase Research Report of the Urban Environmental Management Project. Institute for Global Environmental Strategies (IGES) Mar 2007

12. Shanghai Manual—A Guide for Sustainable Urban Development in the 21st Century, authored by Carlos Felipe Pardo
13. Bhandarkar, S.: Vehicular pollution, their effect on human health and mitigation measures. Veh. eng. (VE) **1**(2) (2013)
14 Dash, D.K.: Article in The Times of India, 31 May 2012

# Phosphorous Recovery as Struvite from Anaerobically Digested Sewage Sludge Liquors in Delhi, India

**Swati Gupta, Arun Kansal and Shivakshi Jasrotia**

## 1 Introduction

During the treatment of municipal sewage, the main solid waste product formed is sludge. Huge quantity of the activated sludge without any scope of proper disposal will be a serious threat to our ecological systems and is certainly responsible in its imbalance mode [1]. Especially, urbanization, industrialization, agriculture and other alterations adversely affect the aquatic ecosystem through over-enrichment of nutrient like nitrogen and phosphorous into aquatic system. This enrichment will lead to the accelerated growth of algae and higher forms of plants and hence responsible for creating an undesirable environment for the balance of organisms and also the quality of water concerned [2, 3].

But despite this fact of being a threat, sludge is also a superior resource as it consists of the large quantity of organic stuff which through anaerobic digestion will be transformed into biogas [1]. Major source of phosphorous and nitrogen in the sludge is urine which contributes greater than 50% of the phosphorous (P) and 80% of the nitrogen (N) mass load to the municipal waste water [4, 5]. A possible solution to the current problem is the use of chemical precipitation technique for the

S. Gupta (✉)
TERI University, C-10, Institutional area, Vasant Kunj 110070, New Delhi, India
e-mail: swatiboond71@yahoo.co.in

A. Kansal
Coca-Cola Department of Regional Water Studies, TERI University,
C-10, Institutional Area, Vasant Kunj 110070, New Delhi, India
e-mail: akansal37@gmail.com

S. Jasrotia
Centre for Global Environmental Research, Earth Science and Climate Change Division,
The Energy and Resources Institute (TERI), IHC Complex, Lodhi Road,
New Delhi 110003, India
e-mail: shivakshi_jasrotia@yahoo.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_25

removal and can also say recovery of phosphorous in the form of struvite which is nothing but magnesium ammonium phosphate or MAP, $MgNH_4PO_4 \cdot 6H_2O$, a white insoluble crystalline compound consisting of equal molar ratios of magnesium, ammonium and targeted phosphorous [6, 7]. In Indian context, pH of sewage sludge is very much in favour of struvite formation due to India being a tropical country with pH of sludge in range of 7.8, stirring or air stripping increases the pH by 1.0 within an hour, hence addition of very less NaOH as base was required to reach the desired pH. So in the present study, characterization of typical anaerobically digested sewage sludge (ADSS) and optimization for the MAP recovery process was evaluated.

## 2 Materials and Methods

### *2.1 Sampling*

All the experiments conducted are based on actual sludge samples from different sewage treatment plants (STPs) sampled after anaerobic digestion processes. Grab samples of anaerobically digested effluent were collected and analysed for the following parameters. Samples were filtered through thin cloth due to dark colour and thick nature, and the sludge liquor was used for further analysis.

### *2.2 Laboratory Experiments*

Sludge characterization was carried out on raw as well as digested sludge according to Standard Methods laid down by American Public Health Association in 1998 [8].

### *2.3 Experimental Studies*

*Preliminary trials Jar Tests:* These were performed for pH optimization, at different rpm, MgOH/$MgCl_2$ dosing, HRT, aged samples. As we have already mentioned the ease of handling sludge here is India, dosing by using MgOH and $MgCl_2$ for struvite precipitation/crystallization as well as different rpm and HRT are looked into for crystal formation. The addition of $MgCl_2$ and NaOH to 300 ml sludge was stirred for 1 h by jar test. This was followed by air stripping to increase the pH and mix the doses of $MgCl_2$ for struvite crystallization

$$Mg^{2+} + NH_4{}^{+} + PO_4{}^{3+} + 6H_2O \rightarrow MgNH_4PO_4 \cdot 6(H_2O) \quad (1)$$

*Treatability studies/Optimization studies:* Operating pH: ADSS is substantially prone to pH increase by simple aeration through decarbonization of excess $CO_2$. *Time of aeration/turbidity:* Turbidity due to stirring is directly proportional to struvite crystallization as $PO_4$ and Mg concentration after MAP crystallization were found to be very low.

# 3 Results and Discussion

Total of 364 MLD of sludge is generated in Delhi. Out of 30 STPs in Delhi, following three were chosen due to different nature of waste to get a composite picture. Weekly samples of ADSS were collected for a period of 6 weeks (Table 1).

## *3.1 Characteristics for MAP crystallization*

Results showed that phosphate levels in ADSS were appropriate to proceed for p recovery as the P conc is higher, $Ca^{+2}/PO_4{}^{3-}$ molar ratio decreases below 1.0 which helps in growth of spherical crystals. At pilot scale, difficulty in handling anaerobically digested sludge due to its black colour and thick nature will be incurred and which will make the analysis for phosphate, Mg, Ca difficult, so the sludge was filtered through a cloth and the liquor was analysed (Table 2).

**Table 1** Nature and inflow of three selected sewage treatment plants (STP)

| STP | Inflow in MLD | Nature of waste |
|---|---|---|
| Rithala | 302.8 (302.5 design capacity) | Domestic |
| Coronation pillar | 47.5 (112.85 design capacity) | Organic |
| Okhla | 425.2 (485.89 design capacity) | Industrial |

**Table 2** Average estimated characteristics of anaerobically digested sewage sludge for MAP crystallization from 3 STPs of Delhi, India

| S. no. | Characteristics | Average reading |
|---|---|---|
| 1 | pH | 7.6 |
| 2 | Total COD (mg/l) | 1000 |
| 3 | Alkanity (mg/l $CaCO_3$) | 5600 |
| 4 | TKN | 354.8 |
| 5 | Total $PO_4{}^{3-}$ (mg/l) | 320 |
| 6 | Total Ca (mg$CaCO_3$/L) | 116 |
| 7 | $Ca^{+2}/PO_4{}^{3-}$ molar ratio | 0.362 |

## 3.2 Preliminary Trials Jar Tests Phosphorous (ADSS $PO_4$ Levels at Different Stages) Refer Fig. 1

### 3.2.1 Crystal Identification

Struvite formation and subsequent recovery in form of MAP were feasible from STPs in India, from anaerobically digested sludge liquors. Optimization of concentration of Mg ions and pH is important factors for MAP crystallization.

Struvite is a white crystalline structure which when air dried takes a spherical shape in the beaker which can be easily scrapped off after 3–4 days. Crystals formed at bench scale experiments were air dried in a beaker (Fig. 2).

Orthorhombic structure of struvite crystals formed at bench scale experiments was clearly visible at 10× magnification. After addition of $MgCl_2$, air stripping/

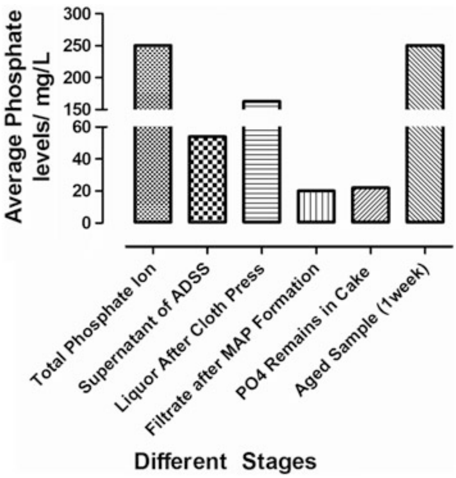



**Fig. 1** Average $PO_4^{-3}$ concentration levels checked for bench scale experiments

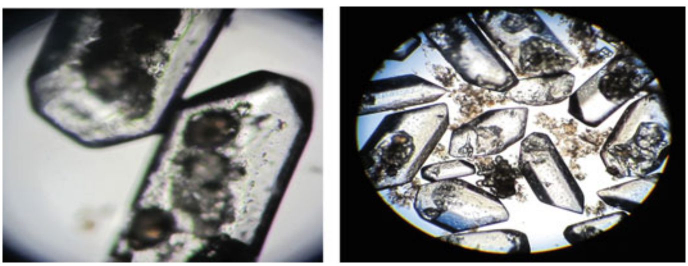


**Fig. 2** Crystal images taken at 10× magnification by camera Zeiss Primo Star microscope (LabMet Asia Pvt. Ltd., Chennai, India)

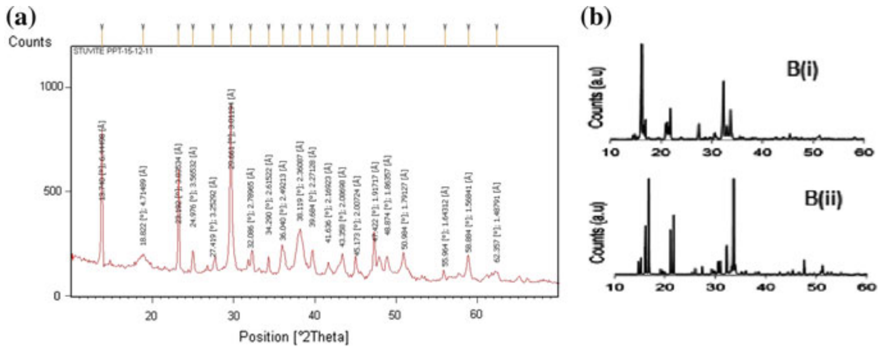



**Fig. 3** **a** Results of X-ray diffraction analysis of the bench scale recovered struvite from ADSS. Vertical lines showing same intensity peaks as 80–85% pure struvite. **b** (i) 100% struvite. **b** (ii) 85% struvite + 15% newberyite

stirring should not be done as the formed crystals are prone to break. HRT and ageing are also important for crystal formation.

X-ray diffraction analyses showed recovery of P in precipitate contained struvite along with other compounds (Fig. 3).

SEM-EDX were done for morphology as well as mineral composition of recovered struvite (Fig. 4) and energy dispersive spectra was shown in Fig. 5.

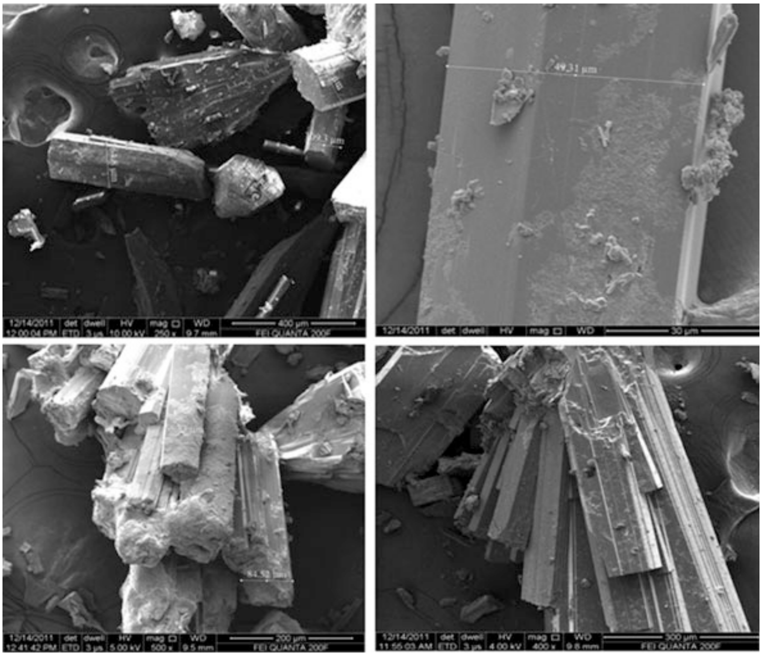


**Fig. 4** Crystal images by SEM (scanning electron microscope)

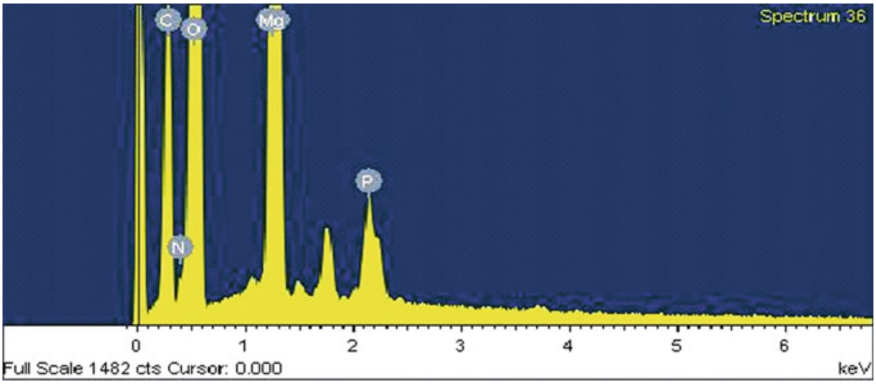



**Fig. 5** Energy dispersive spectra of formed struvite

# 4 Conclusion

Potential for phosphorus recovery as struvite is immense from anaerobically digested sewage sludge liquors from STPs. Struvite is the future sustainable resource recovery product of precipitation and crystallization from ADSS. Struvite solubility is effectively governed by pH control and ionic concentrations of constituent ions of magnesium, ammonium and phosphate for MAP crystallization. Recovery of struvite as a fertilizer is again a viable outcome. Up scaling the bench scale experiments to pilot scale and installing the reactor on site of STP can be a good option for resource recovery. The filtrate can be again returned to the inlet.

**Acknowledgements** The authors would like to thank the officials at Delhi Jal Board (DJB) for providing the samples for the study of the project. We also thank IIT Delhi for training and access to X-ray diffractometry instruments. Due acknowledgement to Mr. Shashank Pandey and Mr. Murugan for their extensive laboratory support.

# References


1. Gong, C., Jiang, J.: Li, D: Ultrasound coupled with fenton oxidation pre-treatment of sludge to release organic carbon, nitrogen and phosphorous. Sci. Total Environ. **532**, 495–500 (2015)
2. Mennaa, F.Z., Arbib, Z., Perales, J.A.: Urban wastewater treatment by seven species of microalgae and an algal bloom: Biomass production, N and P removal kinetics and harvestability. Water Res. **83**, 42–51 (2015)
3. European Commission Directive: Off. J. Eur. Commun. 29–30 (1998). 98/15/EC of 27 February
4. Wilsenach, J.A., van Loosdrecht, M.C.M.: Integration of processes to treat wastewater and source-separated urine. J. Environ. Eng. ASCE **132**(3), 331e341 (2006)
5. Ishii, S.K.L., Boyer, T.H.: Life cycle comparison of centralized wastewater treatment and urine source separation with struvite precipitation: focus on urine nutrient management. Water Res. **79**, 88–103 (2015)

6. Huang, H., Song, Q., Wang, W., Wu, S., Dai, J.: Treatment of anaerobic digestor effluents of nylon wastewater through chemical precipitation and a sequence batch reactor process. J. Environ. Manage. **101**, 68–74 (2012)
7. Di Iaconi, C., Pagano, M., Ramadori, R., Lopez, A.: Nitrogen recovery from a stabilized municipal landfill leachate. Bioresour. Technol. **101**, 1732e1736 (2010)
8. American Public Health Association (1998). URL: https://www.standardmethods.org/. Accessed on 26 July 2015

# Extraction of Energy Precursors in the Form of Volatile Fatty Acids (VFAs) from the Xerophyte Prosopis *(Prosopis juliflora)*

**Pratiksha Patnaik, Tasneem Abbasi and S. A. Abbasi**

## 1 Introduction

Prosopis *(Prosopis juliflora)* is a xerophyte native to harsh desert environments [1]. In that settling, it serves very useful purpose due to its extreme hardiness and survivability. But when it was taken to countries outside its region of origin, it has become weedy. The very same attributes due to which it can thrive in extremes of climate and resource shortage enable it to outcompete most other vegetation in regions of better climate and land-water-nutrient availability. This poses great risk to biodiversity [3].

India—especially its tropical and subtropical parts—is facing a great onslaught of Prosopis [1]. The situation in some regions like Tamil Nadu has become so bad that High Courts have intervened to order the government to clear the landmasses from Prosopis [1, 2].

The stem and the woody branches of Prosopis are usable as fuelwood. Indeed Prosopis fuelwood is in demand at restaurants because it is believed to impart special taste to food roasted over its fire, but the Prosopis leaves have no utility. When rain falls on them, or in moist soil, they keep leaching out allelopathic chemicals which toxify the soil and discourage other species of vegetation [4].

P. Patnaik · T. Abbasi (✉) · S. A. Abbasi
Centre for Pollution Control and Environmental Engineering, Pondicherry University, Puducherry 605014, India
e-mail: tasneem.abbasi@gmail.com

P. Patnaik
e-mail: pratikshapatnaik@rediffmail.com

S. A. Abbasi
e-mail: abbasi.cpee@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_26

Unlike other weeds [5–8], they biodegrade very slowly due to which they exert their negative impacts over a long time span. This raises the urgent need to find ways to utilize Prosopis leaves so that they can be utilized when they fall from live trees or are obtained when Prosopis trees are chopped for wood.

In this chapter, attempts to generate energy precursors from Prosopis leaves in the form of volatile fatty acids (VFAs) are described. The VFAs are directly utilizable to generate energy in the form of biogas as has been illustrated in Chapter 28 of this volume [9].

## 2 Materials and Methods

All chemicals were analytical regent grade unless otherwise specified. Alkali-resistant glassware and deionized, double-distilled water were used for all analytical work.

Prosopis leaves were collected from healthy, adult Prosopis trees standing near the Pondicherry University campus. After the leaves were rinsed with water and wiped—to free them from attached dust and invertebrates—their dry weight was determined. For this, fresh weight of three separate randomly picked samples was taken, and the samples were then oven dried at 105 °C to a constant weight. The reactors were inoculated with fresh cow dung because fresh cow dung contains cellulolytic, acidogenic, and acetogenic bacteria that are needed to biodegrade Prosopis. The cow dung for this purpose was obtained from a nearby dairy. Its dry weight was also determined at 105 °C. For all the computations of the VFA yield, dry weight of cow dung and Prosopis leaves has been used as the basis.

The reactors used for extracting VFAs were comprised of 15 L plastic containers. They had a tap at the bottom with which the contents at the end of each experiment can be drained off.

Two sets of reactors, with or without Prosopis, were operated. The first set, with reactors designated as R1A to R6A, had the following content:

R1A Prosopis 1.5 kg + 12 L water inoculated with 1% cow dung
R2A As above but without Prosopis
R3A Prosopis 1.5 kg + 12 L water inoculated with 2.5% cow dung
R4A As above but without Prosopis
R5A Prosopis 1.5 kg + 12 L water inoculated with 5% cow dung
R6A As above but without Prosopis

The second set, designed as R1B–R6B, was identical and served as the duplicate. The Prosopis content of 1.5 kg fresh leaves was equivalent to 417 g dry weight in all Prosopis-fed reactors.

As the reactors were to be kept in the acid phase [10, 11] which is based on aerobic and facultative bacteria, it was essential that anaerobic conditions were prevented from being developed in the reactors. To enable this, the reactor surface was kept in contact with air by not putting a lid over it but only covering it with a nylon mesh to keep off insects. Also the reactor contents were mixed once every 8 h manually using a fiber glass shovel.

After 24 h had elapsed from the time of starting the reactors, the first sample was drawn. For it, the contents were first stirred to homogenize them. After coarse solids settled in about 10 min, four 25 mL aliquots were pipetted out from four randomly picked locations in the reactors, differing from each other in position at the surface and the depth. The samples were pooled. The reactors were compensated for the 100 mL of reactor content taken out for sampling by adding 100 mL of distilled water to the contents. The sample was then placed in a 500 mL round-bottomed flask kept on a heating mantle, and 100 mL of water with 5 mL concentrated $H_2SO_4$ was provided to it. A few pieces of broken glass were added to prevent thermal stratification by facilitating agitation. A condenser was then fixed and distillation was carried out at a rate of about 5 ml of distillate condensing per minute. The first 3 min (about 15 mL) of distillate was discarded and the distillation resumed to completion.

After the receiving flask was detached from the condenser, the VFA concentration of its contents was determined by titration with a 0.02 N sodium hydroxide solution using phenolphthalein as indicator [12]. As the procedure is highly sensitive to the shape of the glassware, precise quantum of heat provided, and similar other factors, a calibration curve correlating VFA concentration actually taken with the concentration arrived after distillation was drawn up. This was done on the basis of a large number of runs in which a range of known acetic acid concentrations was 'recovered' by distillation.

The experiments of Series A were completed first. The reactors were then cleaned and the entire experiment was repeated using a fresh harvest of Prosopis and freshly acquired cow dung for the duplicate Series B. This was done to enable us to test the reproducibility *vis-a-vis* VFA extraction carried out with different harvests of Prosopis, different sources of cow dung inoculum, and at different times.

## 3 Results and Discussion

The findings are summarized in Tables 1, 2, 3, and 4. The contribution of only cow dung in VFA generation is reflected in Table 1. As expected, the highest blank occurs in reactors with 5% cow dung but the average VFA generated by this blank —542.4 mg/L—is about a fourth of the yield in Prosopis—charged reactors of which average is in the range 2180–2415.7 mg/L (equivalent to 49.9–71.7 g/kg as in Tables 2, 3, and 4). In reactors with 1% cow dung as inoculum, the blank (average 81.4 mg/L) is insignificant in comparison with the VFA generated in presence of Prosopis (2296–2492 mg/L).

Tables 2, 3, and 4 reveal that even as VFA generated on different days in the duplicate reactors has wide variation, the average yields are remarkably similar. It is also seen that by the third day in reactors inoculated with 1% cow dung (Table 2) and 2.5% cow dung (Table 3), the VFA yield reaches near the overall average

**Table 1** VFA generated by different concentrations of cow dung inoculum

| Number of days from the start of the reactor | VFA generated, mg/L, by cow dung | | |
|---|---|---|---|
| | 1% | 2.5% | 5.0% |
| 2 | 36 | 210 | 336 |
| 3 | 66 | 234 | 546 |
| 4 | 66 | 288 | 618 |
| 5 | 99 | 336 | 627 |
| 6 | 126 | 360 | 657 |
| 7 | 144 | 417 | 708 |
| 8 | 165 | 490 | 194 |
| 9 | 48 | 498 | 624 |
| 10 | 54 | 384 | 510 |
| 11 | 78 | 432 | 588 |
| 12 | 30 | 339 | 564 |
| 13 | 180 | 351 | 648 |
| 14 | 72 | 297 | 654 |
| 15 | 60 | 276 | 621 |
| 16 | 39 | 258 | 522 |
| 17 | 48 | 249 | 480 |
| 18 | 72 | 246 | 234 |
| Avg ± SD | 81.4 ± 45.8 | 333.2 ± 88.1 | 542.4 ± 139.1 |

**Table 2** Volatile fatty acids (VFAs) generated by duplicate reactors in treatment R1

| Number of days from the start of the reactor | VFA yield, g/kg | |
|---|---|---|
| | R-1A | R-1B |
| 2 | 38.7 | 31.4 |
| 3 | 54.6 | 50.2 |
| 4 | 69.9 | 59.9 |
| 5 | 70.5 | 63.1 |
| 6 | 72.4 | 65.4 |
| 7 | 82.1 | 76.4 |
| 8 | 107.2 | 71.5 |
| 9 | 90.8 | 80.0 |
| 10 | 84.4 | 80.6 |
| 11 | 84.8 | 71.0 |
| 12 | 86.3 | 73.5 |
| 13 | 79.3 | 69.1 |
| 14 | 57.8 | 79.1 |
| 15 | 69.2 | 48.9 |
| 16 | 78.4 | 45.5 |
| 17 | 42.1 | 83.3 |

(continued)

**Table 2** (continued)

| Number of days from the start of the reactor | VFA yield, g/kg | |
|---|---|---|
| | R-1A | R-1B |
| 18 | 51.0 | 34.5 |
| Avg ± SD | 71.7 ± 18.2 | 63.7 ± 16.2 |
| Overall avg ± SD | 67.7 ± 14.8 | |

**Table 3** Volatile fatty acids (VFAs) generated by duplicate reactors in treatment R2

| Number of days from the start of the reactor | VFA yield, g/kg | |
|---|---|---|
| | R-2A | R-2B |
| 2 | 27.8 | 26.6 |
| 3 | 45.9 | 41.0 |
| 4 | 55.0 | 54.0 |
| 5 | 52.7 | 58.4 |
| 6 | 54.0 | 60.6 |
| 7 | 64.4 | 64.5 |
| 8 | 57.9 | 62.8 |
| 9 | 58.7 | 67.5 |
| 10 | 60.2 | 62.0 |
| 11 | 43.3 | 60.1 |
| 12 | 64.5 | 61.2 |
| 13 | 70.7 | 63.7 |
| 14 | 57.8 | 59.9 |
| 15 | 55.8 | 57.7 |
| 16 | 60.4 | 60.5 |
| 17 | 54.3 | 56.7 |
| 18 | 53.0 | 50.2 |
| Avg ± SD | 55.1 ± 9.6 | 56.9 ± 9.9 |
| Overall avg ± SD | 56 ± 9.3 | |

value. The same happens by fourth day in reactors with 5% cow dung (Table 4). In subsequent days, the VFA levels hover around the overall average. The constancy in VFA levels over the 18-day span of experiments also indicates that either there is no microbical destruction of the VFAs that are generated or the destruction, if it occurs, is compensated by the formation of fresh VFAs.

The average VFA generation with three levels of cow dung as a function of time is depicted in Fig. 1. Whereas reactors with 1% inoculum have given clearly better yield on all days, except the 18th, the performance of reactors with 2.5 and 5% inoculum is not so sharply distinct from each other. Yet it is clear that VFA generation follows the order 1% > 2.5 > 5% *vis-a-vis* inoculum concentration. The difference pertaining to 1% and the other two inoculum concentrations is

**Table 4** Volatile fatty acids (VFAs) generated by duplicate reactors in treatment R3

| Number of days from the start of the reactor | VFA yield, g/kg | |
|---|---|---|
| | R-3A | R-3B |
| 2 | 28.0 | 23.8 |
| 3 | 32.0 | 31.8 |
| 4 | 40.9 | 38.9 |
| 5 | 48.4 | 39.8 |
| 6 | 48.4 | 41.1 |
| 7 | 56.8 | 51.1 |
| 8 | 68.2 | 66.9 |
| 9 | 55.3 | 57.5 |
| 10 | 57.8 | 61.3 |
| 11 | 61.0 | 62.6 |
| 12 | 71.8 | 42.3 |
| 13 | 53.7 | 57.8 |
| 14 | 49.0 | 52.8 |
| 15 | 41.6 | 51.7 |
| 16 | 57.5 | 62.8 |
| 17 | 43.9 | 61.5 |
| 18 | 53.2 | 44.6 |
| Avg ± SD | 51 ± 11.5 | 49.9 ± 12.3 |
| Overall avg ± SD | 50.5 ± 10.8 | |

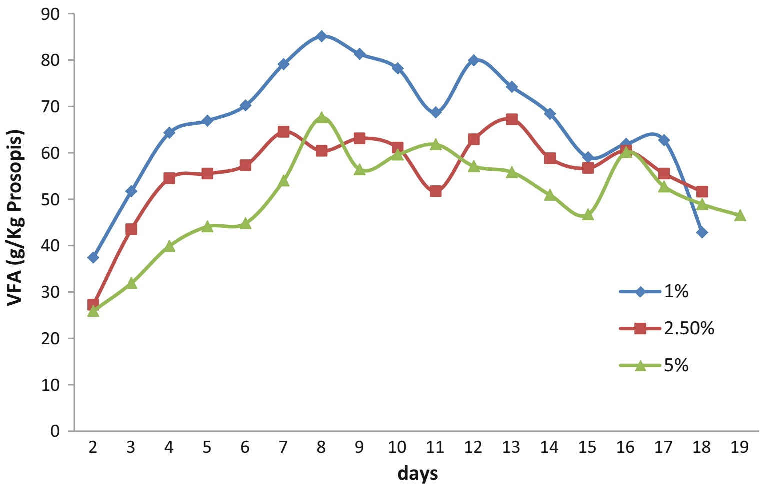



**Fig. 1** VFA generated by Prosopis as a function of time in reactors inoculated with 1, 2.5, and 5% cow dung

statistically significant at confidence level >95% while the difference between the influence of 2.5 and 5% inoculum is not statistically significant. This seems to suggest that cow dung may be hindering, rather than facilitating, VFA generation.

The maximum VFA generation recorded was 107.2 g/kg (Table 2), representing about 11% conversion of Prosopis leaves into VFAs. This finding suggests that pretreatment of Prosopis by NaOH, HCl, or other chemicals known to hydrolyze some of the polymeric sugars to simpler (and more easily biodegradable) molecules [1] may lead to greater than 11% of Prosopis yielding VFAs.

**Acknowledgement** SAA thanks the Council Scientific and Industrial Research (CSIR), New Delhi for Emeritus Scientist Grant (21(1034)/16/EMR-II.

## References

1. Pattnaik, P.: Exploration of prosopis (*Prosopis juliflora*) as a source of energy and fertilizer, Ph.D. Thesis, Pondicherry University, Puducherry (2017)
2. Pattnaik, P.: Prosopis (*Prosopis juliflora*): blessing and bane, Tropical Ecology, in press (2017)
3. Khan F.I., Abbasi S.A.: Techniques and Methodologies for Risk Analysis in Chemical Process Industries, ix + 364 Pages. Discovery Publishing House, New Delhi (1998)
4. Abbasi, T., Abbasi, S.A.: Sources of pollution in rooftop rainwater harvesting systems and their control. Crit. Rev. Environ. Sci. Technol. **41**, 2097–2167 (2011)
5. Abbasi, S.A., Nipaney, P.C., Schaumberg, G.D.: Bioenergy potential of 8 common aquatic weeds. Biol. Wastes **34**, 359–366 (1990)
6. Abbasi, S.A., Nipaney, P.C.: Infestation by aquatic weeds of the fern genus salvinia - its status and control, Environ. Conserv. **13** (3), 235–241 (1986)
7. Ganesh, P.S., Ramasamy, E.V., Gajalakshmi, S., Abbasi, S.A.: Extraction of volatile fatty acids (VFAs) from water hyacinth using inexpensive contraptions, and the use of the VFAs as feed supplement in conventional digesters, Biochem. Eng. J. **27**, 17–23 (2005)
8. Abbasi, T., Abbasi, S.A.: Production of clean energy by anaerobic digestion of phytomass - new prospects for a global warming amelioration technology. Renew. Sustain. Energy Rev. **14**, 1653–1659 (2010)
9. Kumar, M.R., Tauseef, S.M., Abbasi, T., Abbasi, S.A.: Conversion of volatile fatty acids (VFAs) obtained from Ipomoea (*Ipomoea carnea*) to energy. In: Siddiqui, N.A., Tauseef, S.M., Bansal, K. (eds.), Advances in Health and Environment Safety. Springer, New York, Chapter 28, pp. 1–12 (2017). doi:10.1007/978-981-10-7122-5
10. Tauseef, S.M., Premalatha, M., Abbasi, T., Abbasi, S.A.: Methane capture from livestock manure. J. Environ. Manage. **117**, 187–207 (2013)
11. Abbasi, T., Tauseef, S.M., Abbasi, S.A.: Anaerobic digestion for global warming control and energy generation: An overview. Renew. Sustain. Energy Rev. **16**, 3228–3242 (2012)
12. Kumar, M.K., Tauseef, S.M., Abbasi, T., Abbasi, S.A.: Control of amphibious weed ipomoea (*ipomoea carnea*) by utilizing it for the extraction of volatile fatty acids as energy precursors. J. Adv. Res. **6**, 73–78 (2015)

# Study of Mosaic Virus Effects on Physical Properties of Bottle Gourd (*Lagenaria siceraria* Standl.) in Western Himalayas

**Nirmala Koranga**

## 1 Introduction

Bottle gourd is a popular vegetable grown almost throughout the year in plain of India, whereas in hilly areas its cultivation is limited to rainy and summer season. It can be cultivated in all types of soil, but thrives best in loams having larger amount of manure. Generally, three crops of this vegetable are raised in India out of which *Lagenaria siceraria* Standl. has been reported to be affected by various bacterial, viral and fungal diseases. In India, Goel et al. [1], Mayee [2]; Park et al. [3], reported Cucumisvirus-3. A survey was conducted during 1995–96 to not the prevalence of virus diseases on this crop.

During survey, different isolates of mosaic disease were collected. Out of these, two distinct isolates showing characteristics mild and severe symptoms were selected for detailed studies in respect of their identification, varietal reaction, seed transmission, insect transmission and vector virus relationship.

Wenjih [4] tried to find out some effective and easily applicable control measures of mosaic disease of bottle gourd a number of physical factors were tried. Fiedorow [5] reported that all the cultivars of *Cucurbita pepo,* pumpkin, melon and bottle gourd tested were susceptible to cucumber mosaic virus.

## 2 Materials and Methods

In recent years, there has been considerable interest in the control of disease vectors complexes. Although curative measures can occasionally be used, control of virus disease of plants is based largely on prevention rather than cure. Prevention of

N. Koranga (✉)
D.B.S. (P.G) Collage, Dehradun, India
e-mail: nirmalakoranga@yahoo.com

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_27

infection in the first instance or of the spread of the virus may be the most beneficial and applicable method of control.

Though the use of insecticides is expensive and most of the growers cannot afford their cost, yet it is necessary to use some of them to keep the insects away from the crops. Various insecticides were tried out and the most and highly effective of them were used in checking the spread of virus from diseased to healthy plants. Rao et al. [6] identified cucumber green mottle mosaic virus on some cucurbits. Aveglis et al. [7] reported cucumber green mottle mosaic virus from Greece on the basis of symptoms, host range, physical characteristics and serology.

Viruses are able to infect susceptible plants only under certain conditions, such as availability of host at younger stages (seedlings), higher population of insect vectors, favorable environment for the movement of insect vectors. Meer et al. [8] identified and purified a South African isolate of water melon mosaic virus. Singh [9] reported the effect of water melon mosaic virus-1 on growth and yield of bottle gourd. A consideration alteration of sowing dates is likely to reduce or avoid the initial infections to a significant extent. In the study, crop was sown in different dates before and after the normal sowing dates to find out the proper sowing times that may avoid most of the mosaic infections. Qureshi et al. [2] reported a virus inciting severe mosaic virus in *Lageneria siceraria;* this virus was easily sap transmissible but not by aphids and through seeds. Suteri and Bala [10] reported the cucumber mosaic virus, the cause of enation mosaic in *Datura metel*.

Various important *Lagenaria siceraria* cultivars were tested against two different viruses in order to find out some resistant or immune cultivars. Cultivation of such cultivars by the growers will certainly reduce the incidence and spread of the viruses and minimize the yield losses.

During the survey, various diseases samples were collected and subjected for their identification in the laboratory in the following ways:

(1) Stock Culture
(2) Inoculation
(3) Host Range
(4) Varietal Reaction
(5) Physical Properties
(6) Dilution end point
(7) Thermal inactivation
(8) Mechanical transmission
(9) Aphid culture
(10) Aphid transmission
(11) Seed transmission.

## 3 Observation

**Dilution End Point**

The first symptoms were visible after 8 days of inoculation. Inoculated seedlings showed typical symptoms of respective isolates. It was noticed that seedlings inoculated with normal sap (undiluted) developed symptoms earlier than those inoculated with diluted sap. Symptoms gradually decrease with increasing dilution.

Observation taken from the two trials after 15 days of inoculation showed that mild isolate lost its infectivity at a dilution of 1:50,000. While the severe isolate lost its infectivity at higher dilution 1:100,000.

## 4 Results

There are some variations in the results reported earlier which may be due to the differences in strain, different sources of inoculums and different varieties of test plants used.

In the present study, physical properties of two isolates of *Lageunaria* mosaic disease were determined on the basis of dilution end point, thermal inactivation point, and longevity in vitro and longevity in vivo.

Various reports in the literature regarding the physical properties of viruses infecting *Lagenaria sicereria* indicated the dilution end point lying between 1:400–1:100,000, thermal inactivation point ranging from 54–90 °C and longevity in vitro at room temperature between 8 h to more than 90 days (Table 1).

**Thermal Inactivation Point**

The crude sap of each virus isolate was treated at various temperatures for a period of 10 min to find out the temperature at which viruses become inactive. Infectivity of mild isolates was completely lost at 65 °C and that of severe isolate at 70 °C.

**Table 1** Dilute end point of mild and severe isolates of bottle gourd mosaic

| Dilution | No. of plants infected out of 10 inoculated | | | | Total no. of plants infected out of 20 inoculated | |
|---|---|---|---|---|---|---|
| | Trial-I | | Trial-II | | | |
| | Mild | Severe | Mild | Severe | Mild | Severe |
| Control | 10 | 10 | 10 | 10 | 20 | 20 |
| 1:10 | 9 | 9 | 8 | 10 | 17 | 19 |
| 1:100 | 7 | 8 | 8 | 9 | 15 | 17 |
| 1:1000 | 5 | 7 | 7 | 8 | 12 | 15 |
| 1:10,000 | 2 | 5 | 3 | 4 | 5 | 9 |
| 1:50,000 | – | 2 | – | 2 | – | 4 |
| 1:100,000 | – | – | – | – | – | – |
| 1:500,000 | – | – | – | – | – | – |

**Table 2** Thermal inactivation point of mild and severe isolates of bottle gourd mosaic

| Temperature °C | No. of plants infected out of 10 inoculated | | | | Total no. of plants infected out of 20 inoculated | |
|---|---|---|---|---|---|---|
| | Trial-I | | Trial-II | | | |
| | Mild | Severe | Mild | Severe | Mild | Severe |
| Control | 9 | 10 | 10 | 10 | 19 | 20 |
| 40 | 8 | 9 | 8 | 9 | 16 | 18 |
| 45 | 8 | 9 | 5 | 8 | 13 | 17 |
| 50 | 6 | 8 | 5 | 5 | 11 | 13 |
| 55 | 3 | 7 | 3 | 2 | 6 | 9 |
| 60 | 3 | 3 | 2 | 2 | 5 | 5 |
| 65 | 0 | 2 | 0 | 1 | 0 | 3 |
| 70 | – | 0 | – | – | – | 0 |
| 75 | – | – | – | – | – | – |

**Table 3** Longevity in vitro of mild and severe isolates of bottle gourd mosaic

| Storage | No. of plants infected out of 10 inoculated | | | | Total no. of plants infected out of 20 inoculated | |
|---|---|---|---|---|---|---|
| | Trial-I | | Trial-II | | | |
| | Mild | Severe | Mild | Severe | Mild | Severe |
| Control | 9 | 10 | 10 | 9 | 19 | 20 |
| 1 | 8 | 9 | 7 | 8 | 15 | 17 |
| 2 | 3 | 5 | 3 | 4 | 6 | 9 |
| 3 | 3 | 5 | 3 | 4 | 6 | 9 |
| 4 | 1 | 4 | 1 | 4 | 2 | 8 |
| 5 | – | 2 | – | 3 | – | 5 |
| 6 | | 1 | – | 1 | – | 2 |
| 7 | – | – | – | – | – | 0 |
| 8 | – | – | – | – | – | – |
| 9 | – | – | – | – | – | – |

The control lots showed 90–100% infection. Percent infection gradually declined with increasing temperature (Table 2).

### Longevity in Vitro

Result obtained from the two trials showed that the infectivity of the two isolates decreased with the increasing storage period (Table 3).

### Longevity in Vivo

Result of the experiment showed that the infectivity of both the isolated gradually decreases with increased in vivo storage period, longevity in vivo of mild isolated was 9–10 days, while this period was 14–15 days in case of severe isolates (Table 4).

**Table 4** Longevity in vivo of mild and severe isolates of bottle gourd mosaic

| Storage days | No. of plants infected out of 10 inoculated | | | | Total no. of plants infected out of 20 inoculated | |
|---|---|---|---|---|---|---|
| | Trial-I | | Trial-II | | | |
| | Mild | Severe | Mild | Severe | Mild | Severe |
| Control | 9 | 10 | 10 | 10 | 19 | 20 |
| 1 | 10 | 10 | 9 | 9 | 19 | 20 |
| 2 | 8 | 6 | 7 | 9 | 15 | 15 |
| 3 | 5 | 5 | 6 | 8 | 11 | 13 |
| 4 | 4 | 5 | 4 | 6 | 8 | 11 |
| 5 | 3 | 3 | 3 | 5 | 6 | 8 |
| 6 | 3 | 4 | 3 | 3 | 6 | 7 |
| 7 | 2 | 2 | 2 | 3 | 4 | 5 |
| 8 | 1 | 2 | 1 | 3 | 2 | 5 |
| 9 | 1 | 2 | 1 | 3 | 2 | 5 |
| 10 | – | 2 | – | 2 | – | 4 |
| 11 | – | 1 | – | 2 | – | 3 |
| 12 | – | 1 | – | 2 | – | 3 |
| 13 | – | – | – | 2 | – | 2 |
| 14 | – | 1 | – | 1 | – | 2 |
| 15 | – | – | – | – | – | – |
| 16 | – | – | – | – | – | – |

## 5 Discussion

Several viruses have been identified infecting bottle gourd. Some have comparatively wide host range and can infect plants outside. Family *Cucurbit aceae* and other have limited host range and can infect only cucurbitaceous plants.

Variations in temperature influence greatly the rate of plant virus infection. Generally, high temperature 30–40 °C before inoculation increases the susceptibility of plants to virus infection, the seedlings exposed to temperature above 50 °C per inoculation temperature treatments of plants showed a gradual decrease in the susceptibility of the seedling to both CMV and WMV.

## References


1. Goel, R.K., Varma, J.P.: Mosaic disease of ridge gourd (*Luffa actagula* Roxb.) in Haryana. Agric. Univ. J. Res. Haryana **3**, 135–144 (1973)
2. Qureshi, M.A., Mayee, C.D.: Biological relationship of cucumisvirus-3 and powdery mildew fungus in bottlegourd. Experientia **34**(3), 336–337 (1978)
3. Park, W.M., Ryu, K.H., Choj, J.K.: Properties andpurification of cucumber mosaiv virus as strain. Korean J. Plant Pathol. **6**(3), 393–401 (1990)

4. Wenjih, Lin: Correlation of the outbreak of virus disease of water melon and vector with climatic factors. Chin. J. Agrometerology **1**(4), 165–169 (1994)
5. Fiedorow, Z.: Susceptibility of cucurbitaceous plants to cucumber mosaic virus. Ochrona Roslin **37**(9), 11–12 (1993)
6. Rao, A.L.N., Verma, V.A.: Transmission studies with cucumber green mottle mosaic virus. Phytopathotogische Z. **109**(4), 325–831 (1984)
7. Aveglis, A.D., Vovlas, C.: Occurrence of cucumber green mottle mosaic virus in the island of Crete (Greece). Phytopathologia Mediterrancea **25**, 166–168 (1986)
8. MeerF.W.Vander; Garnett, H.M. (1987) Purification and identifications of a South African isolate of water melon mosaic virus, Moracco. J. Phytopathol. **120**(3), 255–270
9. Singh, S.J.: Effect of water melon mosaic virus-1 on growth and yield of bottle gourd (*Lagenaria siceraria).* Indian J. Virol. **5**(1–2), 73–78 (1989)
10. Suteri, B.D., Bala, S.: Cucumber mosaic virus the cause of enation mosaic in *Datura metel* L. Sci. Culture **48**(1), 384–365 (1982)

# Conversion of Volatile Fatty Acids (VFAs) Obtained from Ipomoea (*Ipomoea carnea*) to Energy

**M. Rafiq Kumar, S. M. Tauseef, Tasneem Abbasi and S. A. Abbasi**

## 1 Introduction

As displayed in Fig. 1, when organic waste undergoes biodegradation in absence of free oxygen, it leads to anaerobic digestion. This phenomenon is associated with the breakdown of complex biodegradable organics into simpler molecules. The breakdown occurs in four steps [1–5]:

- In the first step, biomolecules, including complex proteins, fats, and carbohydrates (such as cellulose and starch) are degraded into simpler monomers such as amino acids, long-chain fatty acids, and sugars which are water soluble. The degradation is caused by enzymes present in the facultative and obligatory anaerobic bacteria.
- In the second step 'acidogenesis' occurs wherein short-chain (C1–C5) 'volatile fatty acids' are formed: mainly lactic, propionic, butyric, and valeric acid.
- The third step is characterized by the formation of acetic acid, while much lesser fractions of propionic and butyric acids are retained. This steps, which is dominated by homoacetogenic microorganisms is called 'acetogenesis.'

M. Rafiq Kumar · T. Abbasi (✉) · S. A. Abbasi
Centre for Pollution Control and Environmental Engineering,
Pondicherry University, Puducherry 605014, India
e-mail: tasneem.abbasi@gmail.com

M. Rafiq Kumar
e-mail: kumarrafiq@gmail.com

S. A. Abbasi
e-mail: abbasi.cpee@gmail.com

S. M. Tauseef
Environmental Research Institute, University of Petroleum and Energy Studies,
Dehradun 248007, India
e-mail: sm.tauseef@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_28

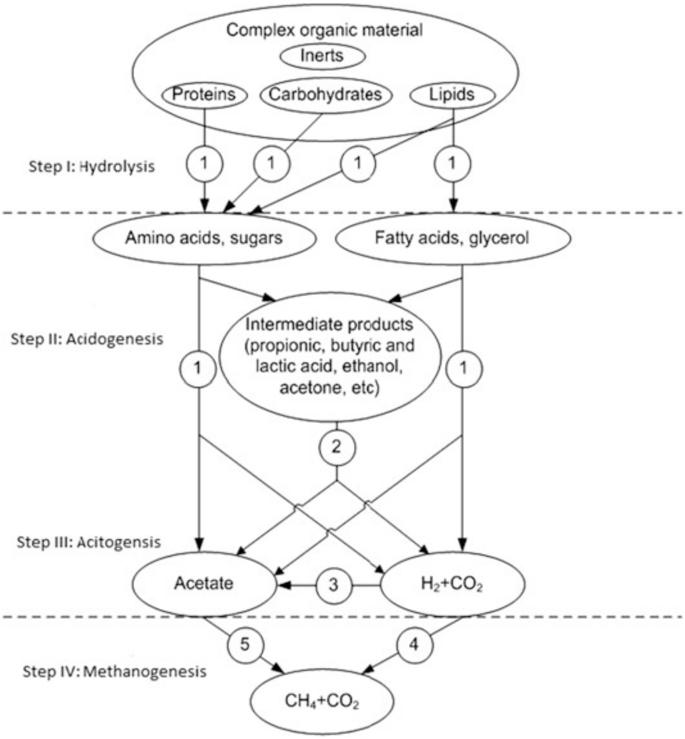



**Fig. 1** Steps associated with anaerobic digestion of organic materials

Finally, the products of the third step are acted upon by methanogenic bacteria, which are strict anaerobes, to generate methane and carbon dioxide in roughly 3:1 ratio. This is achieved via three biochemical routes: (a) the acetotrophic route ($4CH_3COOH \rightarrow 4CO_2 + 4CH_4$); (b) the hydrogenotrophic route ($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$); and (c) the methylotrophic route ($4CH_3OH + 6H_2 \rightarrow 3CH_4 + 2H_2O$).

In all situations in which biogas is generated, whether from organic matter anaerobically decomposing in nature or in controlled anaerobic reactors, this four-step mechanism is always involved [6]. The same set of reactions also occur when methane is generated by rumens [7], termites [8], or a few other invertebrates [9, 10].

Also, whenever biogas is generated by this mechanism, it contains 40–70% of methane or $CH_4$ (by volume), which burns with a clear blue flame. The rest of the biogas is largely made up of $CO_2$, with traces of $NH_4$, $H_2S$, and $H_2$. It can be fed to internal combustion engines or directly burnt as fuel.

The groups of bacteria which are associated with the acidogenic and methanogenic phases have sharply contrasting attributes. Their physiological and nutritional needs are sharply different [11–13]. Their preference for ambient conditions such as temperature and pH are also very dissimilar (Table 1). The rates of reactions occurring in the three phases are also widely different. There is a difference also in the sensitivity to environmental conditions—whereas the methanogenic bacteria (which are strict anaerobes) are strongly effected by even small changes in pH, temperature, and organic loading rate, the bacteria involved in the other two phases can tolerate much wider fluctuations.

In the process described in the preceding paper, the first three steps are accomplished when VFAs—principally acetic acid—are generated from ipomoea as detailed in the preceding paper. In order to convert those VFAs to energy (biogas) only the last step, viz. methanogenesis is needed. This can be accomplished by simply feeding the VFA-laden slurry obtained as in the preceding paper to any functioning anaerobic digester. It can be a 'low-rate' digester like the ones called 'biogas plants' in developing countries—typified by the floating dome Indian designs and fixed done Chinese digesters [7]. Or it can be any one of 'high-rate anaerobic digesters' [14, 15].

The presence of adequate quantities of nitrogen, micronutrients, and water is essential if VFAs are to undergo anaerobic digestion and generate methane-rich biogas because methanogenic bacteria need these nutrients to survive and thrive. Since the VFA generation step does not deplete any of those nutrients present in ipomoea, they are all presents in the VFA-laden slurry.

To check the self-sufficiency of the VFA-laden slurry, generated as described in the preceding paper, as an energy precursor, we fed anaerobic digesters exclusively with this slurry for over a year. The digesters were upflow anaerobic sludge blanket reactors (UASBs); this type was chosen for our trials because UASBs are the most widely used of all high-rate anaerobic digesters [14, 16] due to their high efficiency, resilience, and ease of maintenance. The know-how to scale-up these digesters is also available in open literature. But any and every type of high-rate (or low-rate) anaerobic digester can be used to generate methane from ipomoea-based VFAs because it is liquid feed and can be taken straightaway by all digesters, including anaerobic filters, anaerobic expanded/fluidized bed reactors, anaerobic sequential batch reactors, and others [14, 16].

## 2 Experimental

Upflow anaerobic sludge blanket reactors (UASBs) of the design shown in Fig. 1 were fabricated using alkali-resistant borosilicate glass. The effective (working) volume was kept at 1 L.

All UASBs were started with seed sludge brought from a large-scale UASB reactor running since several years at EID Perry Sugar Industry, Puducherry.

**Table 1** Range of pH and temperature in acid and methane forming bacteria

| Type of bacteria | pH range | Temperature range (°C) | References |
|---|---|---|---|
| Acetogens | 5.5–8 | 27–66 | [17, 18] |
| Methanogens | 6.5–7.6 | 5–65 | [19] |

**Table 2** Performance of UASB reactors at different HRTs with respect to COD removal % and biogas yield when fed with settled cow dung slurry

| HRT (h) | Reactors | No of days of the reactor operation (cumulative) | Influent COD (mg/L) | COD removal efficiency at steady state (%) | Biogas production at steady state (mL/day) |
|---|---|---|---|---|---|
| 24 | R1 | 68 | 458.8 ± 156.8 | 70.1 ± 3.3 | 53.1 ± 12.9 |
| | R2 | | 468.0 ± 135..9 | 70.2 ± 2.2 | 35.3 ± 6.4 |
| | R3 | | 462.2 ± 156.0 | 69.9 ± 4.2 | 39.5 ± 9.4 |
| | R4 | | 446.2 ± 142.3 | 70.9 ± 2.3 | 45.5 ± 3.5 |
| 8 | R1 | 114 | 534.4 ± 52.6 | 78.5 ± 2.3 | 84.2 ± 22.1 |
| | R2 | | 529.6 ± 57.8 | 77.0 ± 1.2 | 66.5 ± 22.1 |
| | R3 | | 534.4 ± 52.6 | 81.1 ± 2.6 | 77.1 ± 38.8 |
| | R4 | | 529.6 ± 57.8 | 79.8 ± 2.4 | 61.5 ± 31.8 |

The UASBs were started with settled cow dung slurry as feed at a hydraulic retention time (HRT) of 24 h [13, 16]. The feed was administered at precisely controlled flow rates using MicLins model VSP-200-24 peristaltic pumps. The relatively high HRT (hence low flow-rate) was kept to enable the reactors to develop granular sludge of good settleability. After the reactors had attained steady state, their HRT was gradually reduced to 8 h till steady state was again reached. This took 114 days (Table 2). The feed was then changed to VFA slurry and the reactor performance was assessed at the HRTs of 8, 6, and 4 h (Table 3).

## 3 Results and Discussion

The performance of the USAB reactors, operated in quadruplicate, during their start-up period when they were fed with settled cow dung slurry is summarized in Table 1.

Even as the influent COD varied by about ±33% in strength during the first 68 days of the reactor operation, the reactors achieved very steady and reproducible level of performance, with COD removal efficiency agreeing between the reactors within 2.2–4.2%. During subsequent 114 days of start-up reactor operation, at the much shorter HRT of 8 h, the influent COD varied by about ±10%. In this case, also, the COD removal at steady state was highly reproducible across the quadruplicate reactors and was constant within the bounds of 1.2–2.6% fluctuation. The feed was changed to ipomoea-derived VFA slurry from 115th day of reactor start-up onward. Steady state was achieved by the 129th day (Fig. 2). The summary of the steady-state performance is presented in Table 2, whereas influent COD varied to a maximum extent of about 30% (in R4), the fluctuation in the maximum extent of COD removal was a mere 3% reflecting the ability of the reactors to withstand wide fluctuating in the influent quality without letting it effect the

**Table 3** Performance of UASB reactors at different HRTs with respect to COD removal % and biogas yield when fed with VFA-laden ipomoea slurry

| HRT (h) | Reactors | No of days of the reactor operation (cumulative) | Influent COD (mg/L) | COD removal efficiency at steady state (%) | Biogas production at steady state (mL/day) |
|---|---|---|---|---|---|
| 8 | R1 | 156 | 1608.0 ± 280.0 | 86.7 ± 3.0 | 128.3 ± 18.6 |
| | R2 | | 1608.0 ± 280.0 | 87.4 ± 1.4 | 133.4 ± 9.9 |
| | R3 | | 1608.0 ± 280.0 | 85.8 ± 1.3 | 125.9 ± 23.2 |
| | R4 | | 1483.1 ± 392.1 | 85.7 ± 1.5 | 130.3 ± 17.6 |
| 6 | R1 | 188 | 2030.6 ± 101.7 | 77.8 ± 2.9 | 94.6 ± 19.6 |
| | R2 | | 2030.6 ± 101.7 | 79.1 ± 4.6 | 90.0 ± 25.4 |
| | R3 | | 2030.6 ± 101.7 | 78.8 ± 2.6 | 94.4 ± 17.9 |
| | R4 | | 2030.6 ± 101.7 | 77.8 ± 3.8 | 91.5 ± 26.8 |
| 4 | R1 | 332 | 2045.3 ± 124.8 | 80.6 ± 1.8 | * |
| | R2 | | 2045.3 ± 124.8 | 78.2 ± 1.2 | * |
| | R3 | | 2074.3 ± 118.9 | 72.9 ± 1.2 | * |
| | R4 | | 2065.0 ± 122.6 | 75.1 ± 1.3 | * |
| 6 | R1 | 470 | 2093.4 ± 128.9 | 82.5 ± 2.9 | * |
| | R2 | | 2118.8 ± 103.1 | 82.0 ± 2.9 | * |
| | R4 | | 2084.0 ± 113.4 | 79.9 ± 1.2 | * |

*Not recorded

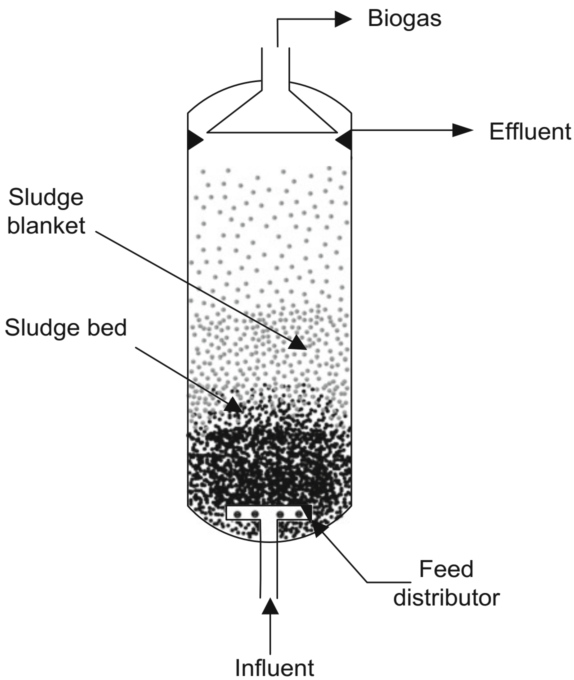



**Fig. 2** Upflow anaerobic sludge blanket reactor (UASB)

reactor's efficiency or steadiness. Quadruplicates agreed with each other very closely. The biogas yield was also fairly steady.

On reducing the HRT to 6 h from 157th day of start-up onward, the treatment efficiency at steady state came down by 6.6–9.6% but the sturdiness and reproducibility of the reactors remained as good as earlier.

With further reduction in HRT to 4 h, steady state was reached in 57 days (Fig. 3). The treatment efficiency was seen to slightly decline in three of the reactors —R2, R3, and R4—by 0.9–6.2% while it improved by 2.8% in R1. After running the reactors at 4 h HRT for 140 days, the HRT of three of the reactors was increased to 6 h to see whether their performance improves to match the earlier performance at 6 h HRT. It did.

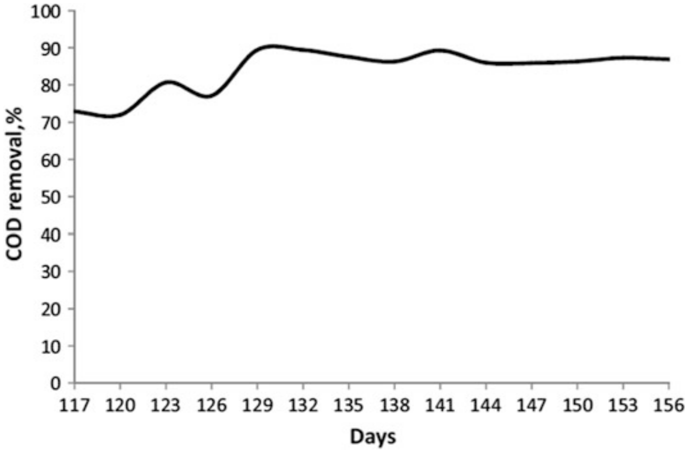



**Fig. 3** Typical steady-state performance of the UASBs at 8 h HRT when fed with VFA slurry derived from ipomoea. This data corresponds to R2 (cf Table 2)

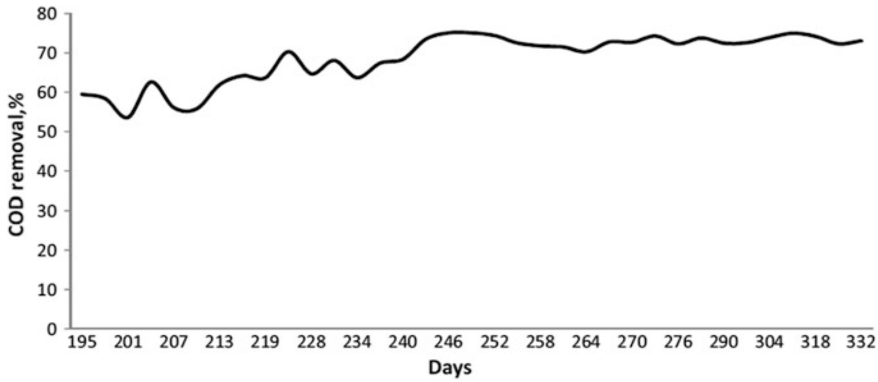



**Fig. 4** Typical steady-state performance of the UASBs at 4 h HRT when fed with VFA slurry derived from ipomoea. This data corresponds to R3 (cf Table 2)

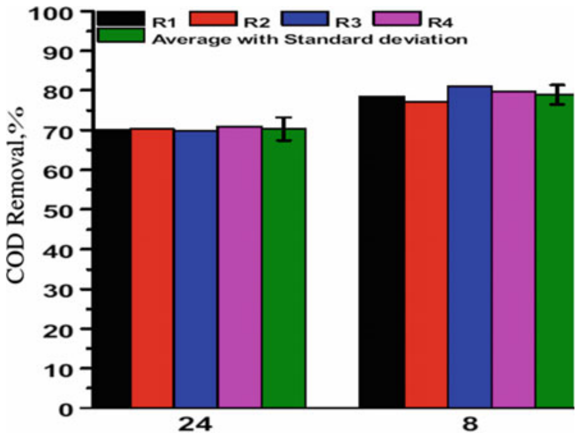



**Fig. 5** Steady-state COD removal in four UASB reactors at HRT of 24 and 8 h when fed with settled cow dung slurry

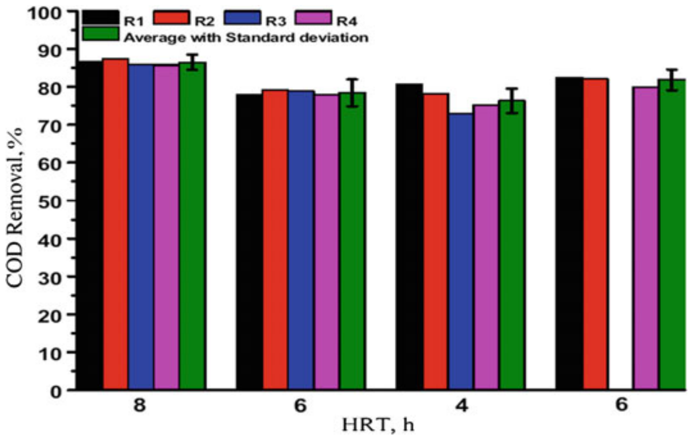



**Fig. 6** Steady-state COD removal in four UASB reactors at HRTs of 8–4 h when fed with VFA slurry derived from ipomoea

Throughout the experiment lasting 1½ years, the reactor performance remained highly reproducible (Figs. 4, 5, 6, 7, and 8).

The extent of significance in the difference of the performance of the UASB reactors at different HRTs is summarized in Table 4. It is seen that at HRT lower than 8 h, there is a significant decrease in the extent of COD removed, even though, in general, the treatment is still substantial, spanning the range 72.9–825%. The biogas yield fell by 30 ± 5% as the HRT was reduced from 8 to 6 h. Sadly, due to a breakdown in gas-flow meters, the biogas yield could not be measured at 4 h HRT and the results on biogas production are, at best, indicative.

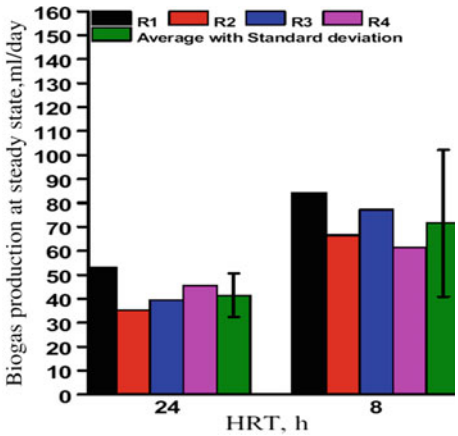



**Fig. 7** Steady-state biogas yield in four UASB reactors at HRTs of 24 and 8 h when fed with settled cow dung slurry

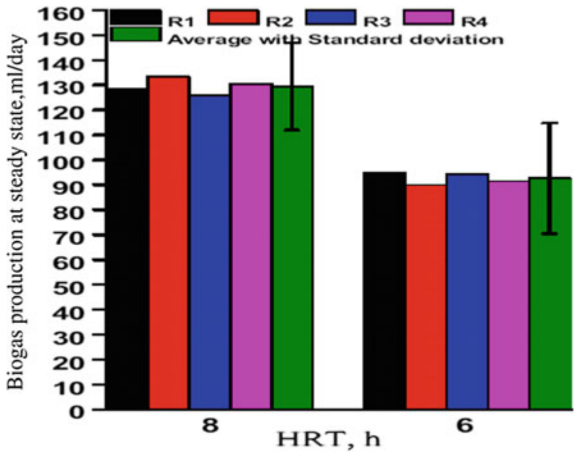



**Fig. 8** Steady-state biogas yield in four UASB reactors at HRTs of 8 and 6 h when fed with VFA slurry derived from ipomoea

The findings establish the feasibility of the overall process whereby up to 10% of the solids present in ipomoea can be retrieved as VFAs and used in generating energy in the form of biogas [20, 21]. The ‘spent’ ipomoea can be converted to organic fertilizer via vermicomposting [22–24]. This opens up the possibility of utilizing ipomoea of which millions of tonnes of biomass is produced every year. Besides monopolizing the use of soil and water in the regions which ipomoea colonizes, it also endangers biodiversity [25]. When dew or rain trickles down its leaves, it takes with it [26] toxic compounds leached from ipomoea, which then

**Table 4** Test of significance in performance of UASB reactors at different HRTs (cf Table 2)

| HRT (h) | Reactors | Nature of change in COD removal | Confidence level (%) at which difference in COD removal significant | Nature of change in biogas yield | Confidence level (%) at which difference in biogas yield is significant |
|---|---|---|---|---|---|
| 8 and 6 | R1 | Decrease | $\geq$ 99.1 | Decrease | 99 |
| | R2 | Decrease | $\geq$ 99.1 | Decrease | 99 |
| | R3 | Decrease | $\geq$ 99.1 | Decrease | 95 |
| | R4 | Decrease | $\geq$ 99.1 | Decrease | 98 |
| 6 and 4 | R1 | Increase | 80 | – | – |
| | R2 | Decrease | 50 | – | – |
| | R3 | Decrease | 99 | – | – |
| | R4 | Decrease | 80 | – | – |
| 8 and 4 | R1 | Decrease | 99 | – | – |
| | R2 | Decrease | $\geq$ 99.1 | – | – |
| | R3 | Decrease | $\geq$ 99.1 | – | – |
| | R4 | Decrease | $\geq$ 99.1 | – | – |

toxify the soil. The decay of ipomoea in the open contributes greenhouse gases [27]. All these negative impacts can be substantially reduced by the process developed by us.

**Acknowledgement** SAA thanks the Council of Scientific and Industrial Research (CSIR), New Delhi, for Emeritus Scientist Grant (21(1034)/16/EMR-II. MRK expresses gratitude to the University Grants Comission (UGC) for Maulana Azad National Fellowship.

## References

1. Khanal, S. K.: Anaerobic Biotechnology for Bioenergy Production: Principles and Applications, pp. 301. Wiley-Blackwell, Singapore (2008)
2. Rosenzweig A, Ragsdale S.W.: Methods in Methane Metabolism: Methanogenesis, pp. 373. Elsevier/Academic Press, USA (2011)
3. Abbasi, T., Tauseef, S.M., Abbasi, S.A.: Biogas Energy, xiv+169 pages, Springer, New Yark & Londan (2012). ISBN 978-1-4614-1039-3
4. Ganesh, P.S., Ramasamy, E.V., Gajalakshmi, S., Abbasi, S.A.: Extraction of volatile fatty acids (VFAs) from water hyacinth using inexpensive contraptions, and the use of the VFAs as feed supplement in conventional digesters. Biochem. Eng. J. **27,** 17–23 (2005)
5. Ramasamy, E.V., Abbasi, S.A.: Energy recovery from dairy waste- waters; impacts of biofilm support system on anaerobic CST reactors. Appl. Energy **65**, 91–98 (2000)
6. Abbasi, T., Tauseef, S. M., Abbasi, S. A.: Anaerobic digestion for global warming control and energy generation: An overview. Renew. Sustain. Energy Rev. **16**, 3228–3242 (2012)
7. Tauseef, S.M., Premalatha, M., Abbasi, T., Abbasi, S.A.: Methane capture from livestock manure. J. Environ. Manage. **117**, 187–207 (2013)

8. Premalatha, M. Tauseef S. M, Abbasi. T., Abbasi S.A.: A website to showcase the human-friendly aspects of termites. Curr. Sci. **105**, 1459–1460 (2013)
9. Premalatha, M., Abbasi, T., Tabassum Abbasi, Abbasi, S.A.: Energy-efficient food production to reduce global warming and ecodegradation: The use of edible insects. Renew. Sustain. Energy Rev. **15**, 4357–4360 (2011)
10. Tabassum-Abbasi., Abbasi. T., Abbasi, S.A.: Reducing the global environmental impact of livestock production: the minilivestock option. J. Clean. Prod. **112**, 1754–1766 (2016)
11. Abbasi, T., Abbasi, S.A.: Formation and impact of granules in fostering clean energy production and wastewater treatment in upflow anaerobic sludge blanket (UASB) reactors. Renew. Sustain. Energy Rev. **16**(3), 1696–1708 (2012)
12. Abbasi, T., Sanjeevi, R., Makhija, M., Abbasi, S.A.: Role of vitamin B-3 and C in the fashioning of granules in UASB reactor sludge. Appl. Biochem. Biotechnol. **167**, 348–357 (2012)
13. Abbasi, T., Sanjeevi, R., Anuradha, J., Abbasi, S.A.: Role of calcium (II) in anaerobic sludge granulation and UASB reactor operation: a method to develop calcium–fortified fludge outside the UASB reactors. Indian J. Biotechnol. **12**, 246–253 (2013)
14. Abbasi, T., Tauseef, S.M., Abbasi, S.A.: Energy recovery from wastewaters with high-rate anaerobic digesters. Renew. Sustain. Energy Rev. **19**, 704–741 (2013)
15. Abbasi, T., Abbasi, S.A.: Production of clean energy by anaerobic digestion of phytomass - new prospects for a global warming amelioration technology. Renew. Sustain. Energy Rev. **14**, 1653–1659 (2010)
16. Abbasi, T., Sanjeevi, R., Anuradha, J., Abbasi S.A.: Impact of Al3+ on sludge granulation in UASB reactor, Indian J. Biotechnol. **12**, 254–259 (2013)
17. Cohen, J.W.: Growth of Acetogens at different pH levels with varying carbon and energy sources. MBL Microbial Diversity, Harvard University (2014)
18. Ljngdhal, L.G.: The autotrophic pathway of acetate synthesis in acetogenic bacteria. Annu. Rev. Microbiol. **40**(1), 415–450 (1986)
19. Abbasi, S.A., Nipaney, P.C., Ramasamy, E.V.: Studies on multiphase anaerobic-digestion of salvinia. Indian J. Technol. **30** (10), 483–490 (1992)
20. Abbasi, S.A., Nipaney, P.C., Schaumberg, G.D.: Bioenergy potential of 8 common aquatic weeds. Biol. Wastes **34**, 359–366 (1990)
21. Rafiq Kumar, M., Tauseef, S.M., Abbasi, T., Abbasi, S.A.: Control of amphibious weed ipomoea (*ipomoea carnea*) by utilizing it for the extraction of volatile fatty acids as energy precursors. J. Adv. Res. **6**, 73–78 (2015)
22. Hussain, N., Abbasi, T., Abbasi, S. A.: Vermicomposting-mediated conversion of the toxic and allelopathic weed ipomoea into a potent fertilizer. Process Saf. Environ. Prot. **103**, 97–106 (2016)
23. Hussain, N., Abbasi, T., Abbasi, S.A.: Toxic and allelopathic ipomoea yields plant-friendly organic fertilizer. J. Clean. Prod. **148**, 826–835 (2017)
24. Abbasi, S.A., Nipaney, P.C.: Infestation by aquatic weeds of the fern genus salvinia - its status and control, Environ. Conserv. **13** (3), 235–241 (1986)
25. Khan F. I., Abbasi S.A.: Techniques and Methodologies for Risk Analysis in Chemical Process Industries, ix + 364 pages. Discovery Publishing House, New Delhi (1998)
26. Abbasi, T., Abbasi, S.A.: Sources of pollution in rooftop rainwater harvesting systems and their control. Crit. Rev. Environ. Sci. Technol. **41**, 2097–2167 (2011)
27. Abbasi, T., Tauseef, S.M., Abbasi, S.A.: Global Warming and the Role of Wetlands, xiv + 264 pages. Lap Lambart Academic, Germany (2011). ISBN 978-3846556009

# Human Health Effects Emanating from Airborne Heavy Metals Due to Natural and Anthropogenic Activities: A Review

**Abhinav Srivastava, N. A. Siddiqui, Rupesh Kumar Koshe and Vishal Kumar Singh**

## 1 Introduction

Heavy metals have found their application which dates back to Roman era when lead was used in pipes, pigment and building materials. In modern society, the demand for heavy metals is on the steady rise and so is it's accumulation since it is non-biodegradable. Still, heavy metals do not have a unified definition and generally defined with density or specific density of 5 g/cm$^3$ or more [1, 2].

Pollution has created a severe impact on the world with its depraved effects on the human race. The studies have visualized that particulate matter has been the major polluting agents but with the time it has been evolving that heavy metals which were present in the soil are enrooting into the air through natural triggered event and human-triggered event [3–5]. It is growing in some parts of the world, mainly in developing countries. Considerably, some challenges have been quantified which has been faced due to limited information on their effects and exposure level.

The source of origin for heavy metals is more from the human activities compared to the biogenic phenomenon. Fine particles from minerals, sea salt, forest fires, industrial and commercial activities, vehicular emission, lead acid batteries, paints, volcanic aerosols and soil dust from the wind are the sources from where heavy metals are emitted in the air and present in the state of gases, aerosols and

A. Srivastava (✉) · N. A. Siddiqui · R. K. Koshe · V. K. Singh
University of Petroleum & Energy Studies, Dehradun, India
e-mail: abhi9.08@gmail.com

N. A. Siddiqui
e-mail: nihal@ddn.upes.ac.in

R. K. Koshe
e-mail: rupeshkuamr.koshe@gmail.com

V. K. Singh
e-mail: vishalkisngh3011@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_29

particulates in ambient air [6–8]. Some of the heavy metals are volatile in nature and their size is less than 1 μm in diameter which binds to the particulate matter and travels a greater distance from the point of discharge. Due to the smaller size, it enters the body through the respiratory tract and binds with complex protein molecule and results in denaturing and death of cell [9].

Widespread dispersion of heavy metals has created concern for human health. Heavy earth metals such as lead, arsenic, chromium and cadmium are mostly found in ambient air. On an average, air is inhaled in an amount from 10,000 to 20,000 litres daily, and metals are absorbed through respirable dust particulate matter and cause damage to lungs tissue [10, 11]. Other organs apart from lungs are also affected because of the minute particles entering into the alveoli of the lungs and travelling through the bloodstream. Several studies have been impounded which focus on the younger generation more susceptible to toxicants because of generic effect evolved due to particulate matter [12].

This investigation is based on the several studies performed on heavy metals. Various anthropogenic and natural sources characterized by amalgamation of heavy metals with the atmosphere and retrograde the air quality is studied. A different aspect of heavy metals on the human population which includes the children and adults is also covered.

## 2 Sources of Heavy Metals

### *2.1 Natural Source*

Activities like volcanic eruption, jungle fires, cyclonic disturbances and cosmic dust are contaminating the ambient air through the release of rare earth metals like Pb, As, Cd and Cr in the form of particulate matter [13], while the maximum dispersion of heavy metals, i.e. 80% is accounted from the volcanic activity and remaining 20% is released from other biogenic sources and forest fire [14]. We have focussed on six heavy metals lead (Pb), cadmium (Cd), arsenic (As), copper(Cu), nickel (Ni) and chromium (Cr) which are liberated in the profuse amount of metric tons per year in ambient air [14].

### *2.2 Anthropogenic Source*

Human interference with the environment has increased spontaneously. Major sources of heavy metal emission in the atmosphere are mining, energy production, construction, non-renewable fuel combustion, municipal waste combustion, vehicular movement and construction material production and demolition activities [15]. In mining industries due to high-temperature refining process, the metals like copper, chromium, nickel are dispersed. The coal contains different elements in trace quantity, and transportation of coal and mine fire releases particulate matter

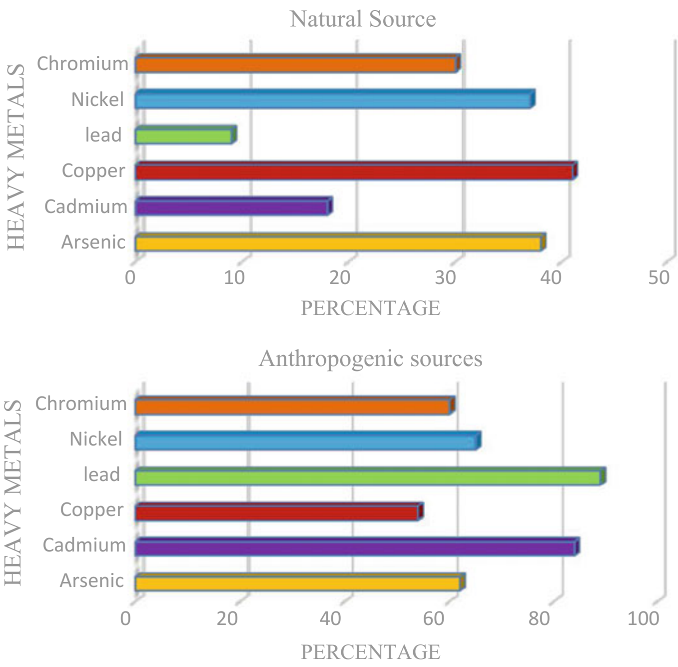



**Fig. 1** Comparative study between natural and anthropogenic source [5]

where the heavy metals are integrated with them. Secondary pollutant and combinations of multiple heavy metals are most common emissions from Chromium and Lead industries [9]. In steel and iron industry, more of a demand has been counted for chromium [16]. Burning of oil, fossil fuels and vehicular emissions are broader areas for study of emission of metals like lead, nickel and arsenic [17], and industrial pollution disperses cadmium in air.

These heavy metals represent spatial variation in their concentration depending upon their point of source and distance covered after the release. Seasonal variation has also been responsible for the quantitative difference in the air such as hot and cold climate. Meteorological variables, i.e. speed and wind directions, have also affected the level of concentration on diurnal and hourly basis [18–21]. This contribution to the ambient atmosphere has potentially elevated a supreme work in air quality management [22] by deteriorating air quality and causing harm to humans (Fig. 1).

## 3 Various Sampling Methods

Different techniques of sampling are followed to recognize the presence of several rare earth metals in ambient air of various countries India, Brazil, Spain, Egypt, Portugal, Denmark and Russia [23–29]. The concentration of $PM_{2.5}$ and $PM_{10}$ is determined by some conventional methods. These conventional methods utilize filter papers for collecting the samples of particulate matter. Extraction of heavy metals from filter papers includes further processing such as acid digestion. It is followed by heat treatment for separating heavy metals and atomic absorption spectroscopy for the approximation of the amount of rare earth metal present in ambient air [30].

Polypropylene filter papers are used in some studies in China for collecting the samples and implemented ICS—MS for quantifying the concentration of heavy metal components (Ni, Cu, Zn, Ni, Cr, Cd, Hg and As) including enrichment factor which acts as indicator for identifying the extent of variation caused by human in environment [30]. Another method graphite furnace atomic absorption spectrophotometry (GFAAS) is used in studies, in urban area for quantitative analysis for the heavy metal present in wide variety of solid or liquid samples composition which was collected in filter papers and using Bergh of microwave digestion [31–37].

Other techniques where filter papers are primarily used for collection of sample and analysis are inductively coupled plasma optical emission spectrometer (ICP-OES) and induced couple plasma atomic spectrometry (ICP-AES) for detection of specific range of heavy metals such as Fe, Cd, Pb, Mn, Cr, Ni and Cu in their respective samples [1]. Meanwhile, for the extraction of heavy metals from the sample, a range of temperature from 80 to 150 °C with a variation in the period of 2–36 h is followed in different studies accordingly for the quantification of the heavy metals [2].

It is found that generally, the samples are collected in filter papers and digested using the microwave and acid extraction [38]. Numerous analysing techniques have been evolved and involved by various individuals for the efficient quantification of the heavy metals, and it signifies that the use of atomic absorption spectroscopy is one of the efficient methods, and it is less expensive comparing to the other techniques.

## 4 Concentration and Emissions Around the World

To characterize the variations in the level of heavy metal contamination between 1990 and 2012, an assessment has been done to understand the trend of heavy metal emission in the atmosphere. The data has been collected from different European countries which is produced by CEIP and MSC-E and reported for period of twenty-two years [39, 40]. This gridded data retrieved from 24 countries of EMEP region signifies that spatial distribution of rare earth metals such as Cd, Pb, As concentration in the atmosphere has decreased gradually over a period of years and consistency of data has been improved [41], but still there is insufficient investigation has been performed in different regions of the world for some of the heavy metals which are becoming a serious concern for the detrition of the air quality.

The beginning for measurement of heavy metals started in 1950s in few sites but most of the inputs are provided in 1900s. The resultant Figs. 2, 3, 4, 5, 6 and 7 depict the concentration level of heavy metals from both anthropogenic and natural sources.

## *4.1 Lead*

Metallic lead, organic lead and inorganic lead are the three forms in which lead exist in nature. Lead metal particles primarily exist in atmosphere. Anthropogenic sources are mostly fossil fuel, and it is responsible for atmospheric lead emission in

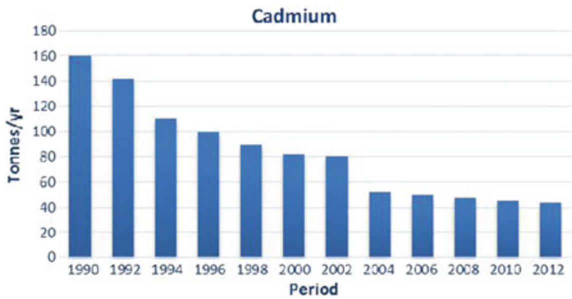



**Fig. 2** Emission of Cd from 1990 to 2012

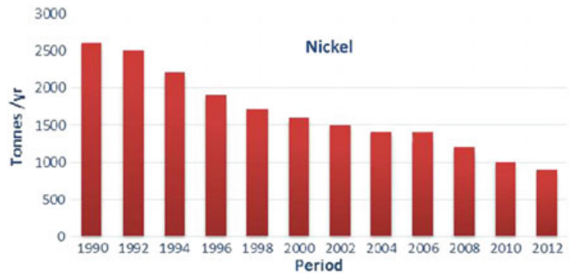



**Fig. 3** Emission of Ni from 1990 to 2012

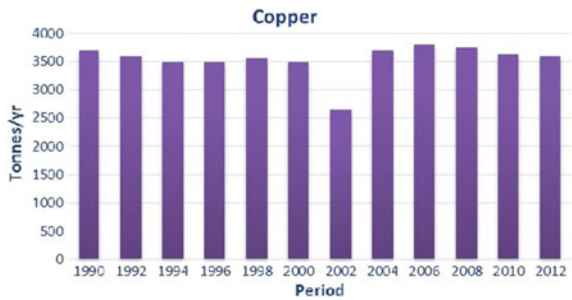



**Fig. 4** Emission of Cu from 1990 to 2012

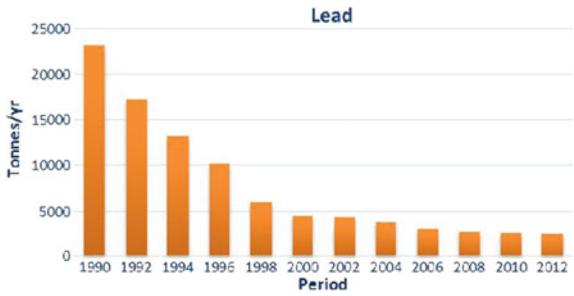



**Fig. 5** Emission of Pb from 1990 to 2012

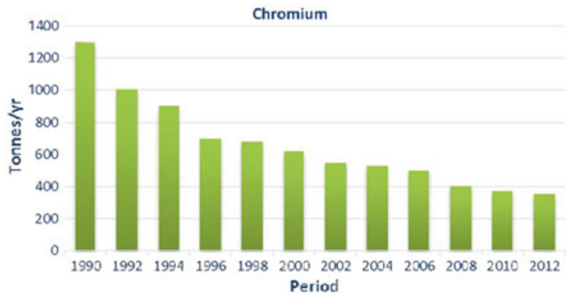



**Fig. 6** Emission of Cr from 1990 to 2012

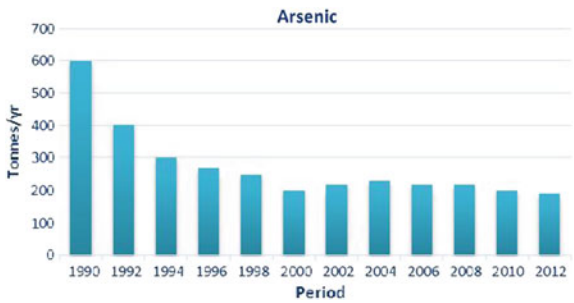



**Fig. 7** Emission of As from 1990 to 2012

traceable quantity, and therefore, this emission is contaminating the global atmosphere [42]. Earlier in 1980s, the emission rate in USA and European Union is 66,000–80,000 tons/year [43]. The emission data which is shown in Fig. 6 depicts that the amount has been decreased up to 90% by reaching an emission rate of 3000 tons/year from period of 1990 to 2012. This has been achieved by restriction in the use of leaded petrol. Further studies also report that one-third of emission of lead is detected from Asia and Europe. Around 2001, it was observed that China is leading polluter of lead according to the statistics observed from past 10 years [44]. The emission rate of China is 56,000 tons/year which is far more than that of Korea and Japan, which emits about 20,000 tons/year and there is no steep declination in emission rate which has been stable for past 5 years in China.

### 4.2 Cadmium

The global cadmium production has been increased from 17,000 tonnes to 22,000 tonnes over a period of 15 years. Several developing countries do not have proper disposable method for products containing cadmium owing to restrictions of community consciousness and unwanted material managing capacity. The total unnatural releases of Cd in atmosphere have reduced from around 7600 tons [45] to 3000 tons in the mid-1900s. While nickel cadmium batteries are a possible cause of Cd discharges from batteries, there has been a reduction of 47% in emissions across the globe. A complete research done on nickel cadmium batteries in European Union demonstrated those European Union countries having a battery collection system, a collection rate of 75% was achieved for the year 2000 which leads to its proper disposal [46]. It must be distinguished that the release of Cd in USA reported by the USEPA is remarkably extraordinary, nearly 2.5 times greater than China. The rate abruptly reduced to 854 tonnes/year in 2001 and successively displayed a steady rise to 2186 tonnes/year in 2010. In EMEP region, the cadmium release has declined to 60% [47] from 160 tonnes/year to 43 tonnes/year. In case of USA, amid 1970 and 1980, chief metals smelting was the chief cause of Cadmium release and in later in 1990 the emission rate decreased significantly, which was possibly connected to the amplified competence of stack emission controls.

### 4.3 Arsenic

The global emission from natural resources has been projected to be 7900 tons yearly, whereas the human-made factors are nearly thrice greater, i.e. 23,600 tons yearly [48]. Arsenic (As) is still used for the production of agricultural chemicals, dependent on the restrictions on the use that are in force the amounts produced vary between countries, such as it is banned in USA [49] as earlier arsenic was utilized in the wood preservation products [50] with a content existence more than 74%. Meanwhile, the Asian countries have contributed about 38% of entire As deposited over arctic and America (North). The Arsenic deposition has declined to 53% between 1990 and 2004 with a sharp decline during 2001 and 2002 [51]. The fossil fuels from the coal mines in northern and China (East) ranged, found the arsenic content from 55.7 to 156.7 mg $kg^{-1}$ [52]. In European countries, the level of arsenic content has declined about 54% from 1990 which is shown in Fig. 7 but the concentration has exceeded in 2013 in industrial and urban areas in countries like Poland, Belgium and Finland which have to induce the annual emission rate in the EMEP region.

## 4.4 Copper

The global emission from natural and the anthropogenic source has been estimated to be 28 and 35 thousand tonnes/year [53]. The maximum levels of Cu in the atmospheric PM were attained from quarrying. The smelter complex has been a major producer of copper worldwide with the estimate of approximately 3000 and 2700 tonnes [54], respectively. In between 1990 and 2012, Cu discharges in the European Union-28 fell by 1.3%. During 2011–2012, emissions reduced by 1.9%, mostly owing to condensed productions from Italy, Germany and Romania. In European countries, there is no significant difference in the emission rate since 1995 which is represented in Fig. 5. In 2002, the copper emission reduction occurred due to the strict regulations in the countries, but the increase in industrial activities has inflated the concentration level.

## 4.5 Nickel

Natural and anthropogenic sources emit nickel particulates in the atmosphere [44]. Nearby 30,000 tons of Ni is estimated to be released per year to the air from natural sources. The discharge of nickel particles from anthropogenic sources is estimated to be 1.4–1.8 times more than that from natural sources. A projected 57 k tons of Ni was discharged from conventional non-renewable fuels globally, and the global emission rate for nickel from other anthropogenic sources has been reported 98,000 tons/year [45, 55]. From Fig. 4, it is clear that the nickel emissions have been decreased up to 71% [45]. The concentration of nickel in Europe is reportedly been decreased by 2% in the year 2012–13. Meanwhile, in China, there has been a gradual increase in the concentration of Nickel every year since 1950, and the emission rate has been lifted to 3500 tonnes/year. There has been remarkable fluctuation from the period of 1978 to 2000 which reflects in the consumption pattern of nickel due to Asian financial crisis [56]. The nickel emissions from various industrial sources vary; it has increased from 165.07 tonnes/year in 1980 to 1637.46 tonnes/year in 2009, at yearly growth rate of nearly 8.3%.

## 4.6 Chromium

The biogenic sources account for 20–30% release of chromium annually. The chromium released into the environment in larger amounts due human activities accounts for 60–70% of the total emissions into the atmosphere [57, 58]. In European region countries between 1990 and 2012, the emission rate has decreased up to 74% by the reduction in concentration from 1300 tonnes/year to

350 tonnes/year which is depicted in Fig. 7. In Asian countries, the total emission of chromium has gradually reduced in last 15 years except 1998. This occurs due to reduced economic growth caused by financial crisis [59]. The probable explanation of economic decline occurred during that period occurred due to the reduction in coal combustion which is steady in the research of Tian [60]. Largest emission of chromium is estimated from Asia and Europe.

## 5 Adverse Health Effects and Its Impact

### *5.1 Lead*

The pure form of lead is a silver-white metal which when exposed to air oxidizes to form a blue-grey colour [61]. Mostly the particle size for lead emissions is less than $PM_{10}$ but emissions from high-temperature combustion can be as small as the particle size of less than $PM_1$ [61]. Large particles have the tendency to deposit around the source, whereas small particles have the potential to travel long distances of several thousand kilometres as studies have found evidence supporting the transboundary movement of lead present in ambient air. Minor elements can easily enter into human lungs leading to the possibility of health effects [61, 62].

**Adverse Health Impacts**

Lead is classified under class 2B carcinogenic element by the IRCA which means it is possibly carcinogenic to humans [63, 64]. For humans, even trace levels of lead exposure are toxic [61]. Lead particles are easily entered and absorbed in the respiratory tract and distributed to liver and kidney and stored in the bones [65]. Due to systemic toxicity, it affects multiple organs which can result in neurological, renal, cardiovascular, haematological, reproductive and gastrointestinal effects [61]. Exposures at the high level can cause damage to kidney, brain, decrease in sperm production for men, miscarriage to pregnant women [66]. Lead exposure to infants and unborn children is more threatening because it may cause premature births, diminish mental and learning ability in infants and young children, respectively [65].

### *5.2 Cadmium*

It is relatively soft metal with silver-white in colour in the purest form. Generally, cadmium is generated as the by-product from processing of mainly Zn, Pb and Cu rocks to lesser extent [61, 67, 68]. Airborne cadmium particles are very small and in the range of less than $PM_1$ [61]. Volatility and vapour pressure are relatively low in cadmium, and its compound however when released from anthropogenic combustion sources of high temperature, metal vapour is emitted which binds with particulate matter rapidly upon cooling [61, 68]. Cadmium has a relatively short lifetime in the atmosphere though available scarce evidence shows otherwise and it is subjected to a certain amount of transboundary movement [68]. Cadmium deposition in the Arctic and other remote regions confirms the intercontinental atmospheric transfer of cadmium particles [68].

**Adverse Health Impact**

Cd is toxic and inessential element for human life. Inhalation along with ingestion is the two major ways to which humans are exposed to cadmium [61–66, 68]. It is a carcinogen for humans by the inhalation route [61, 66, 68]. It does not act as carcinogen if ingested since, epidemiological data confirms lungs being the target organ and excessive levels of cadmium inhalation may severely damage the lungs [61, 66, 68]. In the human body, Cadmium has a very long half-life and slow exertion which leads to increased concentrations with age in tissues [66, 68]. Long-term exposure to low levels cadmium through inhalation and ingestion can result in cadmium build-up in the kidneys [61, 65, 66, 68]. Itai-Itai disease is associated with cadmium exposure in which fragility to bones, proteinuria and severe pain can occur [68]. The Kidney is observed as the most critical organ for cadmium toxicity in humans [61, 66, 68]. This is because it damages the proximal tubular cell due to which excessive protein exertion in urine occurs. However, the extent of exposure and duration determines the severity [68].

## *5.3 Arsenic*

Crystalline metallic arsenic is silver-grey solid with low thermal conductivity [69], [70]. Arsenic and its several compounds display metallic as well as non-metallic properties. Its principle valances are +3, +5, −3. Hence, it generally undergoes into trivalent and pentavalent forms of oxidation states [69, 70]. Arsenic which may present in the air as one of its many compound forms gets adsorbed on the surface of the particulate matter [69, 70]. Fine particles of the size generally less than 2 μm released into the atmosphere is present as arsenite and arsenate [67, 70]. Transboundary movement of arsenic particles is possible until wet or dry deposition again lead them to earth surface [70]. Evidence from the past studies shows that for an average rate dry deposition percentage of 0.5/hour and wet admission rate of 1.2–1.5% hourly, the arsenic aerosol can be transported over thousand kilometres or more [67, 70]. Operational conditions, metrological conditions and size of particles establish the residence time of the particulates [70].

**Adverse Health Impact**

Ingestion and inhalation are the two major routes for arsenic adsorption; however, inhalation of particulate matter bearing arsenic is a minor exposure route [67, 71].

It is absorbed and distributed via blood circulation throughout the body. Particle size, chemical form and solubility affect the level of concentration of As from the human lungs. Sufficient evidences from the studies show that non-living As complexes are carcinogenic for human body [72, 73]. Inhalation of arsenic particles has reported having dire neurological effects. Acute exposure to it can lead to vomiting, nausea, diarrhoea and irritation of respiratory system which in turn can cause bronchitis, laryngitis or rhinitis [67, 71, 74, 75], whereas increased risk of lung cancer, 'Blackfoot disease' skin lesions, severe dermatitis, hypertension, diabetes, cardiovascular and neurological effects are reported from chronic exposures [67, 74]. Several epidemiological studies and literature also indicate reproductive and developmental effects in humans [76], but the consistent evidence which shows any potential association between increased foetal mortality, stillbirths and spontaneous abortions is lacking [76–78].

## *5.4 Copper*

Copper is a metal that is abundantly found in Cu (I) +1 and Cu(II) +2 valence states in nature [79]. It is present naturally as free metal, still 80% of copper production is processed from low-grade ore containing less than 2% of the metal. It is utilized either as metal or an alloy across the globe. Generally, wind-blown dust, forest fires, volcanic eruptions are the reason behind the emission of copper particulate into the atmosphere naturally, and mining site, ore processing facilities, scorching of non-renewable fuels and mostly copper smelters are the man-made sources [79, 80]. Copper loading to surface water and soil is mostly due to the atmospheric deposition of copper [79]. The atmospheric residence time for fine copper particles is speculated to be about 2–10 days and even shorter residence time for polluted areas. Evidence supporting the long-range transboundary movement of copper particles is also observed in some studies [79–82].

**Adverse Health Impact**

There is no evidence available from studies related to carcinogenicity, teratogenicity and mutagenicity of inhaled copper or copper exposure due to which it is classified as non-carcinogenic [79]. However, ingestion is the major route for copper exposure through food and water [79]. The homeostatic mechanism controls the copper levels in the human body and regulates the bioaccumulation in tissues. Genetics, age and copper consumption are some factors on which copper-induced hepatic damage depends on. Studies have shown that severe acute oral toxicity of copper induces toxic effects on liver, brain, blood, kidney, gastrointestinal tract and foetus. Metal fume fever, a transient condition with influenza-like symptoms is observed to be caused due to exposure to copper dust, fumes and mists. Indian childhood cirrhosis, Wilson's disease and idiopathic copper toxicosis are the other diseases that mostly affect infants and children but there is evidence that these diseases are mostly caused due to the genetic defect and immoderate copper ingestion [79].

## 5.5 Nickel

Nickel is ubiquitous on earth surface—an element naturally found to be existing in several mineral forms [83]. There are different isotopes of natural nickel, among which five are stable and nineteen other are unstable isotopes [83]. It is usually present in +2 valence as Ni(II) under ambient condition. It can also present in other oxidation states, such as +4, +3, +1 and −1 but these are very inconsistent as compared to +2 oxidation state [83–85]. Atmospheric nickel emissions are mostly from the anthropogenic sources such as burning of fossil fuel (fossil fuels, diesel oil and fuel oil), mining, metallurgical processes, burning of waste and other multifarious sources. Transboundary movements of airborne nickel particles are possible because the average solubility in wet and dry depositions for nickel is not so high [86]. Since anthropogenic emission of nickel is common around the world, the existence of fine nickel units in the atmosphere might well be mostly due to indigenous sources but still extensive array cross-boundary mobilization of nickel particles cannot be overruled.

**Adverse Health Impact**

Occupational exposure to Ni through breath is prime reason for nickel toxicity, and it can affect the immune system and respiratory tract [83]. However, for the overall populace, food—major route for nickel contamination [87]. Fine particles of nickel of size around 5–10 μm enter into the respiratory tract, deposited and absorbed by the lungs; however, their physical and chemical configurations affect the rate of deposition, whereas the extent of absorption by lungs depends on upon the physical determinant such as surface area and size [87]. It reacts with vital metals from the body thus affecting the metabolism, which in turn may alter the poisonous and cancer-causing effects of Ni [87]. While, high level of Ni exposure can cause skin allergies, lung fibrosis, iatrogenic nickel poisoning and respiratory tract cancer, no reproductive effects of any kind are associated with it [83, 88, 89]. Epidemiological studies confirm that it is the most common and frequent skin allergen among the people around the industrial area [90]. Nickel ions in sensitized individuals on absorption by the skin lead to skin eruption, reddened skin, to ulcers and abscess in extreme cases [87, 91]. Evidence suggesting the great danger for lung cancer and nasal cancer is related with the inhalation of fine particles of nickel at occupational sites [87]. Still, no studies are present to show evidence of cancer to the general population from the nickel uptake from the environment [87].

## 5.6 Chromium

Chromium in free metal state is rare because metallic chromium readily reacts with oxygen from ambient atmosphere [92, 93]. It exists in dissimilar oxidation states among which Cr(III) and Cr(VI) are primarily found in nature [ii]. Chromium(III) compounds are among the most extensively present compounds on earth, whereas chromium(VI) is carcinogen [93]. Around 70% of atmospheric chromium is due to its release from unnatural causes and remaining constitute from natural sources [93]. Combustion of fuels, electroplating, refractory brick industry, metallurgical industries, cement industry and waste incineration are the major anthropogenic activities, meanwhile soil and rock erosion, wildfire and volcanic eruptions are the prime natural events which lead to the emission of chromium in the atmosphere [93]. From findings of several studies, it is observed that long-range transboundary movement of air borne chromium takes place in the atmosphere and particle size determines the rate of atmospheric movement of chromium particle [93].

**Adverse Health Impact**

Hexavalent form of chromium(VI) compounds are carcinogenic and toxic in nature [93]. However, moderate intake of chromium(III) is required for sound health [93]. Air, water, soil, food are the major routes of chromium exposure to general population especially young children. Dermal sensitization, chronic lung inflammation, chronic rhinitis, chronic bronchitis, carcinogenicity and genotoxicity are the chronic health effects of chromium. Chromium exposure to skin could cause skin ulcers, allergic contact dermatitis and swelling of skin [66].

## 6 Conclusion

Most of the heavy metals reached their peak emission level during the last two decade of the twentieth century, although the atmospheric emissions throughout the first period of the twenty-first era saw a sharp decline. This is attributed to the change in processes, end-user product, stringent legal compliance in developed nations and awareness and understanding of the harmful effects of rare earth metals on health and importantly environment. The emission data is limited to cover the fewer regions of the world mostly developed countries. Because developing countries and most importantly the rapidly growing developing economies in South East Asia do not have any mechanism in place which collects the recent emission data particularly related to heavy metal emission. It is very likely that the atmospheric emission of heavy metals have not declined as sharply as it seems. A large amount of manufacturing work involving the processing, utilization and production of heavy metal-containing products is shifted to the developing nations, and these regions, generally, do not have any reliable data about atmospheric emissions of heavy metal. In this review, it is also found that lead, cadmium, arsenic, copper, nickel, chromium possess the potential for long-range transportation of their particles due to which it can be said that its effects are not limited to the region of source emission. The carcinogenicity of the heavy metals is dependent upon the mode of assimilation into the body, and all the airborne heavy metals are not necessarily carcinogen. Several epidemiological studies supported this conclusion.

## References


1. Järup, L.: Hazards of heavy metal contamination. Br. Med. Bull. **68**(1), 167–182. Department of Epidemiology and Public Health, Imperial College, London, UK (2003)
2. Talebi, S.M., Abedi, H.: Concentration of heavy metals in the atmosphere of the city of Isfahan. Pollut. Res. **23**(2), 211–214 (2004)
3. Agarwal, S.K.: Automobile Pollution. Askish, New Delhi (1991)
4. Miranda, J., Crespo, I., Morales, M.A.: Absolute principal component analysis of atmospheric aerosols in Mexico City. Environ. Sci. Pollut. Res. **7**, 14–18 (2000)
5. Duruibe, J.O., Ogwuegbu, M.O.C., Egwurugwu, J.N. Heavy metal pollution and human biotoxiceffects. Int. J. Phys. Sci. **2**(5), 112–118
6. Langmuir, D.: Aqueous Environmental Geochemistry. Prentice Hall, New Jersey (1997)
7. Pope, C.A., Bates, D.A., Raizenne, M.E.: Health effects of particulate air pollution: time for reassessment? Environ. Health Persp. **103**, 472–479 (1995)
8. Gbadebo, A.M., Bankole, O.D.: Analysis of potentially toxic metals in airborne cement dust around Sagamu South Western Nigeria. J. Appl. Sci. **7**, 35–40 (2007)
9. Bennett, B.G.: Modeling exposure routes of trace metals from sources to man. In: Nriagu, J.O. (ed.) Changing Metals Cycles and Human Health, pp. 345–356. Springer, Berlin (1984)
10. Dockery, D.W., Pope III, D.C.A., Xu, X., Spengler, J.D., Ware, J.H., Fay, M.E., Ferris, B.G., Speizer, F.E.: An association between air pollution and mortality in six US cities. N. Engl. J. Med. **329**, 1753–1759 (1993)
11. Silvia, M.S., Annibal, D.P.N.A.D., Pereira, N., Emmanoel, V.S.F., Martha, T.: Short-term and spatial variation of selected metals in the atmosphere of Niteroi City, Brazil. Micro Chem. J. **78**, 85–90 (2004)
12. Katja, V.V., Claude, B., Christophe, F., Tania, B., Carlo, B., Sergey, R., et al.: Seasonal variations of heavy metals in the 1960s Alpine ice: sources versus meteorological factors. Earth Planet. Sci. Lett. **164**, 521–533 (1998)
13. Munir, H.S., Shaheen, N.: Annual and seasonal variations of trace metals in atmospheric suspended particulate matter in Islamabad. Pak. Water Air Soil Pollut. **190**, 13–25 (2008)
14. Figen, V., Yasushi, N., Shigeru, T.: The concentration trend and seasonal variation of metals in the atmosphere in 16 Japanese cities shown by the results of National Air Surveillance Network (NASN) from1974 to 1996. Atmos. Environ. **34**, 2755–2770 (2000)
15. Gulia, S., Nagendra, S.M.S., Khare, M., Khanna, I.: Urban air quality management—a review. Atmos. Pollut. Res. **6**, 286 (2015)
16. Khillare, P.S., Balachandran, S., Bharat, R.M.: Special and temporal variation of heavy metal in atmospheric aerosol of Delhi. Environ. Monit. Assess. **90**, 1–21 (2004)
17. Tian, H., Liu, K.Y., Zhou, J.J., Lu, L., Hao, J.M., Qiu, P.P., Gao, J.J., Zhu, C.Y., Wang, K., Hua, S.B.: Atmospheric emission inventory of hazardous trace elements from China's coal-fired power plants–temporal trends and spatial variation characteristics. Environ. Sci. Technol. **48**, 3575–3582 (2014)
18. Moreno-Grau, S., Perez-Tornell, A., Moreno-Grau, J., Moreno-Clavel, J.: Determination of lead in aerosol sample collected on glass fiber filters by an improved atomic absorption spectrometry method. Water Air Soil Pollut. **96**, 145–153 (1997)
19. Abdel-shafy, H.I., Hindy, K.T., Abdel-sabour, M.: FHeavy metal level in the environmental of Ismailia city. Egypt. J. Environ. Stud. **39**, 279–289 (1992)
20. Vasconcelos, M.T.S.D., Tavares, H.M.F.: Atmospheric metal pollution (Cr, Cu, Fe, Mn, Ni, Pb and Zn) in Oporto City derived from results for low-volume aerosol samplers. Sci. Total Environ. **212**, 11–20 (1997)
21. Karl, X.Y., Swami, K., Liaquat, H.: Determination of trace 264 metals in atmospheric aerosols with a heavy matrix of cellulose by 265 microwave digestion-inductively coupled plasma mass spectroscopy. SpectrochimicaActa **57**, 73–84 (2002)
22. Drobyshev, A.I., Emelina, O.I.: Analysis of atmospheric aerosols by atomic emission spectroscopy with electrical discharge sampling. J. Anal. Chem. **56**, 577–580 (2001)

23. Loska, K., Wiechuła, D., Korus, I.: Metal contamination of farming soils affected by industry. Environ. Int. **30**(2), 159–165 (2004)
24. EMEP Manual for Sampling and Chemical Analysis: EMEP Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe, Norwegian Institute for Air Research (2001)
25. Guidelines for the Measurement of Ambient Air Pollutants: Central Pollution Control Board, India (2011)
26. Meyer, M.B., Rupprecht, E.G.: Particulate matter sampling methods: the importance of standardization. J. Aerosol Sci. **27**, S349–S350 (1996)
27. Hinds, W.C. Aerosol Technology: Properties, Behaviour and Measurement of Airborne Particles, 2nd edn. Wiley, New York (1999)
28. Wagner, R.E. (ed.): Guide to Environmental Analytical Methods, 4th edn. Genium Publishing Corporation, Schenectady (1998)
29. Barbes, L., Barbulescu, A., Rădulescu, C., Stihi, C., Chelarescu, E.D.: Determination of heavy metals in leaves and bark of Populus nigra L. by atomic absorption spectrometry, Romanian Reports. Physics **66**(3), 877–886 (2014)
30. Dulama, I.D., Popescu, I.V., Rădulescu, C., Stihi, C., Ionita, I., Bucurica, I.A., Chelarescu, D. E., Nitescu, O.V., Stirbescu, R.: Characterization of Olt river water quality using analytical methods. Rom. Rep. Phys. **65**(4), 1519–1527 (2013)
31. Jais, N.M.: Kajian Kepekatan Logam Berat Daripada Sampel Kualiti Udara di Kampus, Universiti Tun Hussein Onn Malaysia (UTHM). Degree Thesis. UniversitiTun Hussein Onn Malaysia (2012)
32. Denier van der Gon, D.H.A.C., van het Bolscher, M., Visschedijk, A.J.H., Zandveld, P.Y.J.: Study to the effectiveness of the UNECE Heavy Metals Protocol and costs of possible additional measures. Phase I: Estimation of emission reduction resulting from the implementation of the HM Protocol. TNO-report B&O-AR 2005/193 (2005)
33. Berdowski, J.J.M., Baas, J., Bloos, J.P.J., Visschedijk, A.J.H., Zandveld, P.Y.J.: The European Emission Inventory of Heavy Metals and Persistent Organic Pollutants for 1990. TNO Institute of Environmental Sciences, Energy Research and Process Innovation, UBA-FB report 104 02 672/03, Apeldoorn, 239 p. (1997)
34. Mareckova, K., Wankmueller, R., Moosmann, L., Pinterits, M., Tista, M.: Inventory Review 2014, Technical Report 1/2014, CEIP, ISBN 978-3-99004-300-4 (2014)
35. Murozumi, M., Chow, T.J., Patterso, C.: Chemical concentrations of pollutant lead aerosols, terrestrial dusts and sea salts in Greenland and Antarctic snow strata. Geochim. Cosmochim. Acta. **33**, 1247e1294 (2014)
36. Pacyna, J.M., Lindgren, E.S.: Atmospheric transport and deposition of toxic compounds. In: Brune, D., Chapman, D.V., Gwynne, M.D., Pacyna, J.M. (eds.) The Global Environment, pp. 386–407. Wiley, New York (1997)
37. www.ncbi.nlm.nih.gov/books/NBK304378
38. Rydh, C., Svärd, B.: Impact on global metal flows arising from the use of portable rechargeable batteries. Sci. Tot. Environ. **302**, 167–184 (2003)
39. Pacyna, J.M.: Monitoring and assessment of metal contaminants in the air. In: Chang, L.W. (ed.) Toxicology of Metals, pp. 9–28. CRC Press, Boca Raton (1996)
40. Pacyna, J.M.: Atmospheric trace elements from natural and anthropogenic sources. In: Nriagu, J.O., Davidson, C.I. (eds.) Toxic Metals in the Atmosphere, pp. 33–50. Wiley, New York (1986)
41. Ilyin, I., Travnikov, O., Aas, W.: Heavy metals: transboundary pollution of the environment. EMEP/MSC-E Status Report 2/2006. Meteorological Synthesizing Centre—East, Moscow, Russian Federation (2006)
42. Hao, J.M., Tian, H.Z., Lu, Y.Q.: Emission inventories of $NO_x$ from commercial energy consumption in China, 1995–1998. Environ. Sci. Technol. **36**, 552–560 (2002)
43. EU: Risk assessment report for Cd and CdO, Final report, Belgium (2007)
44. Pacyna, J.M., Pacyna, E.G., Aas, W.: Changes of emissions and atmospheric deposition of mercury, Pb, and Cd. Atmos. Environ. **43**, 117–127 (2009)

45. Pozniakov, V.Y.: The “Severonikel” smelter complex: history of development. In: Kozlov, M.V., Haukioja, E., Yarmishko, V.T. (eds.) Aerial Pollution in Kola Peninsula, Proceedings of the International Workshop, St. Petersburg, 14–16 April. Kola Scientific Centre, Apitity, Russia (1992)
46. Agency for Toxic Substances and Disease Registry: Toxicological Profile for Arsenic. US Department of Health and Human Services, Atlanta, GA (1991)
47. Ilyin, I., Rozovskaya, O., Sokovyh, V., Travnikov, O.: Atmospheric modelling of heavy metal pollution in Europe: further development and evaluation of the MSCE-HM model. EMEP/MSC-E Technical Report 4/2007, 52 pp (2007)
48. Barceloux, D.G.: Vanadium. J. Toxicol. Clin. Toxicol. **37**, 265–278 (1999)
49. Hao, J., Tian, H., Lu, Y.: Emission inventories of $NO_x$ from commercial energy consumption in China, 1995–1998. Environ. Sci. Technol. **36**(4), 552–560 (2002)
50. Tian, H., Cheng, K., Wang, Y., Zhao, D., Lu, L., et al.: Temporal and spatial variation characteristics of atmospheric emissions of Cd, Cr, and Pb from coal in China. Atmos. Environ. **50**, 157–163 (2012)
51. Study on the possible effects on human health and the environment in Asia and the Pacific of the trade of products containing lead, cadmium and mercury, UNEP (2011)
52. U.S. ATSDR: Toxicological profile for lead. (Draft for Public Comment). U.S. Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry, Atlanta, U.S.A. ibid at 107 (2005)
53. He, B., Liang, L., Jiang, G.B.: Distributions of arsenic and selenium in selected Chinese coal mines. Sci. Total Environ. **296**, 1926 (2002)
54. Alimonti, A., Petrucci, F., Krachler, M., Bocca, B., Caroll, S.: Reference values for chromium, nickel and vanadium in urine of youngsters form the urban area of Rome. J. Environ. Monit. **2**, 351–354 (2000)
55. Pacyna, J.M., Ottar, B.: Vertical distribution of aerosols in the Norwegian Arctic. Atmos. Environ. **22**, 2213–2222 (1988)
56. Koren, H.: Handbook of Environmental Health and Safety, vol. I. Levis Publishers, Chelsea (1991)
57. IARCInorganic and Organic Lead Compounds. Monograph on the Evaluation of Carcinogenic Risks to Humans. http://www.monographs.iarc.fr/ENG/Monographs/vol87/mono87.pdf (2006)
58. IARC: A Review of Human Carcinogens, Part C: Arsenic, Metals, Fibres, and Dusts, 100. Monographs on the Evaluation of Carcinogenic Risks to Humans (2012)
59. http://www.monographs.iarc.fr/ENG/Monographs/vol100c/mono100c.pdf
60. Monitoring and Statistical Evaluation of Heavy Metals in Respirable Dust in Jos Metropolitan Area, IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402, p- ISSN: 2319-2399. vol. 8, Issue 9 Ver. IV, PP 01-10 (2014)
61. Martin, S., Griswold, W.: Human health effects of heavy metals. Environmental Science and Technology Briefs for Citizens, Center for Hazardous Substance Research, Issue 15 (2009)
62. Final Review of Scientific Information on Cadmium: UNEP. Chemical Branch, DTIE (2010)
63. Lide, D.R. (ed.): CRC Handbook of Chemistry and Physics, 83rd edn. CRC Press, Boca Raton (2002)
64. Maggs, R.: A review of Arsenic in Ambient Air in the UK. Report prepared for the Department of the Environment, Transport and the Regions, Scottish Executive, The National Assembly of Wales (2000)
65. ATSDR: Toxicological Profile for Arsenic. www.atsdr.cdc.gov/toxprofiles/tp2.html (2000)
66. Slooff, W., Haring, B.J.A., Hesse, J.M., Janu, J.A., Thomas, R.: Integrated Criteria Document Arsenic. Report No 7104001004 (1990)
67. Assessment Report on Arsenic for Developing Ambient Air Quality Objectives, International Programme on Chemical Safety (IPCS). Arsenic and Arsenic Compounds. Environmental Health Criteria 224. Published under the Joint Sponsorship of the United Nations

Environmental Programme, the International Labour Organisation, and the World Health Organisation (WHO) (2001)
68. International Agency for Research on Cancer (IARC): IARC Monographs on the Evaluation of the Carcinogenic Risks to Humans, Vol 100 C, Arsenic, Metals, Fibers and Dusts; IARC: Lyon, France (2012)
69. Some metals and metallic compounds. Lyon, International Agency for Research on Cancer, pp. 39–142 (IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, vol. 23) (1980)
70. Overall evaluations of carcinogenicity: an updating of IARC Monographs Volumes 1 to 42. Lyon, International Agency for Research on Cancer, pp. 100–106 (IARC Monographs on the Evaluation of Carcinogenic Risk to Humans, Supplement 7) (1987)
71. World Health Organization (WHO): Arsenic and Arsenic Compounds: Second Edition (International Programme on Chemical Safety, Environmental Health Criteria, 224), Geneva, Switzerland, World Health Organisation (2001)
72. Institute of Environment and Health (IEH): Review of incineration and other combustion techniques: IEH health effects review. MRC Institute for Environment and Health (2003)
73. Science Report: A review of the toxicity of arsenic in air, Environment Agency (2008)
74. EPA: Summary review of the health effects associated with the copper (1987)
75. Alloway, B.J.: Heavy Metals in Soils, 2nd edn. Blackie Academic and Professional, London (1995)
76. Cempel, M., Nikel, G.: Nickel: a review of its sources and environmental toxicology. Polish J. Environ. Stud. **15**(3), 375–382 (2006)
77. Candelone, J.-P., Hong, S., Pellone, C., Boutron, C.F.: Post-industrial revolution changes in large-scale atmospheric pollution of the northern hemisphere by heavy metals as documented in central Greenland snow and ice. J. Geophys. Res. **100**, 16,605–16,616 (1995)
78. Nriagu, J.O.: Global metal pollution. Environment **32**, 7–33 (1990b)
79. Diagomanolin, V., Farhang, M., Ghazi-Khansari, M., Jafarzadeh, N.: Heavy metals (Ni, Cr, Cu) in the Karoon waterway river, Iran. Toxicol. Lett. **151**(1), 63 (2004)
80. Clayton, G.D., Clayton, F.E.: Patty's Industrial Hygiene Toxicology, 4th edn. In: Morselli, A. L. et al. (eds.) Soluble and insoluble fractions of heavy metals in wet and dry atmospheric depositions in Bologna, Italy. Environ. Pollut. **124** (2003)
81. Wiley-Interscience Publication, New York, pp. 2157–2173 (1994)
82. Schaumlöffel, D.: Nickel species: analysis and toxic effects. J. Trace Elements Med. Biol. **26** (2012)
83. Clarkson, T.W.: Biological Monitoring of Toxic Metals, pp. 265–282. Plenum Press, New York (1988)
84. Kasprzak, K.S., Sunderman, F.W., Salnikow, K.: Nickel carcinogenesis. Mutat. Res. **533**(1–2), 67 (2003)
85. Dermatology: Clinical & Basic Science Series. Nickel and the Skin: Absorption, Immunology, Epidemiology, and Metallurgy (2002)
86. Gad, S.C.: Nickel and nickel compounds. In: Anderson, B., Peyster, A., Gad, S.C., Hakkinen, P.J.B., Kamrin, M., Locey, B., Mehendale, H.M., Pope, C., Shugart, L., Wexler, P. (eds.) Encyclopedia of Toxicology, 2nd edn, pp. 220–223. Elsevier, London (2005)
87. Kohl, W.H.: Handbook of Materials and Techniques for Vacuum Devises, 623 p. Rheinhold Publishing, New York (1967)
88. Chromium(VI) Handbook, Independent Environmental Technical Evaluation Group (IETEG). CRC Press, London (2005)
89. Rowbotham, A.L., et al.: Chromium in the UK environment: an evaluation of exposure of the UK general population and possible adverse health effects. J. Toxicol. Environ. Health B **3**, 145–178 (2000)
90. Seigneur, C., Constantinou, E.: Environ. Sci. Technol. **29**, 222–231 (1995)
91. Nriagu, J.O.: Historical Perspectives; and, Production and Uses of Chromium, Chromium in the Natural and Human Environments, vol. 20, pp. 1–20, 81–104. In: Nriagu, J.O., Nieboer, E. (eds.) Wiley, New York (1988)

92. Spokes, L.J., Jickells, T.D.: Speciation of Metals in the Atmosphere, in Chemical Speciation in the Environment, pp. 137–168. In: Ure, A.M., Davidson, C.M. (eds.) Blackie Academic and Professional, Glasgow, Scotland (1995)
93. Government of Canada: Chromium and its compounds. In: Act, Canadian Environmental Protection (ed.) Priority substances list assessment report. Government of Canada, Minister of Supply and Services Canada, Ottawa, Ontario (1994)

# Soil-Less Use of Aquatic Macrophytes in Wastewater Treatment and the Novel SHEFROL® Bioreactor

**M. Ashraf Bhat, Tasneem Abbasi and S. A. Abbasi**

## 1 Challenges Associated with Sewage Treatment

India and China are not only the two most populous nations of the world, they also happen to be among the most insanitary ones, with ca 80% of the sewage generated by their 2.5 billion inhabitants discharged untreated in waterbodies and on land [1, 2]. This exacerbates the adverse impact of industrial wastewater discharge [3–7] and has led to gross pollution of most of their rivers and lakes, and expenditure worth billions of rupees is incurred every year on diseases to humans and damage to ecosystem services that this pollution causes [8, 9]. The situation in most other countries situated in the southern hemisphere is similar [8, 9], whereas some parts of major cities and towns are serviced by centralized sewage treatment plants, most households are either dependant on septic tanks—which generate highly putrid effluents and are unsuitable except if used in situations when the number of households per unit land area is low—or have no sewage treatment facility at all. Indeed this is how it is in most suburban and rural areas, and in slums which now exist in all cities [2, 8, 9].

M. A. Bhat · T. Abbasi · S. A. Abbasi (✉)
Centre for Pollution Control and Environmental Engineering,
Pondicherry University, 605014 Puducherry, India
e-mail: abbasi.cpee@gmail.com

M. A. Bhat
e-mail: bhatashraf@gmail.com

T. Abbasi
e-mail: tasneem.abbasi@gmail.com

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_30

If we take India as representative of the third world situation, it is seen that:

- Between 2009 and 2015, sewage generation in cities increased by 62% while the sewage treatment capacity increased by only 19%. This trend, which has no prospect of reversal as of now, will keep enhancing the fraction of sewage going untreated as the population rises—thereby burdening the environment more and more.
- As of now 62 billion litres of untreated sewage is released into Indian rivers daily, or about 3 trillion litres annually. This input is also set to increase substantially.
- The pollution of other wetlands, and stretches of land, due to release of raw sewage, is equally enormous.

These statistics indicate the mind-blowing scale of the sewage treatment challenge faced by the majority of the world's population.

## 2 The Imperatives

Given the above context, development of cheaper and greener technologies for wastewater treatment forms one of the greatest challenges for environmental technologists.

There is an even greater need to develop wastewater treatment systems appropriate for small-sized neighbourhoods, peri-urban areas, and rural areas which lie out of the coverage of centralized wastewater treatment facilities. In order to be viable, such systems must have the following attributes:

(i) Should be low-cost;
(ii) Should be easy to install;
(iii) Should be easy to operate and maintain;
(iv) Should generate little or no waste of their own;
(v) Should be economical as well as technically viable at very low to medium scales.

## 3 Pre-existing Systems Based on Soil-Less Use of Plants for Wastewater Treatment in 'Thin-Film' or 'Nutrient-Film' Flow Mode

It has been known to humankind that dirty water flowing into thick stands of vegetation comes out substantially cleaned [10–12], but systematic efforts to harness this ability of plants to cleanse water started only towards the latter half of the previous century. Those efforts were pioneered by, among others, Kickuth [13], Seidel [14–17], Sinha and Sinha [18], and Wolverton and co-workers [13–24].

The approaches were primarily of two types [11, 12, 25]. The first one involved the use of plants like common read *(Phragmites australis)* rooted in soil wherein soil played a key supporting role in water treatment. The other was based on free-floating weeds like salvinia *(Salvinia molesta)* [26] water hyacinth *(Eichornia crassipes)* [27], and duckweed *(Lemna sp, Spirodella sp)* in which the plants rested on the water surface. Such systems did not need soil and could be operated in tanks and trenches. Over the years, many bioreactors were designed which were distinguished from each other principally in terms of their hydraulic regime (horizontal/vertical/subsurface flow), choice of plant species, reactor geometry, and mode of operation.

Attempts to mimic the ability of natural wetlands in treating wastewater led to the concept of 'artificial' or 'constructed' wetlands wherein the range of treatment was sought to be maximized.

A third approach was also taken, inspired by the ancient agricultural technique of hydroponics (Greek: *hydro* for water and *'ponics'* for working) [28]. In hydroponics, plants are either hung aboveground with the roots spread in the air, or allowed to anchor in an 'inert' medium like sand, gravel, or plastic beads, while nutrients are provided in the form of either a spray on the roots (when the roots are unanchored), or as a thin film or sheet of nutrient-laden water flowing through the roots anchored in an inert media [28]. This manner of soil-free agriculture has had very limited application across several centuries but in more recent times it has been explored as a possible means of utilizing wastewater. In still more recent times, the technique is being explored as a means of treating wastewater. The state of the art is summarized in Tables 1, 2 and 3. As may be seen, even though 60 reports exist, originating from all over the world, wherein a myriad of species have been explored, nearly all such systems have hydraulic retention times (HRTs) of 1 day or more; several days in many instances, indicating their inefficiency. On the other hand, the few studies which have used shorter HRTs, for example the studies of Bouzoun et al. [29] and Li et al. [30, 31] have resulted in low extent of treatment.

A common subsequent step is all vascular plant-based wastewater treatment systems is to use the harvested plants as a source of biogas [32–35] and/or organic fertilizer. Even allelopathic plants which release toxic chemicals when rain or dew trickles down their canopy [36] turn to benign fertilizers upon vermicomposting [37–39].

## 4 The SHEFROL Bioreactor®

As detailed elsewhere [40, 41], we have developed a novel bioreactor SHRFROL®, of which a patent claim has been registered. SHRFROL® is also, essentially, based on a hydroponic technique, of the 'thin-film' pedigree. Its novelty lies in its design and operation such that they enable much more rapid, inexpensive, and clean treatment of wastewater than pre-existing thin-film systems. The reactor has been extensively tested at pilot plant and full scale since 2006 [42].

**Table 1** Wastewater treatment systems reported so far by other authors which use no inert media for supporting the roots

| S. no. | Capacity/flow rate, $m^3\ d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | | | | References |
|---|---|---|---|---|---|---|---|---|
| 1. | Not stated | Cucumber (*Cucumis sativus)* | 10 | *P, 54*<br>*Mg, 11*<br>*Fe, 74*<br>*Pb, 80* | *Zn, 21*<br>*Mn, 80*<br>*Ti, 84* | *Ba, 71*<br>*B, 13*<br>*Ag, 43* | *Cu, 65*<br>*Cr, 88*<br>*Ni, 47* | [41] |
| 2. | 0.4, 0.8, 1.5 | Reed canarygrass *(Phalaris arundinacea)* | 9.2,4.6, 2.4 | *BOD, 81*<br>*FC, 90* | *SS, 75* | *TN, 29.9* | *TP, 20.8* | [42] |
| 3. | 1.4, 1.9, 2.8, 3.8, 5.7 | Common reed *(Phragmites australis),* cucumber *(C. sativus),* reed canarygrass *(P. arundinacea),* cattail *(Typha latifolia),* bull rush *(Scirpus lacustris)* | 0.07, 0.11, 0.13, 0.15, 0.16 | *SS, 70*<br>*BOD, 48* | *TN, 42* | *TO, 90* | *TP, 42* | [42] |
| 4. | 11 | Reed canary grass *(P. arundinacea)* | Not stated | *COD, 71.2* | *TSS, 89.3* | *TKN, 57.5* | *TO, 91-98* | [43] |
| 5. | 0.00,075 | Sunflower *(Helianthus)* | 2 | *U, 95* | | | | [44] |
| 6. | 11.5 | Lettuce *(Lactuca sativa)* | 7 | *TP*, 75 | | | | [45] |
| 7. | 14.4 | Pyrethrum *(Chrysanthemum cinerariaefolium*) | 2 | *BOD*, 91<br>*TN*, 40 | *SS*, 95 | *TP*, 80 | *COD*, 99 | [46] |
| 8. | 14.4 | Rose *(Rosa)* | 1 | *COD*, 89 | *SS*, 94 | *BOD*, 95 | *P*, 20-23 | [47] |
| 9. | Not stated | Common reed *(P. australis),* maize *(Zea mays L.)* | 15 | *Cu, 16-19* | | | | [48] |
| 10. | Not stated | Lettuce (*L. sativa*) | 24 | *P*, 98 | | | | [49] |
| 11. | 14.4 | Datura (*Datura innoxia*) | 2 | *BOD, 91* | *COD, 82 N, 93 ± 12 SS, 98* | | *P, 38 ± 9* | [50] |

(continued)

**Table 1** (continued)

| S. no. | Capacity/flow rate, $m^3\ d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | | | References |
|---|---|---|---|---|---|---|---|
| 12. | Not stated | Pistia *(Pistia stratiotes)* | 21 | *BCF > 1000*<br>*for all metals except Ni, BCF (675.80)* | | | [51] |
| 13. | Not stated | Alfalfa *(Medicago sativa)* | 30 | *Azinophos, ≥ 90* | | | [52] |
| 14. | 12.96 | Wooly digitalis *(Digitalis lanata),*<br>foxglove *(Digitalis purpurea)* | 2 | Wooly digitalis<br>*SS*, 82 *BOD*, 93<br>*COD*, 79 | | Foxglove<br>*SS*, 92 *BOD*, 92<br>*COD*, 84 | [53] |
| 15. | Not stated | Common reed<br>*(P. australis)* | 15 | *BCF > 1000, for Cd (1193)* | | | [54] |
| 16. | Not stated | Creeping bentgrass *(Agrostis stolonifera),*<br>rapeseed *(Brassica napus),*<br>white clover *(Trifolium repens)* | 56, 96, 146 | *30,000 mg/kg of Zn was accumulated in roots, 490 mg/kg Zn in shoots of A. Stolonifera* | | | [55] |
| 17. | Not stated | Black willow *(Salix nigra),*<br>hybrid poplar *(Populus)* | 80, 102 | *Total NDMA,* | | | [56] |
| | | | | *in summer, 98.3* | | *in winter, 81.4* | |
| 18. | 0.0009 | Wheat *(Triticum),* barely *(Hordeum vulgare),*<br>timothygrass *(Phleum pratense),*<br>orchardgrass *(Dactylis)* | 21 | *COD*, 88.6 | *TS*, 72.4 | *$NO_4^+$-N, 60.8* | [57] |
| 19. | 0.0009 | Wheat *(Triticum)* | 21 | *COD*, 85.9 | *TS*, 75.7 | *$NO_4^+$-N, 75.6* | [58] |
| 20. | Not stated | Silver beet *(Beta vulgaris)* | 84 | *Accumulation in mg/kg, From secondary treated effluent. Cu, 58.33 and Zn, 3400. From control sol. Cu, 69.30 and Zn, 1836.* | | | [59] |
| 21. | Not stated | Water spinach *(Ipomoea aquatica)* | 2 | *COD, 84.5* | *TSS, 91.1* | *BOD, 88.5* | [60] |

(continued)

**Table 1** (continued)

| S. no. | Capacity/flow rate, $m^3\ d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | | | References |
|---|---|---|---|---|---|---|---|
| 22. | 0.00069 | Barely *(H. vulgare)* | 21 | *TS, 60.5 COD, 83.1*<br>$PO_4^{3-}$*-P, 95.1s* | $NO_4^+$*-N, 76*<br>$NO_2^-$*-N, 99.2*<br>$NO_3^-$ *-N, 81.6* | | [61] |
| 23. | 0.00069 | Water hyacinth *(E. Crassipes),* water lettuce *(P. Stratiotes),* parrot's *(Myriophyllum*feather *aquaticum)* | 6, 12 | *TS, 21.4-48*<br>*COD, 71.1-89.5*<br>$NO_4^+$*-N, 55.9-76* | $NO_2^-$ *-N, 49.6-90.6*<br>$NO_3^-$ *-N, 34.5-54.4*<br>$PO_4^{3-}$ *-P, 64.5-76.8* | | [62] |
| 24. | 0.00069 | Wheat *(Triticum),* barely *(H. vulgare),* oats *(Avena sativa)* | 8, 21 | *TS, 53.3-57.7*<br>*COD, 55.7-78.7*<br>$NO_4^+$*-N, 76-80* | $NO_2^-$ *-N, 85.1-92.9*<br>$NO_3^-$ *-N, 61.2-79.3*<br>$PO_4^{3-}$ *-P, 74.1-93* | | [63] |
| 25. | Not stated | Java waterdropwort *(Oenanthe javanica)* | 1,2,3 | *COD,* 17-47<br>*TP,* 8-15 | *TN,* 31-64<br>$NO_X$*-N,* 71-97 | | [64] |
| 26. | Not stated | Pistia *(P. stratiotes)* | 35 | *At pH5, Pb accumulation* $\mu$*g/gm* | | | [65] |
| | | | | *Dry root, 321* ± *83* | *Dry leaves, 15.1* ± *0.9* | | |
| 27. | Not stated | Lettuce *(L. Sativa)* | 16. 27,39 49, 58 | *Cr, > 92*<br>*Ni, > 85* | *B, Pb, Zn, > 60*<br>*As, Cd, Cu, > 30* | | [66] |
| 28. | Not stated | Gibbous duckweed *(Lemna gibba)* | 5 | *Accumulation (ppm)* | | | [67] |
| | | | | *As, 0.6* | *U, 0.24* | *B, 765* | |

(continued)

**Table 1** (continued)

| S. no. | Capacity/flow rate, $m^3\ d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | References |
|---|---|---|---|---|---|
| 29. | 7.5, 30, 45<br>60, 75, 90 | Watercress (*Nasturtium officinale*) | 0.6, 0.15<br>0.1, 0.075<br>0.06, 0.05 | *Absorption TN,18.0 TP, 16.4*<br>*Sedimentation TN,62.2 TP, 75.9*<br>*Others TN, 19.8 TP, 7.7* | [29] |
| 30. | 0.048 | Tomato *(Solanum lycopersicum)* | 7 | *$NO_3$-N, 99* | [68] |
| 31. | Not stated | Cana *(Canna indica)* | Not stated | *COD*, 64.8; *SS*, 88.7 | [69] |
| 32. | 14.4 | Datura *(D. innoxia)* | 2 | *BOD*, 93; *COD*, 87; *N*, 93 ± 12; *SS*, 97 | [70] |
| 33. | 0.033 | Taro *(Colocasia esculenta)* | 20 | *Pb, 46.3-89.5*; *Cd, 51.5-69.5* | [71] |
| 34. | Not stated | Cucumber *(C. sativus)* | 22 | *CBZ accumulation (µg/kg) of fresh biomass.*<br>*CBZ, 5159.7* | [72] |
| 35. | Not stated | Cattail *(T. latifolia)* | 7, 14, 21 | *CBZ, 56-82* | [73] |
| 36. | Not stated | Ryegrass *(Lolium perenne)* | 10 | *TN, 45-55* | [74] |
| 37. | Not stated | Water hyacinth *(E. Crassipes)*,water lettuce *(P. stratiotes)* | 28 | *COD, 59.05–83.61*<br>*TKN, 85.71*<br>*$PO_4^{3-}$ -P, 54.46–78.46*<br>*$NH_3$ -N, 81.90-84.76*<br>*$NO_2^-$ -N, 54.67-70.76*<br>*$NO_3^-$ -N, 48.62-89.83* | [75] |
| 38. | 2.88, 3.16 | Water hyacinth *(E. crassipes)*, salvinia *(S. molesta)* | 0.5 | E. crassipes<br>*TIN*, 46.0<br>*TKN*, 43.7<br>*$PO_4$*-P, 44.4<br>*TP*, 43.6<br>S. molesta<br>*TIN*, 19.8<br>*TKN*, 30.9<br>*$PO_4$-P*, 23.8 | [76] |

(continued)

**Table 1** (continued)

| S. no. | Capacity/flow rate, $m^3\ d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | | | References |
|---|---|---|---|---|---|---|---|
| 39. | Not stated | Vetiver *(Chrysopogon zizanioides)* | 7, 14, 21 | *N, 64.36*<br>*P, 62.26* | *Ni, 76.65*<br>*EC, 40.90* | *Zn, 100*<br>*Mn, 100* | [77] |
| 40. | Not stated | Water hyacinth (*E. crassipes)* | 7 | *Accumulation mg/kg dry weight. Cu, 7802.1* | | | [78] |
| 41. | Not stated | Water spinach *(I. aquatica)* | 1 | $NH_3$*-N, 83*<br>*TP, 60* | $NO_2^-$ *-N,87*<br>*TSS, 88* | $NO_3^-$ *-N, 70*<br>*BOD, 63* | [79] |

* Where multiple HRT's have been employed, the extent of treatment achieved at the Highest HRT has been given here

**Table 2** Soil-less wastewater treatment systems reported so far which use inert media for supporting the plant roots

| S. no. | Capacity/flow rate, $m^3 d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | | | | References |
|---|---|---|---|---|---|---|---|---|
| 1 | 28.8 | Common reed *(P. australis)*,<br>napier grass *(Pennisetum purpureums)* | 2.5 | *DDT, 65-82* | | | | [80] |
| 2 | Not stated | Gaint reed *(Arundo donax)* | *7* | *N*, 25<br>*K*, 95 | *Zn*, 79<br>*Mn*, 68 | *P*, 90<br>*Fe*, 89 | *Cu*, 8 | [81] |
| 3 | 0.6 | Water spinach *(I. aquatica)*,<br>tomato *(S. lycopersicum)*,<br>romaine lettuce *(L. sativa L.)*,<br>cherry tomato *(S. lycopersicum var.)*,<br>canna *(Canna generalis)*<br>(Dianthus caryophyllus)<br>lily *(Lilium)*,<br>rose *(Rosa)*,<br>gladiolus *(Gladiolus polustris)* | 5.4 | *COD*, 71.4<br>*TP*, 87.4 | *BOD*, 97.5 | *SS*, 96.9 | *TN*, 86.3 | [82] |
| 4 | Not stated | Basket willow *(Salix viminalis)* | 7 | *BOD*, 90 | *TN*, 57.7 | *TP*, 90.6 | *K*, 24.9 | [83] |
| 5 | 0.6 | Water spinach, *(I. aquatica)*,<br>tomato, *(S. lycopersicum)*<br>romaine lettuce *(L. sativa L.)*,<br>cherry tomato *(S. lycopersicum var.)*,<br>canna *(C. generalis)*,<br>(Dianthus caryophyllus),<br>lily*(Lilium)*,<br>rose *(Rosa)*,<br>Umbrella papyrus (C*yperus alternifolius)* | 5.4 | *COD*, 71.4<br>*BOD*, 97.5 | *TP*, 87.4<br>*TN*, 86.3 | | *SS*, 96.9<br>*FC*, 96 | [84] |

(continued)

**Table 2** (continued)

| S. no. | Capacity/flow rate, $m^3\ d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | | | | References |
|---|---|---|---|---|---|---|---|---|
| 6 | Not stated | Napier grass *(P. purpureum)*, signal grass *( Brachiaria decumbens)*, common reed *(P. australis)* | 1 | *Cr, 97-99.6* | | | | [85] |
| 7 | Not stated | Lettuce *(L. sativa)* | 16, 27, 39, 49, 58 | *Accumulation mg/kg Heavy metals* | | | | [86] |
| | | | | *Cr, 3, Cu,12, Ni, 47, Pb,20,* | | *As,6.5, Cd,3.8, Co, 2.8* | | |
| | | | | *Macro elements* | | | | |
| | | | | *Na, 33,983, K, 120,049* | | *Mg, 12,819, Ca,23,338* | | |
| | | | | *Trace elements* | | | | |
| | | | | *Mn,1454, Fe,647* | | *B,85, Zn,2042* | | |
| 8 | Not stated | Ryegrass (*L. perenne*) | 1 | *COD*, 63 *TAN*, 85 | *TN*, 7 *TP*, 80 | *SS*, 91 *VS*, 71 | *TS*, 66 | [87] |
| 9 | 14.4 | Reed *(P. australis)* | 0.125 | *BOD, 85* | *TSS, 92* | *TN, 65* | *FC, 65* | [88] |
| 10 | 4.6, 9.2, 13.8 18.4, 23.0 | Water spinach *(I. aquatica)* | Not stated | *BOD*, 47-65 $NH_3$*-N*, 64-78 | *TSS*, 67-83 $NO^{2-}N$, 68-89 | | *TP*, 43-53 $NO^{3-}N$, 42-65 | [89] |

(continued)

**Table 2** (continued)

| S. no. | Capacity/flow rate, $m^3\ d^{-1}$ | Botanical species used | HRT, d | Extent of treatment achieved, %* | | References |
|---|---|---|---|---|---|---|
| 11 | Barrels, 0.24<br>Channels,<br>0.28-0.38 | Winter squach *(Cucurbita maxima),*<br>green beans ( *Phaseolus vulgaris),*<br>sweet corn *(Zea mays),*<br>eggplant *(Solanum melongena),*<br>cherry tomato *(S. lycopersicum var.),*<br>olives *(Olea europaea)*, | 0.9<br>5-6.8 | Barrels<br>*TSS*, 75-90<br>*COD*, 4567<br>*TP*, 21-51<br>*TN*, 21 | Channels<br>*TSS*, 75-90<br>*COD*, 60-71<br>*TP*, *21-51*<br>*TN*, 34 | [90] |
| 12 | 0.288<br>0.144<br>0.072 | Leaf cattail *(T. latifolia),*<br>common reed *(P. australis)* | 1.73<br>3.47<br>6.94<br>0.40-0.95 | *COD, 77-78*<br>*BOD, 68-71*<br>*FC,* | *TSS, 69-70*<br>*TDS, 6* | [91] |
| 13 | 0.18<br>0.35 | Water spinach *(I. aquatica)* | 0.40-0.80 | $PO_4^{3-}$ *-P, 86-91*<br>$NH_4^+$*-N, 72-86* | *TN, 30* | [30] |

* Where multiple HRT's have been employed, the extent of treatment achieved at the Highest HRT has been given here

**Table 3** Previously patented systems and their shortcomings which have been overcome in SHEFROL®

| Patent number and name | Type of wastewater treated | System | Hydraulic Retention Time (HRT)/capacity of plant | Difference of this invention from the proposed invention |
|---|---|---|---|---|
| W02010/003255 A1 Process for continual multiphase recycling of solid and liquid organic waste for a greenhouse culture | Liquid and solid organic waste from greenhouse culture | Several units employed in sequence to treat the waste-bas technique is one of the units, and it involves marsh wastewater in multiple stages<br>For filtering, marsh plants used: phragmites, cattail, versicolor, typha, spartine, water hyacinth. The bioreactor component uses gravel/sand/peat/bark, etc, for support of the botanical species | Two days per marsh cell; six days overall for 2250 L | The system needs anchorage for the plants (botanical species) it uses (gravel/sand/peat/bark, etc). In contrast, the proposed invention needs no such anchorage<br>It is four to twelve times *slower* than the proposed invention<br>The inventors have specified only certain types of waste (liquid and solid wastes from greenhouse culture) for their invention. On the other hand, the proposed invention can handle most wastewaters, including but not restricted to municipal wastewaters, wastewaters from food processing plants and other such high organic load containing wastewaters |

(continued)

**Table 3** (continued)

| Patent number and name | Type of wastewater treated | System | Hydraulic Retention Time (HRT)/capacity of plant | Difference of this invention from the proposed invention |
|---|---|---|---|---|
| US006830688B2 Integrated hydroponic and wetland wastewater treatment systems and associated methods | Including, but not limited to, domestic wastewater, industrial waste or process water, urban runoff, agricultural wastewater or runoff, even biological | Two embodiments are described; both contain other units in sequence with hydroponic reactors<br>Botanical species used in the hydroponic unit: not specified<br>Needs an aerator, and a rigid rack, which covers the entire surface, to support the plants | HRT: not specified hence it is not possible to gauge the system efficiency.<br>Capacity: 7.57 to 7570 $m^3$/day | This patent is based on a multi-unit system of which both hydroponic and wetlands are well-established ones. In contrast, the proposed system is based on a single unit which makes commissioning, controlling, and maintaining the system much easier<br>The proposed system is at least four times faster<br>This system needs a rigid rack to support the botanical species and an aerator to supply oxygen to them. In contrast, the proposed invention needs no such anchorage or aerator |
| US20050126991A1 Integrated hydroponic and fixed-film wastewater treatment systems and associated methods | The wastewater and methods of the present invention are amenable to the treatment of, for example, but not intended to be limited to, domestic wastewater, industrial waste or process water, urban runoff, agricultural wastewater or runoff, even biological | The treatment i plurality of tre which is in hydroponic reactors<br>Plants used in the hydroponic not specified<br>With an aerator, and a rigid rack, which covers the entire surface, to support the plants | The system as a whole can to 200000 (which is about 7.57 unit: to 7570 m3/day) | This patent is based on a multi-unit system of which both hydroponic and fixed-film systems are well established and documented technologies In contrast; the proposed system is based on a single unit which makes commissioning, controlling, and maintaining the system much easier |

(continued)

**Table 3** (continued)

| Patent number and name | Type of wastewater treated | System | Hydraulic Retention Time (HRT)/capacity of plant | Difference of this invention from the proposed invention |
|---|---|---|---|---|
| | | | | The proposed system is at least four times faster<br>This system needs a rigid rack to support the plants and an aerator to supply oxygen to the plant. In contrast, the proposed invention needs no such anchorage or aerator<br>The nature of plants used and the configuration of the reactor necessitate greater depth of water in the reactor. In contrast, in the proposed invention the reactor is more compact and employs far lesser depths<br>Recirculation is employed in the system whereas in the proposed invention there is no need for it |
| WO 2009/128765 A phytosystem for the treatment of sewage | Residential and industrial sewage | Multiple treatment steps are employed; the plant-based unit forms one part | 1–2 days | The proposed system is nearly 6 times faster than this system.<br>The proposed system is based on far more cost-effective and user-friendly technology.<br>The proposed system is a zero-discharge, zero energy input, and zero chemical input-based system unlike this |

(continued)

**Table 3** (continued)

| Patent number and name | Type of wastewater treated | System | Hydraulic Retention Time (HRT)/capacity of plant | Difference of this invention from the proposed invention |
|---|---|---|---|---|
| | | | | one, which requires the input of energy and chemicals.<br>This system needs prefabricated polyethylene tubular blocks of high porosity with supporting media for the plants; no such support media is needed in the proposed invention |
| US 6814853B2 Water treating method, water treating apparatus, and hydroponic system using the same | The system does not treat wastewater hence is not relevant to discussion on the proposed system. It is meant for treating water to make it free of microbes | | | Not relevant |

**Acknowledgement** Authors thank the Ministry of Water Resources, RD & GR, Government of India, for funding an R&D project which enabled the work and Department of Biotechnology, Government of India, for supporting the patenting of SHEFROL®. SAA thanks the University Grants Commission (UGC) for Emeritus Professorship and the Council Scientific and Industrial Research (CSIR), New Delhi for Emeritus Scientist Grant (21(1034)/16/EMR-II which have enabled him to document the findings presented in the paper.

## References

1. Tauseef, S.M., Abbasi, T., Abbasi, S.A.: Energy recovery from wastewaters with high-rate anaerobic digesters. Renew. Sustain. Energy Rev. **19**, 704–741 (2013)
2. Abbasi, T., and Abbasi, S. A.: Formation and impact of granules in fostering clean energy production and wastewater treatment in upflow anaerobic sludge blanket (UASB) reactors. Renewable and Sustainable Energy Reviews, **16** (3), 1696–1708, (2012)
3. Khan, F. I., Abbasi, S. A.: Techniques and Methodologies for Risk Analysis in Chemical Process Industries, pp. ix + 364. Discovery Publishing House, New Delhi; (1998)
4. Khan, F.I., Abbasi, S.A.: OptHAZOP—an effective and optimal methodology for conducting HAZOP, study. J. Loss Prev. Process Ind. **10**, 191–204 (1997)
5. Khan, F.I., Abbasi, S.A.: MAXCRED—a new software package for rapid risk assessment in chemical process industries. Environ. Model. Softw. Elsevier **14**, 11–25 (1999)
6. Khan, F.I., Abbasi, S.A.: The worst chemical industry accident of 1990s: What happened and what might have been—a quantitative study. Process Saf. Progress (AIChE, USA) **18**, 135–145 (1999)
7. Khan, F.I. and Abbasi, S. A.: Accident hazard index; A multi-attribute method for process industry hazard rating, Transactions of the Institution of Chemical Engineers, **75**, 217–224, (1997)
8. Narain, S.: Excreta Matters, 7th State of India's Environment: A Citizens' Report. Centre for Science and Environment, New Delhi (2012)
9. Narain, S. (ed.): State of India's Environment, 2016: A Down to Earth Annual (State of India's Environment). Centre for Science and Environment, New Delhi (2016)
10. Abbasi, S.A.: Aquatic plant based water treatment systems in Asia. In: Smith, W.H., Reddy, K.R. (eds.) Aquatic Macrophytes for Wastewater Treatment and Resource Recovery, pp. 175–198. Magnolia Publishing, Florida (1987)
11. Abbasi, T., Abbasi, S.A.: Factors which facilitate waste water treatment by aquatic weeds–the mechanism of the weeds' purifying action. Int. J. Environ. Stud. **67**(3), 349–371 (2010)
12. Abbasi, T., Abbasi, S.A.: Enhancement in the efficiency of existing oxidation ponds by using aquatic weeds at little or no extra cost—the macrophyte-upgraded oxidation pond (MUOP). Bioremediation J. **14**(2), 67–80 (2010)
13. Kickuth, R.: Degradation and incorporation of nutrients from rural wastewaters by plant rhizosphere under limnic conditions. In: Utilization of Manure by Land Spreading, pp. 235–243 (1977)
14. Seidel, K.: Zur Problematik der Keim-und Pflanzengewasser. Verh. Internat. Verein. Limnol **14,** 1035–1039 (1961)
15. Seidel, K.: Phenol-Abbau im Wasser durch Scirpus lacustris L. während einer Versuchsdauer von 31 Monaten. Naturwissenschaften **52**(13), 398 (1965)
16. Seidel, K.: Reinigung von Gewässern durch höhere Pflanzen. Naturwissenschaften **53**(12), 289–297 (1966)
17. Seidel, K.: Macrophytes and water purification. In: Tourbier, J., Pierson Jr., R.W. (eds.) Biological Control of Water Pollution (1976)
18. Sinha, S.N., Sinha, L.P.: Studies on the use of water hyacinth culture in oxidation ponds treating digested sugar wastes and effluent of septic tank. Environ. Health **11**, 197–207 (1969)

19. Wolverton, B.C., Barlow, R.M., Mcdonald, R.C.: Application of vascular aquatic plants for pollution removal, energy and food production in a biological system (1975)
20. Wolverton, B.C., McKown, M.M.: Water hyacinths for removal of phenols from polluted waters. Aquatic Botany **2**, 191–201 (1976)
21. Wolverton, B.C., McDonald, R.C.: Wastewater treatment utilizing water Hyacinth Eichhornia crassipes (Mart.) Solms. Vascular Aquatic Plant. Program **61**, 1915–1977 (1977)
22. Wolverton, B.C., McDonald, R.C.: Upgrading facultative wastewater lagoons with vascular aquatic plants. J. Water Pollut. Control Fed. **103**, 305–313 (1979)
23. Wolverton, B.C., McDonald, R.C.: Energy from vascular plant wastewater treatment systems. Econ. Botany **35**(2), 224–232 (1981)
24. Wolverton, B. C.: Higher plants for recycling human waste into food, potable water and revitalized air in a closed life support system. In: National Aeronautics and Space Administration, National Space Technology Laborartories, (1980)
25. Abbasi. S. A., Khan. F. I., Abbasi. N.: Aquatic plants for wastewater treatment. J. Ins. Public Health Eng. India, **2000**(1), 27–35 (2000)
26. Abbasi, S. A., and Nipaney, P.C.: Infestation by aquatic weeds of the fern genus salvinia - its status and control, Environmental Conservation, **13** (3), 235–224, (1986)
27. Ganesh, P. S., Ramasamy, E.V., Gajalakshmi, S., and Abbasi, S. A.: Extraction of volatile fatty acids (VFAs) from water hyacinth using inexpensive contraptions, and the use of the VFAs as feed supplement in conventional digesters, Biochemical Engineering Journal, **27**, 17–23, (2005)
28. Abbasi, S. A., Abraham, N., and Kunhahamed, T.: A hydroponic system for studying the impact of water-quality on germination and early growth of angiosperms, Environmental Technology Letters, **9**(3), 219–226, (1988)
29. Bouzoun, J.R., Palazzo, A.J.: Preliminary Assessment of the Nutrient Film Technique for Wastewater Treatment. (No. CRREL-SR-82-4). Cold Regions Research and Engineering Lab, Hanover NH (1982)
30. Li, X.N., Song, H.L., Lu, X.W., Xie, X.F., Inamori, Y.: Characteristics and mechanisms of the hydroponic bio-filter method for purification of eutrophic surface water. Ecol. Eng. **35**(11), 1574–1583 (2009)
31. Li, C., Dong, Y., Lei, Y., Wu, D., Xu, P.: Removal of low concentration nutrients in hydroponic wetlands integrated with zeolite and calcium silicate hydrate functional substrates. Ecol. Eng. **82**, 442–450 (2015)
32. Abbasi, S.A., Nipaney, P.C., Schaumberg, G.D.: Bioenergy potential of 8 common aquatic weeds. Biol. Wastes **34**(4), 359–366 (1990)
33. Abbasi, T., and Abbasi, S. A.: Production of clean energy by anaerobic digestion of phytomass - new prospects for a global warming amelioration technology. Renewable and Sustainable Energy Reviews, **14**, 1653–1659, (2010)
34. Tauseef, S. M., Premalatha, M., Abbasi, T., and Abbasi, S. A.: Methane capture from livestock manure, Journal of Environmental Management, **117**, 187–207, (2013)
35. Ramasamy, E.V., and Abbasi, S. A.: Energy recovery from dairy waste-waters; impacts of biofilm support system on anaerobic CST reactors, Applied Energy, **65**, 91–98, (2000)
36. Abbasi, T., Abbasi, S.A.: Sources of pollution in rooftop rainwater harvesting systems and their control. Crit. Rev. Environ. Sci. Technol. 41(23), 2097–2167 (2011)
37. Hussain, N., Abbasi, T., Abbasi, S.A.: Vermicomposting eliminates the toxicity of Lantana (Lantana camara) and turns it into a plant friendly organic fertilizer. J. Hazardous Mater. **298**, 46–57 (2015)
38. Hussain, N., Abbasi, T., Abbasi, S.A.: Vermiremediation of an invasive and pernicious weed salvinia (Salvinia molesta). Ecol. Eng. **91**, 432–440 (2016)
39. Hussain, N., Abbasi, T., Abbasi, S.A.: Toxic and allelopathic ipomoea yields plant-friendly organic fertilizer. J. Clean. Prod. **148**, 826–835 (2017)
40. Abbasi, S. A., Gajalakshmi, S., Tasneem Abbasi.: Zero Waste Generating, Zero Chemical Using, High Rate Wastewater Treatment System – SHEFROL, Official Journal of the Patent Office **20**, 7611–7611 (2012)

41. Abbasi, T., and Abbasi, S.A.: A novel low-cost and clean-green technology SHEFROL® for sewage treatment, especially suited to villages and peri-urban dwellings, Workshop on Innovations in Waste, Water and Energy Management for Rural Development Birla Institute of Technology & Science, Pilani Hyderabad Campus Hyderabad, 134–142 (2015)
42. Wallace, A., Patel, P.M., Berry, W.L., Lunt, O.R.: Reclaimed sewage water: A hydroponic growth medium for plants. Res. Recovery Conserv. **3**(2), 191–199 (1978)
43. Bouzoun, J.R., Diener, C.J., Butler, P.L.: Pilot Scale Evaluation of the Nutrient Film Technique for Wastewater Treatment. (No. CRREL-SR-82-27). Cold Regions Research and Engineering Lab, Hanover NH (1982)
44. Jewell, W.J., Madras, J.J., Clarkson, W.W., Delancey-Pompe, H., and Kabrick, R.M.: Wastewater treatment with plants in nutrient films. EPA Project Summary. EPA-600/S2-83-067, pp. 1–5 (1983)
45. Dushenkov, S., Vasudev, D., Kapulnik, Y., Gleba, D., Fleisher, D., Ting, K.C., Ensley, B.: Removal of uranium from water using terrestrial plants. Environ. Sci. Technol. **31**(12), 3468–3474 (1997)
46. Rababah, A.A., Ashbolt, N.J.: Innovative production treatment hydroponic farm for primary municipal sewage utilisation. Water Res. **34**(3), 825–834 (2000)
47. Vaillant, N., Monnet, F., Vernay, P., Sallanon, H., Coudret, A., Hitmi, A.: Urban wastewater treatment by a nutrient film technique system with a valuable commercial plant species (Chrysanthemum cinerariaefolium Trev.). Environ. Sci. Technol. **36**(9), 2101–2106 (2002)
48. Fabian, A.C., et al.: 2000, MNRAS, 318, L65
49. Ali, N.A., Bernal, M.P., Ater, M.: Tolerance and bioaccumulation of copper in Phragmites australis and Zea mays. Plant Soil. **239**(1), 103–111 (2002)
50. Adler, P.R., Summerfelt, S.T., Glenn, D.M., Takeda, F.: Mechanistic approach to phytoremediation of water. Ecol. Eng. **20**(3), 251–264 (2003)
51. Vaillant, N., Monnet, F., Sallanon, H., Coudret, A., Hitmi, A.: Treatment of domestic wastewater by a hydroponic NFT system. Chemosphere **50**(1), 121–129 (2003)
52. Odjegba, V.J., Fasidi, I.O.: Accumulation of trace elements by Pistia stratiotes implications for phytoremediation. Ecotoxicology **13**(7), 637–646 (2004)
53. Flocco, C.G., Carranza, M.P., Carvajal, L.G., Loewy, R.M., De D'Angelo, A.P., Giulietti, A. M.: Removal of azinphos methyl by alfalfa plants (Medicago sativa L.) in a soil-free system. Sci. Total Environ. **327**(1), 31–39 (2004)
54. Vaillant, N., Monnet, F., Sallanon, H., Coudret, A., Hitmi, A.: Use of commercial plant species in a hydroponic system to treat domestic wastewaters. J. Environ. Qual. **33**(2), 695–702 (2004)
55. Ali, N.A., Bernal, M.P., Ater, M.: Tolerance and bioaccumulation of cadmium by Phragmites australis grown in the presence of elevated concentrations of cadmium, copper, and zinc. Aquatic Botany **80**(3), 163–176 (2004)
56. Bernhard, R., Verkleij, J.A., Nelissen, H.J., Vink, J.P.: Plant-specific responses to zinc contamination in a semi-field lysimeter and on hydroponics. Environ. Pollut. **138**(1), 100–108 (2005)
57. Yifru, D.D., Nzengung, V.A.: Uptake of N-nitrosodimethylamine (NDMA) from water by phreatophytes in the absence and presence of perchlorate as a co-contaminant. Environ. Sci. Technol. **40**(23), 7374–7380 (2006)
58. Ghaly, A.E., Farag, H.A., Verma, M.: A hydroponic system for purification of anaerobically treated dairy manure and production of wheat as a nutritional forage crop. Am. J. Agric. Biol. Sci. **2**(3), 206–217 (2007)
59. Ghaly, A.E., Farag, H.A.: Phytoremediation of anaerobic digester effluent for water purification and production of animal feed. Am. J. Agric. Biol. Sci. **2**(1), 1–14 (2007)
60. Nair, J., Levitan, J., Oyama, N.: Zinc and copper uptake by silver beet grown in secondary treated effluent. Biores. Technol. **99**(7), 2537–2543 (2008)
61. Hu, M.H., Ao, Y.S., Yang, X.E., Li, T.Q.: Treating eutrophic water for nutrient reduction using an aquatic macrophyte (Ipomoea aquatica Forsskal) in a deep flow technique system. Agric. Water Manag. **95**(5), 607–615 (2008)

62. Snow, A.M., Ghaly, A.E.: A comparative study of the purification of aquaculture wastewater using water hyacinth, water lettuce and parrot's feather. Am. J. Appl. Sci. Vails Gate **5**(4), 440–453 (2008)
63. Snow, A.M., Ghaly, A.E.: Use of barley for the purification of aquaculture wastewater in a hydroponics system. Am. J. Environ. Sci. **4**(2), 89 (2008)
64. Snow, A.M., Ghaly, A.E., Snow, A.: A comparative assessment of hydroponically grown cereal crops for the purification of aquaculture wastewater and the production of fish feed. Am. J. Agric. Biol. Sci. **3**(1), 364–378 (2008)
65. Yang, Z., Zheng, S., Chen, J., Sun, M.: Purification of nitrate-rich agricultural runoff by a hydroponic system. Biores. Technol. **99**(17), 8049–8053 (2008)
66. Fernando, D.R., Guymer, G., Reeves, R.D., Woodrow, I.E., Baker, A.J., Batianoff, G.N.: Foliar Mn accumulation in eastern Australian herbarium specimens: prospecting for 'new' Mn hyperaccumulators and its potential application in taxonomy. Ann. Bot. **103**, 931–939 (2009). doi: 10.1093/aob/mcp013
67. Rababah, A., Al-Shuha, A.: Hydroponics reducing effluent's heavy metals discharge. Water Sci. Technol. **59**(1), 175–183 (2009)
68. Sasmaz, A., Obek, E.: The accumulation of arsenic, uranium, and boron in Lemna gibba L. exposed to secondary effluents. Ecol. Eng. **35**(10), 1564–1567 (2009)
69. Gonzales, J.A., Maruo, T., Shinohara, Y.: Uptake ability of tomato plants (Solanum lycopersicum L.) grown using nutrient film technique (NFT) by ascending nutrient concentration method. J. ISSAAS **16**, 31–39 (2010)
70. Wang, C., Yongxiang, R., Hai, Z., YongZhe, Y.: Feasibility of using hydroponic cultivation as a pretreatment process for constructed wetland. China Environ. Sci. **30**(8), 1079–1085 (2010)
71. Vaillant-Gaveau, N., Monnet, F., Sallanon, H., Coudret, A., Hitmi, A.: Removal of organic load from wastewater by using Datura innoxia Mill. In: Mendez-Vilas, A. (ed.) Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology. Sustain. Energy Rev. **19**, 704–741
72. Bindu, T., Sumi, M.M., Ramasamy, E.V.: Decontamination of water polluted by heavy metals with Taro (Colocasia esculenta) cultured in a hydroponic NFT system. Environmentalist **30** (1), 35–44 (2010)
73. Shenker, M., Harush, D., Ben-Ari, J., Chefetz, B.: Uptake of carbamazepine by cucumber plants—a case study related to irrigation with reclaimed wastewater. Chemosphere **82**(6), 905–910 (2011)
74. Dordio, A.V., Belo, M., Teixeira, D.M., Carvalho, A.P., Dias, C.M.B., Picó, Y., Pinto, A.P.: Evaluation of carbamazepine uptake and metabolization by Typha spp., a plant with potential use in phytotreatment. Biores. Technol. **102**(17), 7827–7834 (2011)
75. Cao, H., et al.: The impact of MIG1 and/or MIG2 disruption on aerobic metabolism of succinate dehydrogenase negative Saccharomyces cerevisiae. Appl Microbiol Biotechnol. **89** (3), 733–738 (2011)
76. Akinbile, C.O., Yusoff, M.S.: Assessing water hyacinth (Eichhornia crassopes) and lettuce (Pistia stratiotes) effectiveness in aquaculture wastewater treatment. Int. J. Phytoremediation **14**(3), 201–211 (2012)
77. Henares, M.N.P., Camargo, A.F.M.: Estimating nitrogen and phosphorus saturation point for Eichhornia crassipes (Mart.) Solms and Salvinia molesta Mitchell in mesocosms used to treating aquaculture effluent. Acta Limnol. Bras. **26**(4), 420–428 (2014)
78. Mudhiriza, T., Mapanda, F., Mvumi, B.M., Wuta, M.: Removal of nutrient and heavy metal loads from sewage effluent using vetiver grass, Chrysopogon zizanioides (L.) Roberty. Water SA **41**(4), 457–463 (2015)
79. Melignani, E., de Cabo, L.I., Faggi, A.M.: Copper uptake by Eichhornia crassipes exposed at high level concentrations. Environ. Sci. Pollut. Res. **22**(11), 8307–8315 (2015)
80. Lam, S.S., Ma, N.L., Jusoh, A., Ambak, M.A.: Biological nutrient removal by recirculating aquaponic system: Optimization of the dimension ratio between the hydroponic and rearing tank components. Int. Biodeterior. Biodegrad. **102**, 107–115 (2015)

81. Dewedar, A., Ahmed, M.T., Bahgat, M.M.M.: The efficacy of gravel bed hydroponic system in the removal of DDT residues from sewage effluent. Res. Conserv. Recycl. **14**(1), 47–52 (1995)
82. Mavrogianopoulos, G., Vogli, V., Kyritsis, S.: Use of wastewater as a nutrient solution in a closed gravel hydroponic culture of giant reed (Arundo donax). Biores. Technol. **82**(2), 103–107 (2002)
83. Cui, L. H., Luo, S. M., Zhu, X. Z., Liu, Y. H.: Treatment and utilization of septic tank effluent using vertical-flow constructed wetlands and hydroponic cultivation of vegetables. Ecol. Sanitat. Res. 1–4, (2002)
84. Mant, C., Peterkin, J., May, E., Butler, J.: A feasibility study of a Salix viminalis gravel hydroponic system to renovate primary settled wastewater. Biores. Technol. **90**(1), 19–25 (2003)
85. Cui, L.H., Luo, S.M., Zhu, X.Z., Liu, Y.H.: Treatment and utilization of septic tank effluent using vertical-flow constructed wetlands and vegetable hydroponics. J. Environ. Sci. **15**(1), 75–82 (2003)
86. Mant, C., Costa, S., Williams, J., Tambourgi, E.: Phytoremediation of chromium by model constructed wetland. Biores. Technol. **97**(15), 1767–1772 (2006)
87. Rababah, A.: Best Septic Approximation of Circular Arcs with Fifteen Equioscillations, International journal of control theory and allicaptions, **10**(11), 65–75 (2017)
88. Pan, J., Sun, H., Nduwimana, A., Wang, Y., Zhou, G., Ying, Y., Zhang, R.: Hydroponic plate/fabric/grass system for treatment of aquacultural wastewater. Aquac. Eng. **37**(3), 266–273 (2007)
89. Shalaby, I.M., Altalhy, A.D., Mosallam, H.A.: Preliminary field study of a model plant for sewage water treatment using gravel bed hydroponics method. World Appl. Sci. J. **4**(2), 238–243 (2008)
90. Endut, A., Jusoh, A., Ali, N., Wan Nik, W.N.S., Hassan, A.: Effect of flow rate on water quality parameters and plant growth of water spinach (Ipomoea aquatica) in an aquaponic recirculating system. Desalin. Water Treat. **5**(1–3), 19–28 (2009)
91. Haddad, M., Mizyed, N.: Evaluation of various hydroponic techniques as decentralised wastewater treatment and reuse systems. Int. J. Environ. Stud. **68**(4), 461–476 (2011)
92. Tasneem Abbasi, S.A. Abbasi, (2012) Formation and impact of granules in fostering clean energy production and wastewater treatment in upflow anaerobic sludge blanket (UASB) reactors. Renewable and Sustainable Energy Reviews **16**(3):1696–1708

# Managing and Identifying the Risks Related to Biochemical Conversion of Waste-to-Energy

**Praveen Ghodke, B. R. Manohar Reddy and S. Vamsi Krishna**

## 1 Introduction

The ever-increasing release of greenhouse gas emissions leading to global warming has ignited development of a number of newer technologies for reducing the effect of energy production. One of the technologies emerging for utilization of wastes to generate energy, i.e., produces syngas by gasification to generation heat and power. Energy industries have safety issues relating to steam pressure, combustion, turbines, generators, heat and power distribution are well defined as per standards [1].

The ascent in the quantity of biofuel process plants has brought about various occasions bringing about death toll and property [2]. We have deduced that roughly six to seven fire blast occurrences are accounted for consistently from biodiesel and ethanol enterprises in the India and other countries. The procedure business is very much aware of the money-related dangers and natural risks related with creation and utilizing biofuel as an eco-accommodating option fuel. Be that as it may, restricted data is accessible on the procedure dangers because of the dangers required in the creation of the biofuels [3]. New advancements particularly for refinement, negligible operational involvement with untalented/semi-talented administrators, building and operation of biofuel process plants in hypothetically wrong areas (close to defenseless populaces), require a need to distinguish the procedure perils which bring down the dangers [4, 5]. Overall population organization administrators are not completely mindful of the dangers related with the creation of biofuel. This paper will include the vital perils and necessity of overseeing procedure hazards in the biofuel business. The discoveries are from hazard examining thinks about led for various sorts of biofuel tasks and biofuel prepare plants.

P. Ghodke (✉) · B. R. M. Reddy · S. Vamsi Krishna
Department of Electrical Power and Energy, University of Petroleum and Energy Studies, Dehradun 248007, Uttarakhand, India
e-mail: gpkumar@ddn.upes.ac.in

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_31

## 2 Material Identification

It is said in process safety and loss prevention that half the battle is won once the hazards have been identified. Various peril distinguishing proof strategies and procedures are accessible and drilled. Diverse techniques are required at various phases of a procedure and are distinguished [6, 7]. A rundown of average process perils (not thorough) related with the biofuel enterprises that are should be considered in the hazard administration forms. The data depends on various risk recognizable proof reviews completed for mechanical scale generation of ethanol, biodiesel, and syngas plants and from episode examination reports including mischances in biofuel offices.

### *2.1 Materials Hazards*

The essential dangers from materials as crude materials, intermediates, impetuses and completed items are fire risks, blast perils and overpressure discharges, runaway/uncontrolled response, dangerous perils and steam flashes. Substance and physical risks related with a portion of the normal materials utilized as a part of the biofuel assembling are given underneath: C1–C3 alcohols are named Class IB combustible fluids, i.e., streak focuses beneath 23.1 °C and breaking point higher than 38 °C and can without much of a stretch burst into flames at room temperature. Ethanol and blends more prominent than around half ethanol are combustible and gets effortlessly touched off [8].

Ethanol has been appeared to build the danger of numerous types of malignancy, contracting cirrhosis of the liver, and liquor abuse. Ethanol is possibly destructive. Methanol utilized as a part of assembling of biodiesel is harmful substance as well as profoundly combustible [9]. Methanol presentation on everyday measurements of little sum makes aggregate harm the body, perhaps prompting visual impairment and demise. It is exceptionally touchy in nature like oil when blended with acidic pop. There is a genuine danger of flame and blast. Sodium hydroxide (utilized as a part of biodiesel assembling) is amazingly destructive. It can prompt consuming to uncovered skin and is awful to the eyes. Mixing the fluid regularly create a fine fog of fluid beads. Inward breath of this fog can bring about extreme aggravation of the respiratory tract and shortness of breath. Coincidental gulping can make significant harm the stomach-related framework and throat lining.

Sulfuric acid corrosive is a destructive risk. The principle dangers included are skin contact which prompts consuming of the skin and the inward breath of pressurized canned products which can prompt extreme aggravation of eyes. Albeit sulfuric acid corrosive is non-combustible when interacts with metals in case of a leakage can prompt the creation of the hydrogen gas. Corrosive diffusion of mist concentrates and vaporous sulfur dioxide is likewise a reason for peril of flames [10].

Syngas is both poisonous and combustible. Carbon monoxide and hydrogen are the principle parts of syngas dangerous and are combustible. Woody chips and saw dust are the fundamental biomass crude substantial for biofuel creation. They can be dangerous in a few structures or under convinced capacity circumstances. The crude materials, for example, sawdust and woodchip heap turn into a fire danger (particularly when damp). Woodchip heaps can possibly get warmed inside and suddenly combust if not oversaw appropriately. Unconstrained warming might be brought about when warmth delivered by the microbial rot of woody is not promptly declined. Fires happen while warmed chips are attempted to be isolated when they are presented to adequate air bringing about ignition.

## 2.2 Operations and Handling

Operational mischances seen in the biofuel enterprises are for the most part fire blast. Perilous occasions and related results amid operation and taking care of (capacity, preparing, dealing with and so forth) are capacity of combustible and harmful materials. Case of combustible and lethal materials incorporates added substances, intermediates materials, crude materials, completed items and by items in various stages, sizes, temperatures and weight as required by the procedure [11]. Unsafe material stocks are dangers brought about from mass stockpiling of toxics and flammables. It is now and then noticed that the stock of risky materials is not relative to the generation necessities, i.e., more than plan purpose which expands the capability of danger. Designs of capacity are insufficient dispersing or partition. Flammable area not determined and maintained properly. Inadequate labeling leads to selection of wrong batch of material or chemical for production.

Absence of establishing, clinging to keep away from electrostatic perils and assurance from helping are few instances of operation taking care of hazard. Deficient insurance from antagonistic climate condition, it might prompt harm of materials (e.g., feedstock stockpiling in open yards). Deviation from outline goal, versatile capacity winds up plainly transitory process vessel, e.g., crude materials pumped from tank trucks straightforwardly to process plant. This may prompt blasts or flames while emptying. Risks from long haul stockpiling of unsaturated mixes, i.e., bring down softening focuses may bring about arrival of combustible vapors. Weight or vacuum connected over as far as possible.

## 2.3 Processing of Hazardous Materials

One of the significant dangers is the mishaps that could come about because of biofuel assembling is the arrival of flammables, toxics and corrosives. This could be accordingly of various reasons identified with process hardware, apparatus, working parameters, control and instrumentation and so on. No or lacking/improper control framework to gauge and oversee level, weight, temperature and quality bringing about deviation from outline expectation by leaving as far as possible. A few cases of the perils identified with preparing are given underneath:

- High operating temperature and pressure;
- Storage temperature and pressure;
- Overflow of tank, vessel, reactor or tanker;
- Cold temperature often results in plugging due to solidification of biodiesel;
- Inappropriate choice of apparatus, machinery, rated containers or pipe work compulsory for the procedure;
- Insufficient fitting, examination and maintenance;
- Use of uncategorized apparatus and equipment in hot-headed atmosphere.

The majority of the biofuel fabricating receives clump preparing and particular perils are related with group handling. Fierce synthetic responses happen oftenly because of poor blending, making excessively on the double or committing an error with the technique like receiving the amount of chemicals wrong or including the chemicals in the wrong request, e.g., adding C1 alcohol to boiling oil in biodiesel generation which may prompt fire at the moment.

## 2.4 Other Related Hazards

***Material handling***

A scope of materials in various structures, i.e., strong, fluid and gas is exchanged between gear, handle vessels, stockpiling and so forth. This includes various apparatuses and exchange frameworks from blending pit to transport framework to pipelines and pumps. In littler plants, frequently manual blending and taking care of are the primary methods for material taking care of [12]. Manual treatment of risky materials for the most part results in word-related wounds and in some cases fatalities. Related risks are material misfortune, harm because of deficient or ill-advised transport framework. Poor housekeeping prompting dust dangers and tidy blast risks. Spillage discharge from pipelines, vessels, valves and so forth.

Various different perils are there which can happen, for example, dangers from plant adjustments, risks to condition and neighborhood from process upsets/ deviation and so forth. Risks from unified works are the physical action (upkeep, repair and so forth) on live gear, vessel or reactor. Hot deals with combustible stockpiling, bound space section (suffocation), and waste stream transfer makes extra wellbeing and dangers to people and the earth. Glycerol and wastewater are two of the record widely recognized waste streams gotten from the biodiesel production procedure. Service goods, for example, nitrogen under put away weight, super-warmed steam, high-voltage power and so on are potential wellsprings of a few dangers. Despicable lighting and deficient ventilation are two other huge risks particularly in restricted ranges and structures.

### 2.5 Hazards from Design, Construction and Commissioning

For the most part, biofuel plants are for the most part little or medium scale and every so often expansive scale plants worked in a current office or close to a current office/plant. A portion of the dangers are anything but difficult to happen when the current offices (old horse shelter, carport or capacity expel) are adjusted/changed over to a biofuel preparing office. The most well-known issues to perceive extra prerequisites required, e.g., building direction codes, electrical establishment prerequisites and so forth. The accompanying are a portion of the causes related to biofuel plant extends that may come about dangers and perilous occasions. Uncalled for determination of the innovation for the assembling, the compound and crude materials utilized for the creation and the area of the office are some risky occasions.

Deficient offices for the chose procedure are land zone, closeness to utilities like water, steam, control and so on and dangerous plan and format, and warm radiation from open blazes/flares or hardware/vessel working at high temperature. Defective development and appointing are utilization of unseemly material of development of the office (inconsistent for the material took care of/prepared), inappropriate establishment and insufficient quality of load bearing individuals. Ventilation and lighting, rust and cleaning, climate security, assurance from outside components like vehicle impact, assaults from creatures/bothers and insufficient arrangement for weight help, safe release of hazardous discharge and overpressure insurance. No arrangement for remote observing and control of the procedure, arrangement for creation utilizing brief/make move game plans and lacking appraisal of risks in building up association with existing office for sharing force, utilities, structure and so forth.

## 3 Discussion

### 3.1 Incidents

Various episodes have been accounted for including biofuel preparing, stockpiling and dealing with plant. The mischances revealed are from a wide range of biofuel creation independent of scale or of the kind of generation. A point-by-point examination of the examination reports and mischance information is not done for this paper. In any case, a portion of the occurrence causes detailed are methanol spillage touching off and fire distribution to capacity tanks, individuals being scorched by sulfuric acid corrosive because of poor preparing/observation/appropriateness, little process (biodiesel) detonating because of incidentally exchanging on electric submersion radiators, pipe work blasting because of utilization of contrary materials.

Little flames heightening to expansive flames because of utilizing plastic reactor vessels, office not sticking to construction laws, old and improper wiring and partition from contiguous building, e.g., horse shelter isolated by just wooden framing (not heat proof) and nonappearance of flame quenchers or fire dousers not active or not worked appropriately.

In process control, bringing about blend sprinkling or bubbling over, creating genuine consumes. Tank flood because of lacking level control (the level gage not reasonable for the scope of materials with various densities). It ought to likewise be noticed that there will be various episodes and mischances (predominantly from little scale creation) which are not revealed, examined and broke down. Absence of records on operational parameters, patterns, close misses and so on from the biofuel business does not investigate the deviation and decrease chance. Emergency administrations are absence of crisis arranging and readiness is each other consider that may come about deficient moderation and frequently acceleration of minor episodes to major. Some are insufficient means for discovery and seclusion of unsafe discharges, lacking means for dynamic and inactive fire and blast security and deficient staff and insufficient preparing for crisis reaction faculty.

## 3.2 Human Factors

Biofuel offices are regularly outlined and worked by not all that reasonably qualified and experienced people. Absence of preparing, mindfulness and supervision regularly prompts misguided thinking, deficient basic leadership at last which may bring about real process annoyed or episode. A portion of the issues identified with human variables are:

- Lack of preparing and comprehension could miss/supervise real process deviation that could bring about lethal mischances.
- Lack of consciousness of wellbeing risks and performing exercises without individual defensive rigging that could bring about wounds and ailment.
- Production without standard working method or direction, particularly in little and medium-scale creation offices.

## 3.3 Risk Management

Hazard administration is the term used to cowl the whole procedure of describing, recognizing and evaluating hazard, defining objectives and making working frameworks for its control. In spite of the fact that the biofuel fabricating office regularly does not go under real mischance danger controls, it is judicious that the hazard from the biofuel commercialization are evaluated and overseen since the way of perils and the associates included. The perceptiveness of hazard evaluation ought to be matching to the degree of hazard required all the while and office.

Compeling danger management can aid the biofuel corporate in the aversion of calamitous instances; it can likewise promotion administrator/worker's data about operations, enhance expert techniques; keep up process safety data and augmentation general office's productivity of generation. Since a large number of the existing biofuel makers are little operations, an arrangement of rules including process wellbeing administration, however, less thorough, might be produced for such offices. A point-by-point chance administration process is not secured as a feature of this paper. The non-specific approach for process chance administration should be embraced for the biofuel business where dangers are distinguished and examined efficiently utilizing required devices and techniques by appropriately prepared and equipped people. Any holes or shortages recognized to control hazard ought to be tended to properly. As a rule, the disposition for vital regulator actions ought to be.

- Anticipatory over mitigative;
- Passive over vibrant;
- Engineered over regulatory;
- Panels with the most astounding untiring quality;
- Controls nearest to the peril.

Ventures including biofuel assembling, stockpiling as well as conveyance ought to be dealt with as a practice including unsafe resources and perilous tasks. Every vital stride for vulnerability management ought to be done at, respectively, stage of the venture, to form up a hazard administration outline and pledge the sufficiency of the framework by examination, upkeep and inspecting. A share of the observations and control actions recommended for the hazard administration of the biofuel enterprises.

Utilize practical resources (inalienably sheltered) for the expansion of basins, reactors and pipe work. Pick steel over plastic for biodiesel reactors. Keeps away from disruptions from fixtures because of operative cycles (temperature variations) and furthermore give some security against flames (e.g., from methanol discharge) close-by. Evade use of pliable channeling for the automobile of any liquid containing methanol, mainly downstream of any pump.

Utilize electrical and mechanical hardware that complies with required directions for unstable zones that may contain methanol vapor. Utilize an altered vessel for reheating vegetable oil and do not familiarize electrical warming up components in biodiesel reactors. Smartly tranquil guidelines and standard operational systems evade mishaps from wrong blend or wrong formula. Setup general operational rules are counsel not to add methanol to hot oil. Never add water to acidic, never add methanol to scathing pop. Continuously have great ventilation and lighting in the workspace. Never make biofuel in the community or in a carport neighboring, or some share of, a family. Office to be worked by appropriately prepared and qualified dependable individual as it were. Guarantee great housekeeping and set up a crisis arrange.

## 4 Conclusion

The utilization of as a substitute biofuels to regular vitality sources is a becoming slanted over mainstream researchers. By expanding the creation and utilization of biofuels, the hazard related has additionally expanded and numerous episodes including biofuels have been accounted for. The business has recognized the noteworthiness of tending to money-related hazard and natural hazard, however, much of the time wellbeing is precluded because of the straightforwardness of the procedure and absence of attention to the potential risks. This conviction is a calculation of a wide range of ventures, however, significantly more so in biofuel plants where absence of experience and a basic procedure are joined to deliver a domain in which blunders happen. It ought to be noticed that waste-to-energy frameworks speak to a piece of an incorporated waste administration methodology and are not in all cases the most manageable arrangement.

## References

1. Bellchambers, L.M., Fisher, E.A., Harry, A.V., Travaille. K.L.: Identifying and mitigating potential risks for Marine Stewardship Council assessment and certification. Fish. Res. **182**:7–17 (2016)
2. Bogdanowicz, K.M., Stewart, R., Chang, C.-K., Downs, J., Khondoker, M., Shetty, H., et al.: Identifying mortality risks in patients with opioid use disorder using brief screening assessment: secondary mental health clinical records analysis. Drug Alcohol Depend. **164**:82–88 (2016)
3. Jacobson, K., Maheria, K.C., Kumar Dalai, A.: Bio-oil valorization: A review. Renew. Sustain. Energy Rev. [Internet] [cited 18 Nov 2015] **23**:91–106 (2013)
4. Walter, J., Hustedt, M., Staehr, R., Kaierle, S., Jaeschke, P., Suttmann, O., et al.: Laser cutting of carbon fiber reinforced plastics—investigation of hazardous process emissions. Phys. Procedia [Internet] [cited 18 Nov 2015] **56**:1153–1164 (2014)
5. Shemfe, M.B., Gu, S., Ranganathan, P.: Techno-economic performance analysis of biofuel production and miniature electric power generation from biomass fast pyrolysis and bio-oil upgrading. Fuel [Internet] [cited 28 June 2015] **143**:361–372 (2015)
6. Röthlisberger, V., Zischg, A.P., Keiler, M.: Identifying spatial clusters of flood exposure to support decision making in risk management. Sci. Total Environ. **598**:593–603 (2017)
7. Liu, W., Ramirez, A.: State of the art review of the environmental assessment and risks of underground geo-energy resources exploitation. Renew. Sustain. Energy Rev. **76**:628–644 (2017)

8. Achilias, D.S., Roupakias, C., Megalokonomos, P., Lappas, A.A., Antonakou, V.: Chemical recycling of plastic wastes made from polyethylene (LDPE and HDPE) and polypropylene (PP). J. Hazard. Mater. **149**:536–542 (2007)
9. Addai, E.K., Gabel, D., Krause, U.: Experimental investigation on the minimum ignition temperature of hybrid mixtures of dusts and gases or solvents. J. Hazard. Mater. [Internet] [cited 21 Oct 2015] **301**:314–326 (2015)
10. Li, H., Ye, X., Geng, Z., Zhou, H., Guo, X., Zhang, Y., et al.: The influence of biochar type on long-term stabilization for Cd and Cu in contaminated paddy soils. J. Hazard. Mater. [Internet] [cited 18 Nov 2015] **304**:40–48 (2015)
11. Kiendl, I., Klemm, M., Clemens, A., Herrman, A.: Dilute gas methanation of synthesis gas from biomass gasification. Fuel [Internet] [cited 3 Oct 2015] **123**:211–217 (2014)
12. Al-Salem, S.M., Evangelisti, S., Lettieri, P.: Life cycle assessment of alternative technologies for municipal solid waste and plastic solid waste management in the Greater London area. Chem. Eng. J. [Internet] [cited 4 Jan 2015] **244**:391–402 (2014)

# Treatment of Effluent from Pharmaceutical Industry Using Calcium Oxide Obtained from Eggshells

**Vishal Kumar Singh, Mikesh H. Chevli, S. M. Tauseef and Nihal A. Siddiqui**

## 1 Introduction

Wastewater contaminated with varying amount of toxic substances mostly heavy metals generated from various industries such as pharmaceuticals, organic chemicals, pesticides, mining has shown to have harmful consequences for human and aquatic ecosystems [1, 2]. The hazardous heavy metals considered in this study have been reported as potential pollutants with the capability to contaminate water streams causing disturbance in the naturally functioning of the ecological cycle [3, 4]. The metals falling in group with density of atoms greater than 4 gm/cc or which are five or more times heavier than water are considered as heavy metals [5–7].

Wastewater generated from variety of manufacturing unit is loaded with numerous types of heavy metals [As, Cd, Pb, Zn, Hg, Ag, Cr, Cu, Fe, elements from Pt. group, etc., and their various ions and oxides] along with the presence of complex organic and inorganic compounds [8]. Industries considered for the study produce effluents loaded with heavy metals which are disposed, without proper treatment, thereby causing environmental pollution. The reason behind this is not the lack of technology but absence of cognizance in applying such technology in an efficient manner with novel approaches.

V. K. Singh · M. H. Chevli · S. M. Tauseef (✉) · N. A. Siddiqui
University of Petroleum and Energy Studies, Bidholi via Premnagar, Dehradun 248007, India
e-mail: smtauseef@ddn.upes.ac.in

V. K. Singh
e-mail: Vishalksingh3011@gmail.com

M. H. Chevli
e-mail: chevli.mikesh@gmail.com

N. A. Siddiqui
e-mail: nihal@ddn.upes.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*, Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_32

Removal of heavy metals is done conventionally using coagulation, ion exchange, biodegradation, dehydration, chemical precipitation, solvent extraction, and membrane technologies (novel separation approach). However, these methods are reported to be very costly and on the other hand, they do not result in complete removal of heavy metals [9] and most of them require certain primary treatment before application [10]. Recently, adsorption using low-cost biosorbents extracted from various natural materials and wastes of agricultural origin has been used for heavy metal removal from industrial effluent [11].

Various types of nonconventional low-cost biosorbents are reported in the literature. They are divided into six broad categories such as solid waste and coal waste sorbents such as pinewood, corncob, bagasse, waste carbon slurries, sewage sludge, rice husk, materials from the agriculture origin include sugar industry sludge, fly ash, metal hydroxide sludge, banana peel, coir pith, bark of eucalyptus plant, natural materials such as Ireland charred dolomite, Turkey, Spain origin activated bentonite, glass powder, chitosan and chitosan-based biomaterials such as cross-linked chitosan bead, bead, crab, lobster-based chitosan, peat materials, various types of biomass such as biomass from activated sludge, yeasts, Chlorella vulgaris, dead fungus *Aspergillus niger*, and others such as cotton waste, starch-based materials, cross-linked cyclodextrin [12].

Application of eggshell as a cost effective bioadsorbent for the elimination of various types of contaminants in wastewater generated from pharmaceutical, dye, organic chemicals, biodiesel manufacturing industries, etc., has been reported. Moreover, several studies have identified their suitability by using synthesized heavy metal solution. In these studies, eggshells from hen, duck, crab, quail, ostrich, etc., have been used as an effective adsorbent and their effectiveness have been assessed based on adsorption isotherms and by using various kinetic models.

Kose et al. [13] have studied phosphate ion removal from aqueous solution using calcined waste eggshell and concluded that calcined eggshell is a probable less expensive biosorbent for phosphate ions removal from wastewater. Adsorbent dosage was observed to have optimum value at 0.1 g/50 mL. Temperature was not observed to have significant effect on the removal efficiency which was observed to be >99% in 2–10 pH range [5]. Saha et al. [14] studied eggshells feasibility for hazardous anionic dye (Direct Red 28) removal from solution considering batch and continuous mode of operation. The experiment was conducted by varying pH, initial dye concentration, particle size, residence time, and temperature. It was concluded from the experiment that eggshells can be used for the removal of Direct Red 28.

On the other hand, Markovski et al. [15] studied the removal of arsenate using calcined eggshell modified with goethite and $\alpha$-$MnO_2$ in a batch experiment. Various conditions such as pH, initial arsenate concentration, ions interference, residence time, temperature were studied to have a better idea of the adsorption phenomena. The collected data was fitted with available adsorption models to know the best fit. Calcined modified eggshell was observed to be an effective low-cost biowaste sorbent for arsenate removal from solutions.

Apart from this, the use of modified eggshell for the production of biodiesel from different sources has been reported [16, 17]. Rohaizar et al. [1] examined potential of using chicken eggshell for Cu (III) removal from water. Park et al. [10] have demonstrated the likelihood of using modified and chemically treated eggshell both in raw form as well as in calcined state on synthetically produced solution and real effluent. They observed that calcined eggshell is more favorable for the removal of Cd and Cr in synthetically produced wastewater. On the other hand, raw eggshell (i.e., without treatment) has more affinity for Pb. This can be elucidated, and various metals have different affinity for various surfaces and because of varying compositions of the adsorbent and the aqueous solution in contact with the adsorbent.

Removal of metals ion contaminants such as iron and chromium to facilitate the recycling of spent solution generated from hard chrome plating process has been studied by Rubcumintara [18]. He compared the effect of modified and unmodified eggshells on the adsorption efficiency of the metal ions and observed that hydrochloric acid-modified eggshell possesses better removal efficiency as compared to unmodified eggshell.

The major source of eggshell waste is food processing industry, egg hatching and egg breaking industry. Majority of the waste eggshell is discarded and buried in landfills, and only a small portion is used as a fertilizer and for animal feed [15]. Eggshells are considered as useless, and therefore they are disposed or thrown away without pretreatment thereby creating serious environmental problems [19]. The consumption of eggs has increased at a rate of 8.9 kg/capita/year in the year 2009, accounting to approximately 167 eggs consumption per person per year as compared to that in 1990 (an increase of 41%); worldwide egg production has reached to about $6.5 \times 107$ ton/year (185% increment as compared to 1990 production) [20]. Due to such an enormous consumption and simultaneous waste generation (3–12% of the egg mass) and because of its attractive properties (pores—7000–17,000, calcite—$\sim$85–90%, 1.4% $MgCO_2$, 0.7–0.8% phosphate, 4–5% organic matter and traces of metals such as Na, K, Zn, Fe, Cu), eggshells are considered as an appropriate and highly favorable adsorbent [21].

The objective of the present study is to develop a commercially viable technology for heavy metals removal from industrial effluents using calcined eggshell. Most of the research work done so far focuses on assessing the effectiveness of using eggshell as a suitable adsorbent for heavy metals removal from synthetically produced solution; very less work has been done on applying eggshell on real effluent of industrial origin and providing a method to implement it in the industrial arena.

While keeping in mind the useful properties of eggshell, the need of an hour is to apply eggshell on real effluent in order to validate this adsorption technique and to provide valuable suggestions to potential industries in using eggshells instead of the conventionally used activated carbon and other adsorbents which offers the disadvantage of high cost apart from usual regeneration problems.

In this work, the effluent composition was determined to know the types of heavy metals present in it. After adsorption with eggshell, the final composition was analyzed to know which heavy metals are removed by adsorption under suitable operation conditions.

Considering such huge amounts of eggshells produced throughout the world, the goal of this research work is to provide a commercially viable technology by the practical application of calcined eggshells on real effluent in batch as well as continuous mode. The main objective is to assess the removal efficiency of heavy metals from the real effluent using calcium oxide obtained from the calcination of calcium carbonate which is the major constituent of eggshells. The work which is presented herein is divided into following parts, firstly to analyze the industrial effluent for its heavy metal composition, secondly to study the physiochemical properties of calcined eggshell through XRD, SEM, EDAX, PSA, BET analysis, then to study the adsorption process in batch and continuous operation, and then lastly to analyze the treated effluent to know the types and the amount of heavy metals removed to assess the effectiveness of adsorption process.

## 2 Methodology

### *2.1 Adsorbent Preparation*

The raw eggshells were collected from various restaurants, bakery shops, and from other small shops. Firstly, the eggshells were washed and cleaned with tap water. After cleaning, the eggshells were dried under direct sunlight for 3 h. The eggshells after drying were crushed into small pieces and placed in silica crucible for heating in muffle furnace at 500 °C for 5 h. After the initial heat treatment, the eggshells were treated with acid.

The eggshells were dispersed in 20 ml of nitric acid ($HNO_3$) for 6 h. The pre-heated eggshells were given acid treatment for opening of the pores. When the acidification is completed, the eggshells were washed with tap water properly and the pH was adjusted within a range of 6.5–7. For adjusting the pH sample, NaOH was used as the level of pH was found less than 4 due to acid treatment. After the pH is maintained, the eggshells are dried and kept again for final heat treatment at 1000 °C for the calcination. Finally, a fine white colored calcined eggshell was obtained and it was manually powdered using pestle and mortar into fine particles.

### *2.2 Adsorbate Preparation*

The adsorbate is the effluent which is collected from the pharmaceutical industry. This effluent is collected from a Pharma company located in the Selaqui Industrial Estate of Dehradun. The untreated effluent from various drug manufacturing processes was collected in a centralized wastewater collection tank. Drug manufacturing process releases many heavy metals which are present in the wastewater. The commonly found heavy metals are cadmium, lead, arsenic, chromium, and copper.

**Characterization of Calcined Eggshells**

To study the physiochemical properties of the calcined eggshells, characterization was performed. Different types of analysis were performed such as X-ray dispersive (XRD) analysis which is used for the phase identification of a material. The phase is amorphous or crystalline at 2° theta. Energy dispersive X-ray spectroscopy (EDS) is an analytical technique used for the elemental analysis or chemical characterization of the calcined powder. The particle size of calcinated and powered eggshell greatly influences the adsorption of heavy metals from the effluent. The particle size of the calcined powder was in nanometer or micrometer as determined using particle size analyzer (PSA).

The t-plot method is used to determine the micropore and mesopore volumes, and specific surface of calcium oxide powder. While the pore size distribution was determined using Barrett-Joyner-Halenda (BJH) analysis and the total pore volume was obtained by converting the nitrogen adsorption amount at a relative pressure of 0.98 to the liquid volume.

The surface morphology of calcined eggshells was identified by using scanning electron microscopy (SEM) technique.

## 2.3 *Characterization of Adsorbate*

The adsorbate which is collected from the pharmaceutical industry for the treatment is collected from storage tank without any primary treatment. The effluent contains heavy metals, and their concentration is determined by using atomic absorption spectrophotometer (AAS). Through this technique, the concentration of major heavy metals like cadmium, arsenic, lead, chromium, nickel, and copper can be determined. After the characterization of heavy metals in the effluent, its

**Table 1** Characterization of real effluent for heavy metal determination

| Heavy metal | Concentration (mg/L) |
|---|---|
| Lead | 0.1025 |
| Copper | 0.314 |
| Cadmium | 0.192 |
| Chromium | 1.369 |

concentration was found for cadmium, lead, copper, and chromium which is shown in Table 1.

After the characterization of calcined eggshell and quantification of heavy metal concentration in effluent, experiments were done in batch as well as in continuous mode, under specified operating conditions, to verify the effectiveness of heavy metal removal using calcined eggshell.

## 2.4 Batch Adsorption Studies

The biosorption studies were conducted in batch mode in order to evaluate the effect of dosage (150–450 mg), effect of pH (2–8) and effect of temperature (20–80 °C) and contact time. The experiments were carried out in 250 mL of glass stoppered, Erlenmeyer conical flasks with 100 mL of working volume of the effluent. Different parameters were considered for the batch studies which were performed by varying the conditions. For the effect of dosage, the calcined eggshell was added in the conical flask with the varying dosage amount of 150, 250, 350, and 450 mg. These four different concentrations of adsorbent were added in the effluent and kept in the incubator shaker from 20 to 80 min for the effect of adsorbent on the concentration of the adsorbate.

pH levels were varied from acidic to basic in order to determine its effect on the rate of adsorption of the heavy metals in the effluent. The pH levels were varied in four steps—pH 2, pH 4, pH 6 and pH 8. These four levels were considered to estimate the pH required for maximum adsorption of the heavy metals.

Temperature is also an important phenomenon to identifying the effectiveness on the calcined eggshells on the effluent. Temperature effects the rate of adsorption by increasing the activity on the substrate. Contact time can determine the removal efficiency of the calcined eggshell and the activity rate on the effluent. If the contact time is more, will it be more effective or less effective for the heavy metals removal from the effluent.

## 2.5 Continuous Adsorption Studies

Adsorption experiment in continuous mode was conducted in a 3 cm diameter and 50 cm heigh glass column under normal condition. A known quantity of biosorbent was packed inside the glass column. At the bottom of the column, 1 cm in height, nonabsorbent cotton was placed to support the sample and prevent its leakage from the outlet. A known quantity of adsorbent was added to the glass column. A layer of glass beads (1 mm in diameter) was added to the glass column to prevent washout of the biosorbent and ensure proper flow of the feed, through the column, at a constant rate. The column is fed with the help of a funnel fitted to the top of the glass column. The column is fed with effluent and the activity of the adsorbent is determined. The effect of feed flow rate (5–15 ml $min^{-1}$) and bed height (h) (3.5–5.5 cm) is studied. The treated effluent from the outlet of the column is collected at a regular interval, and the flow rate is also measured. The removal efficiency is studied by using atomic absorption spectroscopy (AAS). The operation of column is stopped when the feed concentration reaches to its initial level depending upon its physical appearance.

# 3 Results and Discussion

## *3.1 XRD Analysis*

The phase and structure characterization of calcined eggshells were carried out using X-ray diffraction (XRD) analysis, and the obtained XRD patterns are shown in Fig. 1. The XRD diffraction spectra of the sample were obtained with CuKα radiation in a 2θ scan range of 5°–80°. The XRD peaks of raw eggshells at 2θ occurred at angle 29.39, 35.98, 39.41, 43.17, and 48.50. While in case of eggshells calcined at 1000 °C for 1 h, the XRD peaks are produced at an angle 34.07, 47.16, 50.81 indicating calcium oxide as a pure phase. The physical reformation occurs

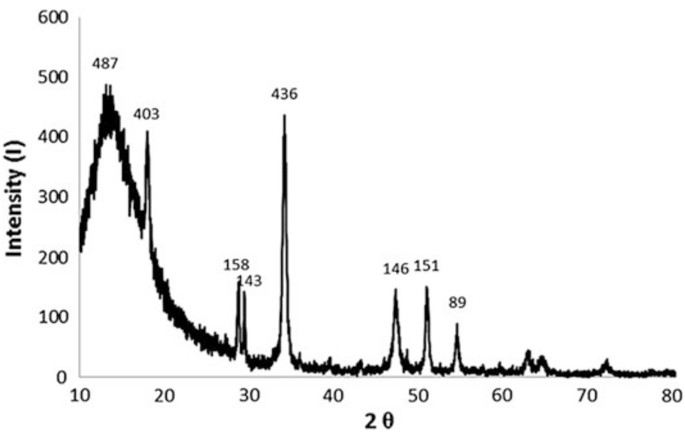
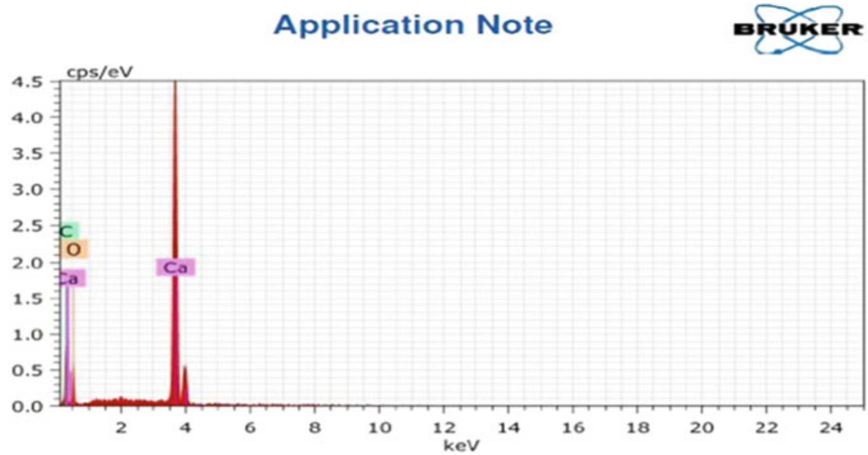



**Fig. 1** XRD pattern of eggshells calcined at 1000 °C




Spectrum: training

| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| O | 8 | K-series | 50.54 | 39.91 | 45.49 | 13.94 |
| Ca | 20 | K-series | 43.76 | 34.55 | 15.72 | 1.45 |
| C | 6 | K-series | 32.35 | 25.54 | 38.78 | 8.45 |
| | | Total: | 126.65 | 100.00 | 100.00 | |

**Fig. 2** EDS analysis of calcium oxide obtained from eggshells

when the eggshells are heated at more than 700 °C. The maximum spectrum originated at 34.07 represents the crystalline phase of the calcium oxide obtained.

## 3.2 *EDS Analysis*

The result of EDS analysis is shown in Fig. 2. The quantitative analysis determines the percentage of calcium oxide at 3.8 keV; the peak obtained at 4.5 cps/ev shows the presence of calcium metal. The percentage of calcium oxide as distributed in Fig. 2 is 74 wt% of the calcined eggshells. This is the elemental analysis for any composite material. The EDS analysis shows that calcined eggshell as used in this research work contains high percentage of pure calcium.

## 3.3 *Particle Size Analysis*

For performing PSA, the sample of calcium oxide was mixed with ethylene glycol which acts as surfactant to reduce the surface tension of the particles and also it acts as a wetting agent. The process includes ultra-sonication, as due to addition of surfactant the particles gets agglomerated and diameter of individual particle cannot

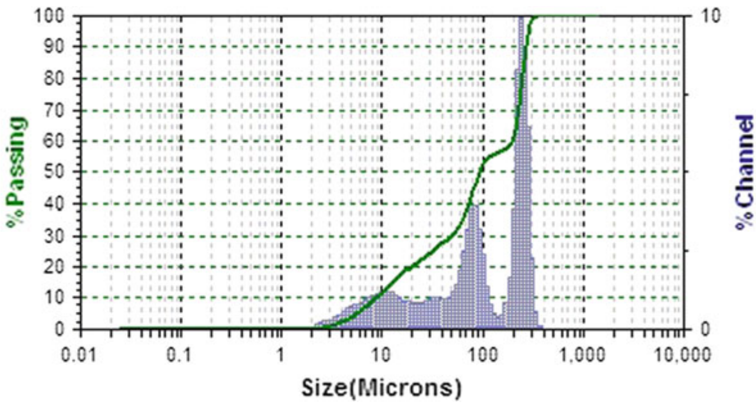



**Fig. 3** Particle size before ultra-sonication

**Table 2** Mean diameter of calcium oxide before ultra-sonication

| | |
|---|---|
| MV (μm) | 132.4 |
| MN (μm) | 4.51 |
| MA (μm) | 29.4 |
| SD | 118.6 |

be identified. For better results, ultra-sonication is performed so the particles remain separated. The particle size of calcium oxide is represented in Fig. 3 and Table 2. The particle size analysis conducted before ultra-sonication in a triplet decides the particle size in microns. The average value of the triplet is considered. The mean particle size based on the volume distribution of more than 50% of the particles is 132 μm. The diameter of particles is large due to agglomeration of particles.

The particle after ultra-sonication is shown in Fig. 4 and Table 3. This analysis was performed using glycerol as a surfactant for calcium oxide to inhibit agglomeration in a triplet. The mean particle size after ultra-sonication was found to be 16 μm.

## 3.4 BET Analysis

The BET analysis was performed, at a temperature of −195.5 °C, for 0.4213 g of powered calcium oxide. Nitrogen ($N_2$) gas was supplied. The calcium oxide absorbs the gas till it attains a saturation pressure of 786.4 mmHg. The desorption of the gas helps in determination of the porosity of the calcium oxide particles per unit volume. The parameters analyzed (Fig. 5) were surface area, mesopore volume, macropore volume, and pore radius. The results are summarized in Table 4.

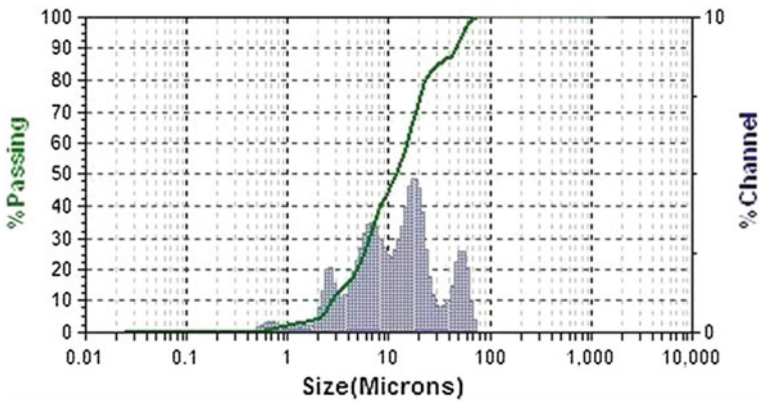



**Fig. 4** Particle size after ultra-sonication

**Table 3** Mean diameter of calcium oxide after ultra-sonication

| | |
|---|---|
| MV (μm) | 16.7 |
| MN (μm) | 0.934 |
| MA (μm) | 6.14 |
| SD | 12.10 |

## *3.5 SEM Analysis*

The SEM images of calcium oxide obtained from eggshells before and after calcination are shown in Figs. 6 and 7, respectively. Before adsorption, the surface area shown is more exposed and the particle size diameter at 2000 × resolution shows the particle are much separated. After the calcination of eggshells is done, the results show enlargement of particle size and it is denser and distance between the particles is also decreased.

## *3.6 Batch Adsorption Studies*

### 3.6.1 Effect of Dosage

The adsorption of ions present in the solution mainly depends upon the extent of pH of the solution which affects the surface charge of the adsorbents. Initially the pH of the solution is acidic in nature, and to determine the activity of adsorbent in the solution, the concentration of calcium oxide has increased eventually ranging 150–450 mg/100 ml. The absorbance rate is determined by using

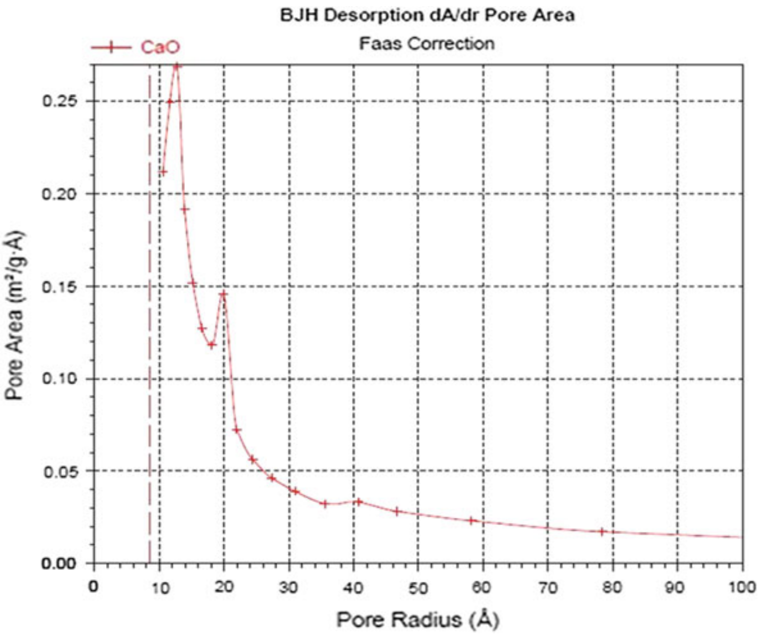



**Fig. 5** Plot between pore radius and pore area of calcium oxide

**Table 4** Surface area and pore volume of calcium oxide powder

| BET surface area ($m^2/g$) | Mesopore volume ($cm^3/g$) | Macropore volume ($cm^3/g$) | Pore radius Å |
|---|---|---|---|
| 6.0978 | 0.032812 | 0.9945031 | 1763.142 |

UV—spectrophotometer where the initial absorbance value from 1.339 has decreased to 0.0172 which shows that the maximum removal has been achieved up to 86%. It is shown in Fig. 8, with increase in the dosage amount, the removal percentage increases and maximum removal occurred using 450 mg. With increase in dosage value, the removal efficiency is decreased as it attains the saturation level.

### 3.6.2 Effect of pH

As we have found in the earlier run that the dosage has affected the removal efficiency of the adsorbate. The dosage level was kept constant at 450 mg and the experiments by varying the pH level (2–10). The metal oxide shows maximum adsorption at pH 6, while there was a decline in removal efficiency with increase in pH level. At low pH level when the calcium oxide reacts, it tries to neutralize the condition by combining with the negative ions. Moving toward more basic

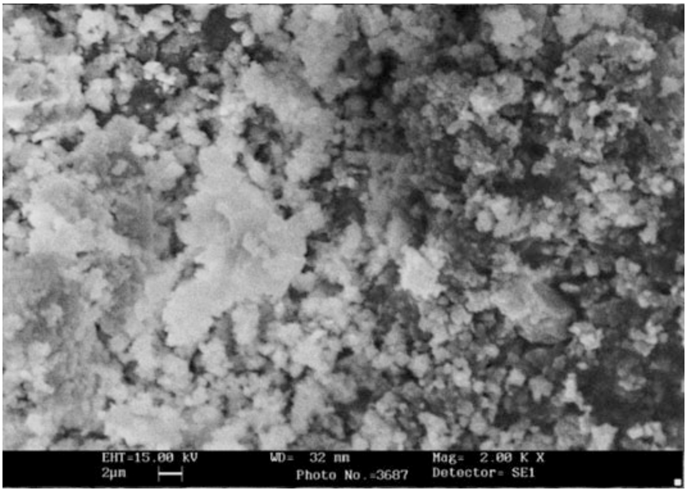



**Fig. 6** SEM image before calcination of eggshells

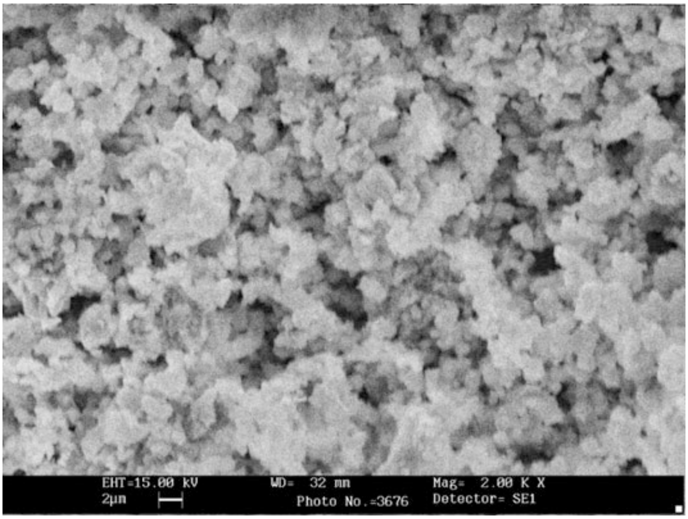



**Fig. 7** SEM image after calcination of eggshells

conditions, the ions lose the property of binding as more positive charge are developed in the solution and this results in its activity. At pH 6, conditions become more favorable to the adsorbate and ions bind to the metal oxide surface as shown in Fig. 9 and thus create more effective conditions and cause maximum removal of ions.

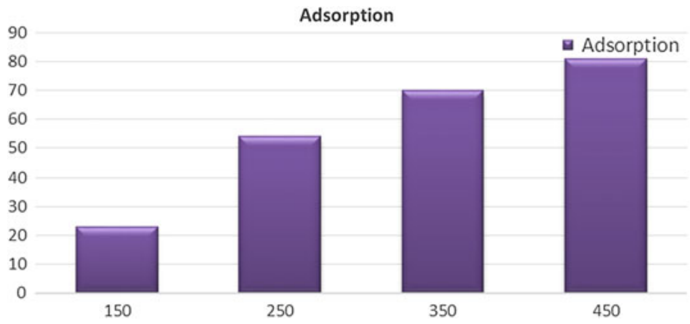



**Fig. 8** Effect of varying dosage on % removal efficiency

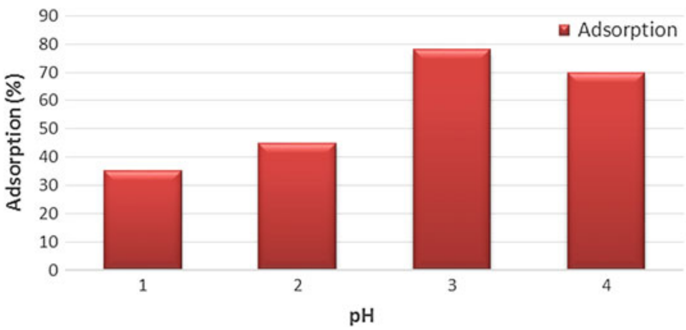



**Fig. 9** Effect of pH on the ions removal using calcium oxide

### 3.6.3 Effect of Temperature

The conditions were optimized for increasing the removal efficiency of the ions from the solution. Temperature plays an important role in varying the capacity of the calcium oxide. The adsorbent always requires an optimum temperature to perform better activity on the ions to bind on their surface. The temperature was varied from 20 to 80 °C. With increase in temperature, the adsorption rate rises but at very high temperature the removal rate eventually decreases. The removal efficiency is achieved maximum at 40 °C as shown in Fig. 10. The efficiency has decreased at higher temperature (80 °C) because high temperature can change the chemical properties of the adsorbate as the ions try to evaporate and even the adsorbate surface area may also change.

### 3.6.4 Effect of Contact Time

The effect of contact time was studied with pH 6 and temperature 40 °C. The maximum dosage has shown its effect on the adsorbate. The calcium oxide shows

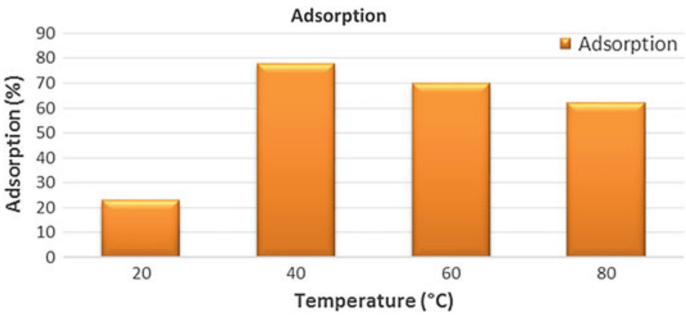



**Fig. 10** Effect of temperature on effluent by using calcium oxide

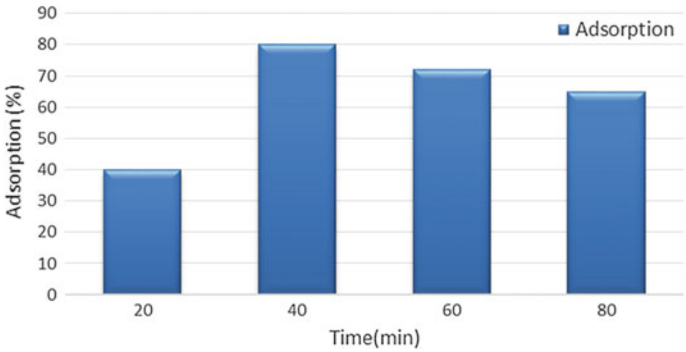



**Fig. 11** Effect of contact time on effluent by the activity of calcium oxide

its effect just after 10 min in contact with the solution, and the ions get bind to the surface due to availability of active binding sites and high porous nature. Initially, the ions try to capture the binding site and with the period of time the ions remain in contact leading to occupancy of the possible binding site, and this causes saturation of the active site and the effect gets decreases as shown in Fig. 11. In initial 20 min the adsorption increases, and at 40 min the binding of ions to the active site is maximum which is observed through its removal efficiency. But at 80 min, the calcium oxide is saturated and finally stops binding on its surface and thus no effect occurs further on.

## *3.7 Continuous Adsorption Studies*

### 3.7.1 Effect of Bed Height

The biosorption of heavy metals at different bed height is shown in Fig. 12. The increase in breakthrough time increases with the bed height. The variance in the

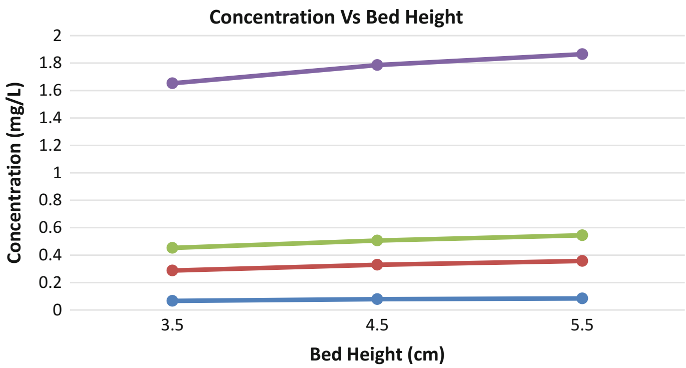



**Fig. 12** Concentration of heavy metal with varying bed height

**Table 5** Effect of bed height on heavy metal removal

| Bed height (cm) | Pb | Cu | Cd | Cr |
|---|---|---|---|---|
| 3.5 | 0.066 | 0.222 | 0.165 | 1.2 |
| 4.5 | 0.079 | 0.251 | 0.176 | 1.28 |
| 5.5 | 0.084 | 0.273 | 0.188 | 1.32 |

concentration of various heavy metals can be seen with the changes in the bed height as shown in Table 5. Longer the contact time between the metal ions and absorbent, higher is the removal efficiency. With higher bed height, a longer residence time in column for heavy metal ions is obtained. But saturation occurs with decreased removal efficiency when the bed height is increased.

### 3.7.2 Effect of Flow Rate

One of the important parameters to evaluate the effectiveness of biosorption process in continuous operation is flow rate; this parameter is also useful for treatment on commercial scale. The effect of flow rate was studied with varying its rate from 5 to 15 mL/min with concentration of effluent on as received basis and constant bed height 5.5 cm. The results are presented in Fig. 13. Therefore, reduction in the concentration of heavy metals was observed with the change of flow rate. It can be seen from the figure that lower flow rates result in higher removal efficiency and vice versa. This is because higher contact time between adsorbent and adsorbate results in higher removal efficiencies (Table 6).

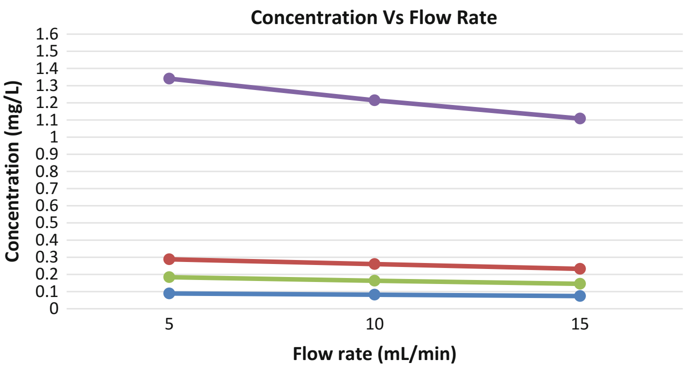



**Fig. 13** Concentration of heavy metal with varying flow rate

**Table 6** Effect of flow rate on heavy metal removal

| Flow rate (mL/min) | Pb | Cu | Cd | Cr |
|---|---|---|---|---|
| 5 | 0.089 | 0.288 | 0.184 | 1.341 |
| 10 | 0.082 | 0.26 | 0.163 | 1.214 |
| 15 | 0.074 | 0.232 | 0.145 | 1.108 |

## 4 Conclusion

The experimental study as presented in this paper for heavy metals (Pb, Cu, Cr, Cd) removal from the effluent collected from pharmaceutical industry using calcined eggshell showed promising results with overall removal efficiencies up to 86% and 98% by batch and continuous studies, respectively. For continuous operation, removal efficiency was observed maximum for Cr (98%), whereas Pb showed minimum reduction (65%).The sorption experiments were carried out by varying conditions in batch (adsorbent dosage, pH, temperature, contact time) operation and continuous operation (bed height, flow rate). Optimum conditions were obtained at dosage (450 mg), pH (6.0), and temperature (40 °C) for batch experiments; for continuous operations, optimum conditions were analyzed at bed height (5.5 cm) and flow rate (5 mL/min). From the results, it can be concluded that calcined eggshell can be used as an effective adsorbent for effluent treatment and can be used for commercial purpose using the optimum conditions as described in this study.

## References


1. Rohaizar, N.A., Hadi, N.A., Sien, W.C.: Removal of Cu(II) from water by adsorption on chicken eggshell. Int. J. Eng. Technol. IJET-IJENS **13**(01), 40 (2013)
2. Baysal, A., Ozbek, N., Akman, S.: Determination of trace metals in waste water and their removal processes. Waste Water—Treatment Technologies and Recent Analytical Developments (2013)
3. Akar, S.T., Uysal, R.: Un-treated clay with high adsorption capacity for effective removal of C. I. Acid Red 88 from aqueous solutions: batch and dynamic flow mode studies. Chem. Eng. J. **162**, 591–598 (2013)
4. Hutton, M., Symon, C.: The quantities of cadmium, lead, mercury and arsenic entering the U. K. environment from human activities. Sci. Total Environ. **57**, 129–150 (2013)
5. Nriagu, J.O., Pacyna, J.: Quantitative assessment of worldwide contamination of air, water and soil by trace metals. Nature **333**, 134–139 (1988)
6. Nriagu, J.O.: A global assessment of natural sources of atmospheric trace metals. Nature **338**, 47–49 (1989)
7. Hawkes, J.S.: Heavy metals. J. Chem. Educ. **74**(11), 1374 (1989)
8. Duruibe, J.O., Ogwuegbu, M.O.C., Egwurugwu, J.N.: Heavy metal pollution and human biotoxic effects. Int. J. Phys. Sci. **2**(5), 112–118 (1989)
9. Kam, S.K, Hong J.Y., Hyun, S.S. et al.: Removal of copper ion by Na-P1 synthesized from Jeju scoria. J. Korean Environ. Sci. **11,** 75–83 (2002)
10. Park, H.J., Jeong, S.W., Yang, J.K., Kim, B.G., Lee, S.M.: Removal of heavy metals using waste eggshell. J. Environ. Sci. **19**, 1436–1441 (2007)
11. Gupta, V.K., Suhas, : Application of low cost adsorbents for dye removal: a review. J. Environ. Manage. **90**, 2313–2342 (2009)
12. Crini, G.: Non-conventional low-cost adsorbents for dye removal: a review. Bioresour. Technol. **97**, 1061–1085 (2006)
13. Kosea, T.E., Kivanc, B.: Adsorption of phosphate from aqueous solutions using calcined waste eggshell. Chem. Eng. J. **178**, 34–39 (2011)
14. Saha, P.D., Chowdhury, S., Mondal, M., Sinha, K.: Biosorption of Direct Red 28 (Congo Red) from aqueous solutions by eggshells: batch and column studies. Sep. Sci. Technol. **47**, 112–123 (2012)
15. Markovski, J.S., Markovic, D.D., Đokic, V.R., Mitric, M., Ristic, M.D., Onjia, A.E., Marinkovic, A.D.: Arsenate adsorption on waste eggshell modified by goethite, $\alpha$-$MnO_2$ and goethite/ $\alpha$-$MnO_2$. Chem. Eng. J. **237**, 430–442 (2014)
16. Khemthong, P., Luadthong, C., Nualpaeng, W., Changsuwan, P., Tongprem, P., Viriya-empikul, N., Faungnawakij, K.: Industrial eggshell wastes as the heterogeneous catalysts for microwave-assisted biodiesel production. Catal. Today **190**, 112–116 (2012)
17. Tan, Y.H., Abdullah, M.O., Nolasco-Hipolito, C.: The potential of waste cooking oil-based biodiesel using heterogeneous catalyst derived from various calcined eggshells coupled with an emulsification technique: a review on the emission reduction and engine performance. Renew. Sustain. Energy Rev. **47**, 589–603 (2015)
18. Rohaizar, N.A., Hadi, N.A., Sien, W.C.: Removal of Cu(II) from water by adsorption on chicken eggshell. Int. J. Eng. Technol. **13**(01) 40 (2013). (IJET-IJENS)
19. Verma, N., Kumar, V., Bansal, M.C.: Utilization of egg shell waste in cellulase production by neurosporacrassa under wheat bran-based solid state fermentation. Pol. J. Environ. Stud. **21** (2), 491–497 (2012)
20. FAO, FAOSTAT, [WWW Document], URL http://faostat3.fao.org/browse/Q/*/E (2016)
21. Chojnacka, K.: Biosorption of Cr (III) ions by eggshells. J. Hazard. Mater. **B121**, 167–173 (2005)

# Chemometric Techniques: A Comparative Study of Drinking Water Sources of Dehradun and Haridwar, Uttarakhand (India)

**R. S. Aswal, P. Singh, N. Kamboj and R. Singh**

## 1 Introduction

Dehradun and Haridwar both are economically significant districts of the Uttarakhand due to large-scale industrialization.

In the present study, 11 physico-chemical water quality variables have been assessed with reference to Bureau of Indian Standard (BIS), 2012 during April, 2015 from 5 drinking water sources of both districts. The analyzed water quality data set is subjected to chemometric techniques such as principal component analysis (PCA), cluster analysis (CA) and factor analysis (FA) to determine the cause(s) and source(s) of contamination of drinking water sources being used for public supply, which are responsible for water quality deterioration of Dehradun and Haridwar districts of Uttarakhand, India.

R. S. Aswal (✉) · P. Singh
Department of Chemistry, D.A.V. (P.G.) College, Dehradun, India
e-mail: ravi_aswal1998@yahoo.co.in

P. Singh
e-mail: prashantraj86@yahoo.com

N. Kamboj
Department of Zoology and Environmental Sciences, Gurukula Kangri University, Haridwar, India
e-mail: kambojgurukul@gmail.com

R. Singh
Department of Chemistry, D.B.S. (P.G.) College, Dehradun, India
e-mail: rakesh72chem@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_33

## 2 Materials and Methods

### 2.1 Study Area

The place of sampling along with name of drinking water source of both Dehradun and Haridwar districts are summarized in Table 1.

### 2.2 Methodology for Sampling and Preservation

The water samples from 5 sampling sites each of Dehradun and Haridwar districts were collected by applying grab-sampling method. The preservation and analysis of water samples collected for the study were done as per standard protocols and methods of APHA [1] and BIS [3].

**Chemometric Techniques**

*Principal Component Analysis (PCA)/Factor Analysis (FA)*
Both principal component analysis (PCA) and factor analysis (FA) are variable reduction techniques. Factor loading matrix was calculated using the principle component method. The factor with highest eigenvalue was considered to be the most significant, and the factors with eigenvalues greater than or equal to 1.0 were considered to be significant. FA helps in correlating the underlying factors, which are not directly discernible, with the observations [8].

*Cluster Analysis (CA)*
The cluster analysis (CA) is used to categorize different objects into groups depending on the degree of association between the objects [2]. In a dendrogram, groups with high level of similarity are depicted as having small distances between clusters, while dissimilar groups are represented by showing clusters with maximum possible distances between them.

**Table 1** Drinking water places/sources of Dehradun and Haridwar Districts

| S. no. | Place/source of Dehradun | Place/source of Haridwar |
|---|---|---|
| 1 | Dehradun City/Bandal | Laksar/Nalkoop no. 1 |
| 2 | Dehradun City/Massifall | Devpura/Pump no. 38 |
| 3 | Dehradun City/Bhitarli | Pandeywali/Nalkoop |
| 4 | Doiwala/Nalkoop no. 1 | Jhabreda/Nalkoop no. 1 |
| 5 | Mussoorie/Bhiladu | Bahadrabad/Nalkoop no. 1 |

## 3 Results and Discussion

Eleven water quality variables (mean values) of 5 drinking water sources of each Dehradun and Haridwar districts obtained during April, 2015 were separately applied in computation of chemometric techniques namely PCA/FA and CA and are given in Table 2.

### *3.1 Dehradun District*

Factor 1 shows significant bipolar characteristic and exhibits 51.243% out of total variance of 96.942% of data set. It has strong positive loadings on alkalinity, TDS, calcium, magnesium and sulphate, whereas negative pole has strong loading only

**Table 2** PCA/FA of drinking water sources of Dehradun and Haridwar Districts

| Rotated sums of squared loadings | | | | | |
|---|---|---|---|---|---|
| Dehradun | | | Haridwar | | |
| Total | % of total variance | % of cumulative total variance | Total | % of total variance | % of cumulative total variance |
| 5.637 | 51.243 | 51.243 | 4.450 | 40.459 | 40.459 |
| 3.323 | 30.206 | 81.448 | 3.609 | 32.805 | 73.264 |
| 1.704 | 15.493 | 96.942 | 2.556 | 23.236 | 96.500 |

| Rotated component matrix | | | | | | |
|---|---|---|---|---|---|---|
| Water quality parameters | Dehradun | | | Haridwar | | |
| | Factor 1 | Factor 2 | Factor 3 | Factor 1 | Factor 2 | Factor 3 |
| Turbidity | −0.087 | 0.056 | 0.977 | 0.223 | −0.715 | 0.653 |
| pH | −0.846 | −0.003 | 0.459 | −0.117 | −0.987 | 0.027 |
| Total hardness | 0.366 | 0.916 | 0.146 | 0.053 | −0.073 | 0.971 |
| Alkalinity | 0.995 | −0.005 | −0.037 | 0.178 | 0.892 | 0.415 |
| Chloride | 0.431 | 0.772 | −0.467 | 0.968 | 0.043 | −0.058 |
| TDS | 0.949 | 0.276 | −0.127 | 0.825 | 0.561 | −0.066 |
| Calcium | 0.855 | 0.403 | −0.231 | 0.622 | 0.493 | −0.436 |
| Magnesium | 0.979 | 0.199 | 0.005 | 0.896 | 0.341 | 0.201 |
| Sulphate | 0.809 | 0.568 | −0.126 | 0.645 | 0.702 | −0.293 |
| Nitrate | 0.496 | 0.726 | −0.292 | 0.968 | −0.196 | −0.092 |
| Iron | −0.335 | 0.870 | 0.356 | −0.439 | 0.341 | 0.826 |
| | Rotation converged in 5 iterations | | | Rotation converged in 6 iterations | | |

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

Component loadings with bold value indicates "strong pollution" on one water quality variable, i.e. pH. The first component/factor indicates mixed sources of pollution—natural and anthropogenic (including domestic sewage). The physico-chemical parameters for factor 1, viz. alkalinity, TDS, calcium, magnesium and sulphate, are caused by dissolution of minerals [5, 7].

Factor 2 accounts for 30.206% of the total variance. This factor has strongly influences the total hardness, iron and chloride. This factor indicates agro-based organic source of pollution including anthropogenic and geogenic sources.

Factor 3 exhibits 15.493% of the total variance of 96.942%. The turbidity shows strong positive loading factor, which is indicative of pollution caused by continuous erosion of soil from the banks of water bodies or other sources such as discharge from urban development areas, erosion of road edges and surface run-off [4].

## *3.2 Haridwar District*

Factor 1 explains the 40.459% of total variance. According to Liu et al. [6], total variance (Table 2) has strong positive loadings on chloride, TDS, magnesium and nitrate. Thus, it may be ascribed owing to "anthropogenic and geogenic pollution" factor.

Factor 2 accounts for 32.805% of the total variance of 96.500%. It has been found with strong positive loading on alkalinity, while negative pole has obtained strong loading on pH. This component also points out to "anthropogenic and geogenic pollution".

Factor 3 exhibits 23.236% of the total variance. This factor has strong positive loadings on total hardness and iron. This factor is also an indicative of "anthropogenic and geogenic pollution".

## *3.3 Cluster Analysis of Drinking Water Sources of Dehradun District*

The mean values of 11 water quality variables were used to make the clusters for evaluation of site variation among different sampling sites of Dehradun district. The dendrogram of 5 drinking water sources of Dehradun district illustrates two clusters and duly shown through Fig. 1.

Cluster 1: For water quality data of three drinking water sources of Dehradun district, (sampling sites no. 2 (Dehradun City, Massifall), 4 (Doiwala, Nalkoop No. 1) and 5 (Mussoorie, Bhiladu) formed first cluster of the dendrogram.

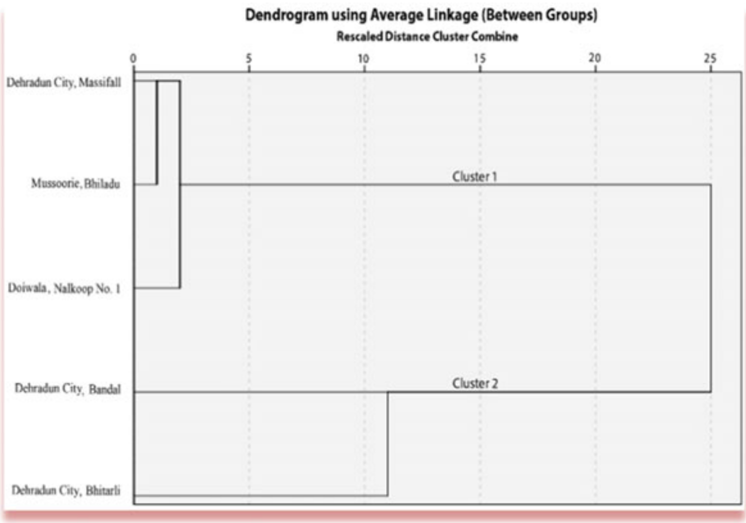



**Fig. 1** Dendrogram of cluster analysis for different drinking water sources of Dehradun

Cluster 2: Two drinking water sources no. 1 (Dehradun City, Bandal) and 3 (Dehradun City, Bhitarli) together make second cluster of the dendrogram.

## *3.4 Cluster Analysis of Drinking Water Sources of Haridwar District*

The dendrogram consisted of 5 drinking water sources of Haridwar district shows two clusters and duly shown through Fig. 2.

Cluster 1: For water quality data of 3 drinking water sources of Haridwar district, sampling sites no. 1 (Laksar, Nalkoop No. 1), 2 (Devpura, Pump No. 38) and 3 (Pandeywali, Nalkoop) formed first cluster of the dendrogram.

Cluster 2: For water quality data of 2 drinking water sources of Haridwar district, sampling sites no. 4 (Jhabreda, Nalkoop No. 1) and 5 (Bahadrabad, Nalkoop No. 1) together make second cluster of the dendrogram.

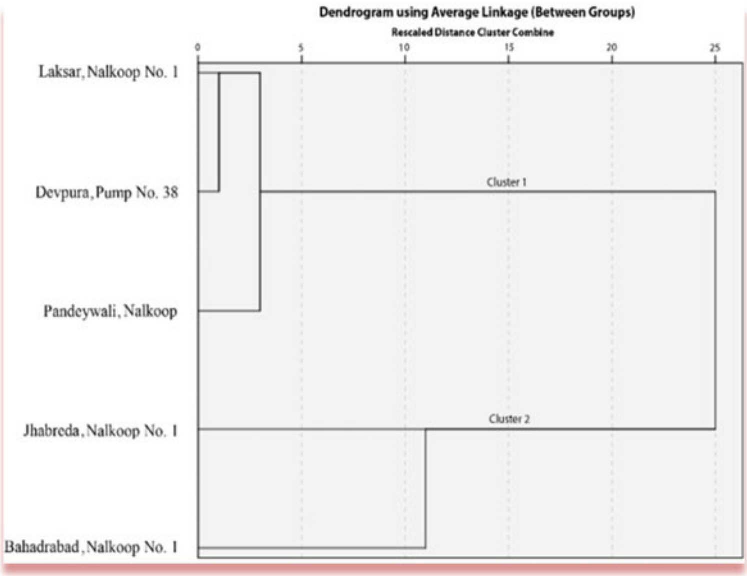



**Fig. 2** Dendrogram of cluster analysis for different drinking water sources of Haridwar

## 4 Conclusion

The multivariate statistical analysis—principal component analysis/factor analysis and cluster analysis—was applied to the observed data set, which generated three factors indicating the strength and nature of factor loadings on each of the eleven water quality variables. In Dehradun district, factor 1 pointed to mixed source of pollution coming from natural as well as anthropogenic activities. Factor 2 indicates organic source of pollution. While factor 3 indicates that the source of pollution is natural. Cluster 1 formed by three drinking water sources namely Massifall, Nalkoop No. 1 and Bhiladu of Dehradun district formed first cluster, whereas cluster 2 is made by Bandal and Bhitarli. However, in Haridwar district, factor 1, 2 and 3 all represent “anthropogenic and geogenic pollution”. The dendrogram showed 2 clusters in which, 3 sampling places, viz. Laksar, Devpura and Pandeywali formed first cluster and 2 sampling sites namely Jhabreda and Bahadrabad made second cluster.

A total of 10 strong loadings were recorded in data table of PCA/FA applied for studied water sources of Dehradun district, while it was only 8 loadings in Haridwar district. Thus, on the basis of results generated through chemometric techniques, it was obtained that the drinking water quality of water sources of Haridwar district was found to be better than the water sources of Dehradun district.

**Acknowledgements** The authors extend a sincere thank to Uttarakhand State Council for Science and Technology (UCOST), Dehradun; Uttarakhand Jal Sansthan, Dehradun and Gurukula Kangri University, Haridwar for providing support for the study.

## References

1. APHA, AWWA, WEF: Standards for examination of water and wastewater. 22nd ed. American Public Health Association, Washington, DC, USA (2012)
2. Aris, A.Z., Praveena, S.M., Isa, N.-Mohd., Lim, W.Y., Juahir, H., Yusoff, Mohd.-K., Mustapha, A.: Application of environmetric methods to surface water quality assessment of Langkawi Geopark (Malaysia). Environ. Forensics, **14**(3): 230–239 (2013)
3. Bureau of Indian Standards (BIS). Specification for drinking water. 1S: 10500. Bureau of Indian Standards, New Delhi (2012)
4. Goonetilleke, A., Thomas, E., Ginn, S., Gilbert, D.: Understanding the role of land use in urban storm water quality management. J. Environ. Manage. **74**(1), 31–42 (2005)
5. Jang, C.S.: Applying scores of multivariate statistical analyses to characterize relationships between hydrochemical properties and geological origins of springs in Taiwan. J. Geochem. Explor. **105**(1), 11–18 (2010)
6. Liu, C.W., Lin, K.H., Kuo, Y.M.: Application of factor analysis in the assessment of groundwater quality in a blackroot disease area in Taiwan. Science of Total Environmental **313**, 77–89 (2003)
7. Yidana, S.M., Ophori, D., Banoeng-Yakubo, B.: A multivariate statistical analysis of surface water chemistry data: the Ankobra Basin. Ghana. J. Environ. Manage. **86**(1), 80–87 (2008)
8. Yu, S., Shang, J., Zhao, J., Guo, H.: Factor analysis and dynamics of water quality of the Songhua River Northeast China. Water Air and Soil Poll. **144**, 159–169 (2003)

# Treatment of Sewage by the Weed *Ipomoea Aquatica*: A Feasibility Study on Bench-Scale SHEFROL® Bioreactor

**S. A. Abbasi, G. Ponni and S. M. Tauseef**

## 1 Introduction

As detailed in Chapter 30 of this volume [1], most of the sewage generated in developing countries is discharged untreated in rivers, lakes, oceans, and on land. It not only pollutes precious water and land, but also is a major source of water-borne diseases, straining the already fragile healthcare systems in developing countries to breaking point. Given this context, developing of simple, inexpensive, and clean-green yet efficient technologies to treat this sewage is one of the greatest challenges before environmental engineers.

Also, as detailed in Chapter 30 of this volume [1], a novel reactor named "SHEet Flow ROot Level (SHEFROL)" bioreactor has been developed by us that has shown promise to meet this challenge. A patent claim for SHEFROL® has been registered [2]. The reactor is capable of utilizing aquatic, amphibious, as well as terrestrial macrophytes to achieve primary, secondary, and some tertiary treatment of sewage in a single unit process.

In this paper, we present studies which have explored the suitability of a common weed water spinach (*Ipomoea aquatica*) as a bioagent for SHEFROL®.

S. A. Abbasi (✉) · G. Ponni
Centre for Pollution Control & Environmental Engineering, Pondicherry University, Chinakalapet, Puducherry 605 014, India
e-mail: abbasi.cpee@gmail.com

G. Ponni
e-mail: ponnipondy2006@gmail.com

S. M. Tauseef
Environmental Research Institute, University of Petroleum and Energy Studies, Dehradun 248 007, India
e-mail: sm.tauseef@gmail.com

 
N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*, Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_34

### 1.1 *Water Spinach* (Ipomoea Aquatica)

Water spinach (*Ipomoea aquatica*) is a trailing vine, with hollow stems which root at the nodes and float in water. Two basic forms, with several varieties in each, occur worldwide of *I. aquatica*: a red form with red-purple tinged stems and pale pink to lilac flowers; and a green form, with fully green stems and white flowers.

Similar to other noxious aquatic weeds salvinia [3], and waste hyacinth [4], *I. aquatica* colonizes shallow water bodies, especially marshes, canals, and ditches but it can also invade deeper water courses such as ponds and lakes. It thrives in flooded soils or in waters which are either still or flowing slowly [5]. It is highly susceptible to freezing temperatures which has prevented its spread in boreal habitats. Indeed *I. aquatica* cannot grow well when temperatures are below 24 °C, but is very comfortable at higher temperatures common in the tropics and subtropics. So much so that it becomes a serious pest when it invades profusely irrigated croplands such as rice paddy and sugarcane fields.

As is the case with some other aquatic/amphibious weeds like four leaf clover *(Marsilea quadrifolia),* water spinach also forms dense floating mats of intertwined stems over water surfaces, shading out native submersed plants and out-competing other emergents. It is a moderate-to-serious weed in many areas in the tropics [5]. Its tangled masses choke canals and drainage channels, hindering the flow of water though them. In lakes, ponds, and shallows of rivers, *I. aquatica* harms biodiversity by displacing several species of other vegetation needed by fish and wildlife. The densely intertwined masses of ipomoea create impenetrable canopies over small ponds and retention basins. This creates stagnant water conditions which favor breeding of mosquitoes and other disease vectors, thereby creating serious hazards [6].

Water spinach is used as a subsistence food plant in some situations. It is rich in iron [5]. Due to its high S-methyl methionine (Vitamin U) content, *I. aquatica* is used in traditional medicine for the treatment of digestive disorders. It has been shown to possess insulin-like properties and has been found to be anti-hyperglycemic [7].

## 2 Materials and Methods

Bench-scale SHEFROL® systems were set up as depicted in Fig. 1. After lead-up studies on channels of different dimensions, a width of 15 cm and a depth of 10 cm was found to best suit the system as it helped the plants, when densely packed, to remain erect without any support media or anchor. The dimensions also minimized short circuiting and maximized agitation as the wastewater flowed through the plant roots.

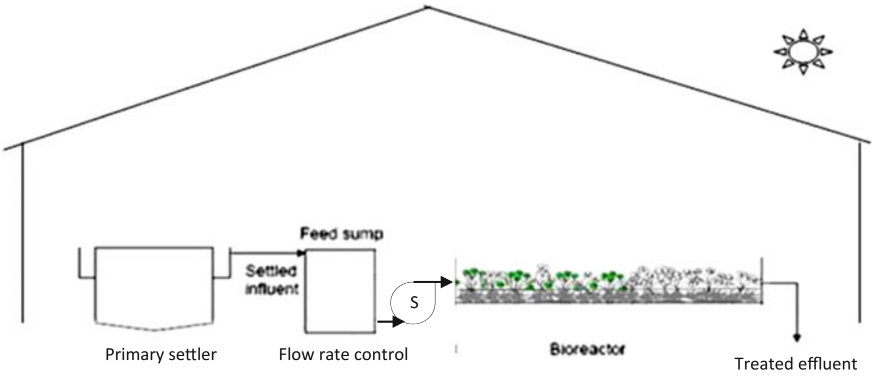



**Fig. 1** Schematic of the SHEFROL bio reactor

## 2.1 The Bioagent

The *I. aquatica* plants were collected from in and around the Pondicherry University campus. Care was taken to choose healthy, adult, plants with full roots. On being brought to the laboratory, they were washed to rid them of adhering soil and invertebrates. They were then introduced into the SHEFROL® channels. At the maximum stocking density, they had the biomass of 7.8 kg/m$^2$. A control channel identical to the ipomoea-stocked channel but without ipomoea was operated simultaneously.

## 2.2 The SHEFROL® Set Up

The SHEFROL® channels, which were 4 m long, were fabricated with aluminum foil of 28 gauge thickness and were lined with high density polyethylene (HDPE) sheets to prevent rusting and leakage.

In the initial stages of the work, the wastewater was fed at the receiving end of each channel using plastic buckets which had a tap fixed near their bottom. The buckets were so positioned that they released the wastewater at the top end of the entrance to each channel. The treated water was allowed to flow out from near the bottom at the other, exit, end of each channel. In this manner, the flow was maintained by utilizing the liquid head and without the need of any pumps. The hydraulic retention time (HRT) for any given depth of channel operation was controlled by appropriately positioning the influent release level and the rate of inflow-outflow. After the initial trials, and for the sake of generating utilizable basic data, the bucket-based feed arrangement was substituted with peristaltic pumps. The latter delivered precisely controlled flows and enabled accurate maintenance of the HRTs.

As the study area has bright sunshine for most parts of the year, with outdoor temperatures approaching or surpassing 40 °C during two-thirds of the time, outdoor units were protected from daylong exposure to direct sunlight, as also from occasional rains that come during November–January or June–July, by an inverted V-shaped roof. The roof was of coconut thatch, supported on a scaffold of sticks obtained from inexpensive casuarina trees. The roof was topped with LDPE sheets for protection from rain.

### *2.3 Assessment of the Performance of* I. Aquatica

Sewage of different strengths, in terms of COD, was tested. Initially, diluted sewage of chemical oxygen demand (COD) 230 mg/L was fed to the SHEFROL® channels stocked with *I. aquatica*. The strength of the sewage was gradually increased to 1600 mg/L over a 40-day span of continuous reactor operation. The hydraulic retention time (HRT) was maintained at 6 h. COD was used as the indicator parameter for the following reasons: (a) It includes biological oxygen demand (BOD) and hence reflects the action of the plant on most forms of organic carbon present in the wastewater; (b) it can be rapidly assessed in contrast to BOD which takes five days; (c) biodegradable carbon is the highest priority in sewage treatment, and (d) plants take up nitrogen, phosphorous, and other elements from water for their growth; hence those components of sewage are certain to get attenuated if a plant can survive in sewage and reduce its organic carbon.

## 3 Results and Discussion

The results are summarized in Table 1. *I. aquatica* adapted to the sewage very quickly. By the fourth day of the start of the reactor, the COD removal had exceeded 61%. By the eight day, the plant's ability to reduce COD in SHEFROL® had crossed 70%. From then onward, the extent of COD reduction hovered in the 80 ± 3% range most of the time, reaching more precise 81 ± 1% levels from 23rd day onward. In contrast, the maximum treatment achieved in the control channel was only 35.8%. The pattern of the treatment achieved in the test channel in comparison with the control channel is depicted in Fig. 2.

All through the experiment, the ipomoea plants remained healthy and vigorous. They developed an extensive, intertwined, root system which got more and more intense as the influent COD was raised. There was no pest attack.

The findings establish the appropriateness of *I. aquatica* as one of the plants that can be used in SHEFROL®. It is shown to treat sewage varying in strength from 230 mg/l to 1600 mg/l with near identical efficiency. This attribute is very significant because in real-life situations the quality of inflow in terms of COD and after variables keeps going up and down, sometimes varying widely from hour to hour.

**Table 1** Performance of *I. aquatica* in SHEFROL® in terms of COD removal with maximum plant density (8 $kg/m^2$) at 6 h HRTs

| Number of days from the start of the reactor | Influent COD strength (mg/l) | COD removal (%) in reactors | |
|---|---|---|---|
| | | With plants | Without plants |
| 2 | 230 | 36.8 | 17.7 |
| 3 | 265 | 47.1 | 1.8 |
| 4 | 355 | 61.7 | 23.7 |
| 5 | 360 | 61.5 | 20.7 |
| 6 | 370 | 61.9 | 19.9 |
| 7 | 380 | 65.0 | 25.8 |
| 8 | 410 | 70.1 | 23.3 |
| 9 | 610 | 70.4 | 22.1 |
| 10 | 620 | 73.0 | 19.6 |
| 11 | 625 | 68.7 | 21.8 |
| 12 | 645 | 75.3 | 23.3 |
| 13 | 650 | 72.5 | 19.1 |
| 14 | 655 | 78.4 | 22.8 |
| 15 | 675 | 77.0 | 29.0 |
| 16 | 680 | 78.2 | 24.0 |
| 17 | 685 | 78.4 | 29.3 |
| 18 | 700 | 75.5 | 26.4 |
| 19 | 775 | 78.3 | 18.8 |
| 20 | 885 | 78.1 | 32.8 |
| 21 | 915 | 76.0 | 34.1 |
| 22 | 940 | 79.5 | 31.6 |
| 23 | 960 | 80.1 | 35.8 |
| 24 | 980 | 80.5 | 35.3 |
| 25 | 990 | 80.8 | 35.6 |
| 26 | 1120 | 80.5 | 30.8 |
| 27 | 1125 | 80.1 | 34.9 |
| 28 | 1200 | 80.7 | 34.6 |
| 29 | 1200 | 81.8 | 32.2 |
| 30 | 1225 | 83.1 | 32.5 |
| 31 | 1250 | 81.2 | 32.1 |
| 32 | 1260 | 82.7 | 31.6 |
| 33 | 1280 | 82.8 | 33.2 |
| 34 | 1510 | 80.4 | 34.1 |
| 35 | 1515 | 80.3 | 34.3 |
| 36 | 1540 | 80.4 | 34.5 |

(continued)

**Table 1** (continued)

| | | | |
|---|---|---|---|
| 37 | 1550 | 79.6 | 33.7 |
| 38 | 1560 | 80.3 | 34.8 |
| 39 | 1570 | 80.2 | 34.6 |
| 40 | 1600 | 80.7 | 33.8 |

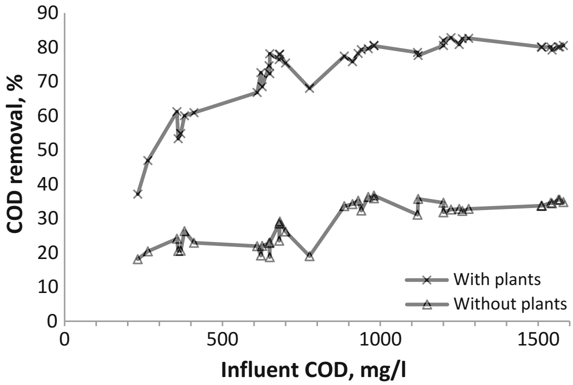



**Fig. 2** Performance of *I. aquatica* in outdoor SHEFROL® in terms of COD at a maximum plant density (7.8 kg/m$^2$) and 6 h HRT

For such situations, *I. aquatica* has shown promise to deliver a steady performance in terms of pollutant removal.

As we have reported elsewhere, weeds like the ipomoea plants that die in the channels, or are harvested to check overgrowth, can be anaerobically digested to generate energy in the form of biogas [8–11] or converted to organic fertilizer through vermicomposting [12–15]. In this manner, utilization of the weed is possible, leaving nothing to waste.

**Acknowledgements** Authors thank the Ministry of Water Resources, RD & GR, Government of India, for funding an R&D project which enabled the work and Department of Biotechnology, Government of India, for supporting the patenting of SHEFROL®. SAA thanks the University Grants Commission (UGC) for Emeritus Professorship and the Council Scientific and Industrial Research (CSIR), New Delhi for Emeritus Scientist Grant (21(1034)/16/EMR-II which have enabled him to document the findings presented in the paper.

## References

1. Abbasi, T., Bhat, M. A., Abbasi, S.A.: Soil-less use of aqutic macrophytes in wastewater treatment and the Novel SHEFROL® bioreactor. In: Siddiqui, N.A., Tauseef, S.M., Bansal, K. (eds.), Advances in Health and Environment Safety, Springer, New York, Chapter 30, pp. 1–16 (2017). doi:10.1007/978-981-10-7122-5
2. Abbasi, S.A.: Zero waste generating, zero chemical using, high rate wastewater treatment system – SHEFROL. Off. J. Pat. Off. **20**, 7611 (2012)

3. Abbasi, S.A., Nipaney, P.C.: Infestation by aquatic weeds of the fern genus salvinia - its status and control. Environ. Conserv. **13** (3), 235–241 (1986)
4. Ganesh, P.S., Ramasamy, E.V., Gajalakshmi, S., Abbasi, S.A.: Extraction of volatile fatty acids (VFAs) from water hyacinth using inexpensive contraptions, and the use of the VFAs as feed supplement in conventional digesters. Biochem. Eng. J. **27**, 17–23 (2005)
5. Langeland, K.A., Burks K.C. (eds.): Identification and biology of non-native plants in Florida's natural areas. University of Florida, Gainesville, Florida (1999)
6. Khan F.I., Abbasi S.A.: Techniques and methodologies for risk analysis in chemical process industries. Discovery Publishing House New Delhi (1998), ix + 364 pages
7. Malalavidhane, T.S., Wickramasinghe, S.N., Jansz, E.R.: Oral hypoglycaemic activity of Ipomoea aquatica. J. Ethnopharmacol. **72**(1), 293–298 (2000)
8. Abbasi, S.A., Nipaney, P.C., Schaumberg, G. D.: Bioenergy potential of eight common aquatic weeds. Biol. Wastes **34** (4), 359–366 (1990)
9. Abbasi, T., Abbasi, S.A.: Production of clean energy by anaerobic digestion of phytomass - new prospects for a global warming amelioration technology. Renew. Sustain. Energy Rev. **14**, 1653–1659 (2010)
10. Tauseef, S.M., Premalatha, M., Abbasi, T., Abbasi, S.A.: Methane capture from livestock manure. J. Environ. Manage. **117**, 187–207 (2013)
11. Abbasi, T., Abbasi, S.A.: Is the use of renewable energy sources an answer to the problems of global warming and pollution? Crit. Rev. Environ. Sci. Technol. **42**, 99–154 (2012)
12. Hussain, N., Abbasi, T., Abbasi, S.A.: Vermicomposting-mediated conversion of the toxic and allelopathic weed ipomoea into a potent fertilizer. Process Saf. Environ. Prot. **103**, 97–106 (2016)
13. Hussain, N., Abbasi, T., Abbasi, S.A.: Toxic and allelopathic ipomoea yields plant-friendly organic fertilizer. J. Clean. Prod. **148**, 826–835 (2017)
14. Hussain, N., Abbasi, T., Abbasi, S.A.: Vermicomposting transforms allelopathic parthenium into a benign organic fertilizer. J. Environ. Manage. **180**, 180–189 (2016)
15. Hussain, N., Abbasi, T., Abbasi, S.A.: Vermiremediation of an invasive and pernicious weed salvinia (Salvinia molesta). Ecol. Eng. **91**, 432–440 (2016)

# Development of Multimedia Hazardous Material Information System

**S. Aravind, Kanchan Deoli Bahukhandi and Prasenjit Mondal**

## 1 Introduction

Numerous health effects such as skin irritation, sensitization, burns, organ damage, and cancer can occur due to exposure to hazardous materials [1]. Improper storage and transport can lead to fire, explosion, and other hazardous scenarios [2]. Appropriate and adequate information on the inherent hazards and their usage and effective means of communicating the information to the workers who are responsible for safety and health are the key elements in safe usage of chemicals.

Having a standardized method for communication and comprehensibility of hazardous material information is one of the major problems in industries [3]. In the year 2003, United Nations developed Global Harmonized System, which helped in achieving standardization to a certain level [4].

Hazard communication is presently accomplished by requiring chemical manufacturers and importers to evaluate the hazards of the chemicals they produce or import and to provide information about them through labels on containers and more detailed information sheets called Material Safety Data Sheets (MSDSs) [5]. Comprehensibility continues to be a problem due to the incomprehensibility of MSDS sheets and unfamiliarity with symbols depicted on labels [6]. Taking into consideration, the positive effect pictograms and symbols have been conducted in Zambia [7] and Taiwan [8], a Hazardous Material Information System is developed in semi-descriptive language with cautionary labels and symbols. To bridge the gaps

S. Aravind · K. D. Bahukhandi (✉) · P. Mondal
Department of Health, Safety and Environment, University of Petroleum and Energy Studies, Dehradun, India
e-mail: Kanchan@ddn.upes.ac.in

S. Aravind
e-mail: aravindsureshn@gmail.com

P. Mondal
e-mail: pmondal@ddn.upes.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_35

posed by the system and as a part of the transition to new age machine display equipment, [9] Multimedia Hazardous Material Information System is developed which conveys information with the assistance of audio and visuals and also in different languages.

# 2 Materials and Methods

## 2.1 Worker HSE Comprehensibility Study

Each chemical has its own potential hazards. In order to improve workplace safety in the use and handling of chemicals, every chemical must be labeled based on its hazardous properties and hazard information must be adequately communicated to various target audiences such as workers, chemical transporters, storekeepers, distributors, users, and/or regulating authorities.

The level to which workers have fully understood and comprehended hazard information has a big role to play in safety of the organization since they come in contact with the chemicals the most. Many factors such as education level, current position, company scale, awareness, training and safety culture have a role in hazard comprehensibility level. The requirement of the ISO criterion for hazard comprehensibility is at least 67% [10].

Worker HSE comprehensibility study has been carried out with the help of questionnaires among 20 randomly sampled employees from various departments to evaluate the level of hazard comprehensibility among workers of Star Paper Mills Pvt. Ltd. when the hazard communication techniques used are labels and MSDSs.

Objectives of the questionnaires:

- To ascertain demographic and other related data as basis for analysis of comprehensibility study
- Recall reading and comprehensibility of labels and MSDS
- To evaluate respondent's familiarity with labels and MSDS
- Comprehensibility of MSDS to test respondent's ability to identify appropriate information from MSDS
- To assess type of information in MSDS that respondent finds to be useful, appropriate, and comprehensible
- To assess whether respondents have had any training related to chemical safety.

## 2.2 Material Safety Data Sheet Analysis

There are about 3000 different types of chemicals, which can be used in papermaking. In practice, only about 200 individual chemicals are typically used, each satisfying a specific need (Fig. 1).

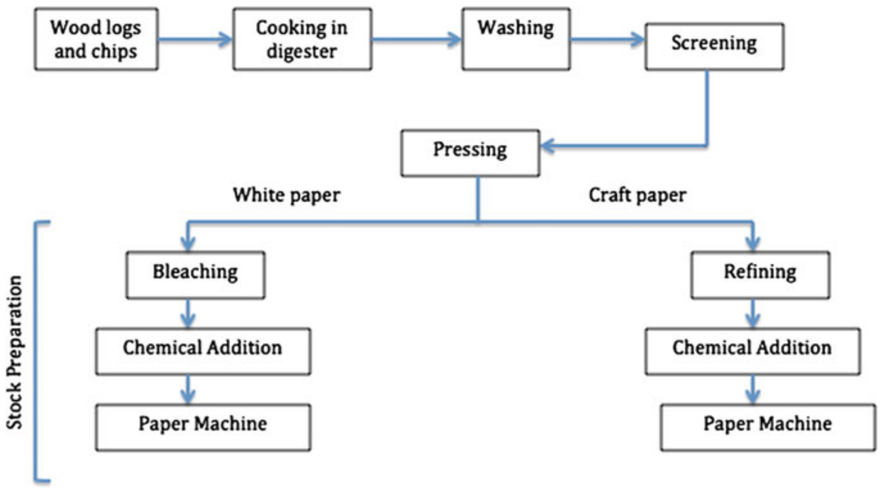



**Fig. 1** Process of papermaking


**Fig. 2** Sample HMIS entry

The entire papermaking process has been considered, and list of chemicals used in the process at the selected site is prepared. The Material Safety Data Sheets have been analyzed, and information required for the preparation of Hazardous Material Information System is deduced.

### 2.3 *Hazardous Material Information System Development*

Hazardous Material Information System is developed with the help of existing templates and the information collected from MSDSs. Six elements, which represent relevant hazard information, are selected out of the 16 elements provided in MSDS [11]. They have been represented using symbols and semi-descriptive language, which enable workers to understand hazard information more efficiently and clearly (Fig. 2).

### 2.4 Multimedia Hazardous Material Information System Development

Multimedia Hazardous Material Information System is a simplified hazard communication system, which uses audio (in different languages that workers understand) and videos (animations, real-time visuals) to effectively communicate hazard information to workers using computer software (Fig. 3).

The software conveys information on hazards with the help of audio and texts in a language that worker understands as well as with the help of visuals, which will help workers retain information for a longer duration and more thoroughly.

### 2.5 HMIS and MHMIS Effectiveness Study

Level of HSE comprehensibility is studied at the end of each step, i.e., HMIS and MHMIS development with the help of questionnaires.

Objectives of the questionnaire:

- To evaluate respondent's familiarity with HMIS and MHMIS
- To evaluate respondent's memory retention of hazard information
- To understand the understandability of HMIS and MHMIS over MSDS
- To understand accessibility of HMIS and MHMIS over MSDS.

The results obtained from HMIS and MHMIS effectiveness study are compared with that of MSDS so as to evaluate the tools.


**Fig. 3** Multimedia HMIS home page

# 3 Results and Discussion

## *3.1 Worker HSE Comprehensibility Study*

Major hazardous material communication method used at Star Paper Mills is through information boards painted near storage areas in the local language in the industry. This is not a very effective method since many workers have comprehensibility problems.

From the study, it was found that a large number of employees rely on their direct superior officer for safety and hazardous material information. There are a fairly large number of workers who are not aware of MSDS. Number of people who knew about MSDS and who understood what MSDS is after giving an explanation was a very small percent.

People who were familiar with MSDS found difficulty in availability of MSDS, length of information, unknown language, and descriptive nature of MSDS (Fig. 4).

In the HSE knowledge check questionnaire, all the respondents scored less than 50%, which is less than ISO comprehensibility requirement of 67%.

## *3.2 HMIS Effectiveness Study*

The workers, who were trained on the use of HMIS sheet, had a clear idea about the locations where HMIS sheet has been put on display in the organization. They were familiar of the notion to be followed while obtaining information from the HMIS sheet. However, workers felt that the semi-descriptive language, which explains important information in English, a language majority of them are not very comfortable with as a barrier.

## *3.3 MHMIS Effectiveness Study*

Stakeholders of the organization who were introduced to the use of MHMIS found the information more understandable and retainable. However, they found

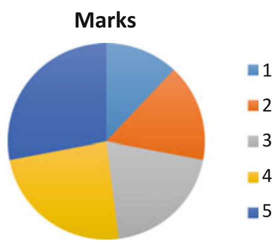



**Fig. 4** HSE knowledge check questionnaire results

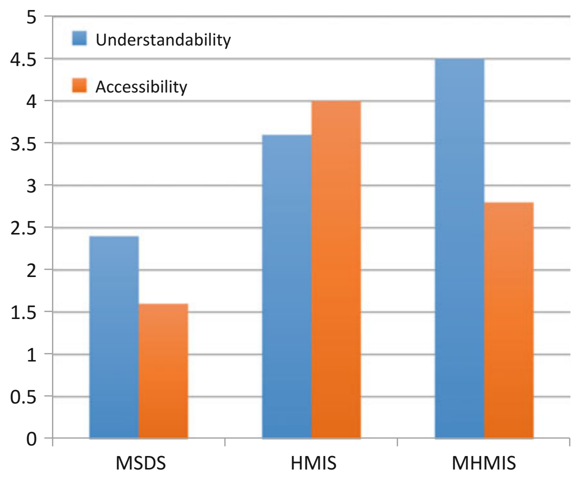



**Fig. 5** Comparative study of understandability among MSDS, HMIS, MHMIS

accessibility issues since computer access was limited to medium and top-level employees. Hence, MHMIS was found to be more of a tool for safety training than hazard information communication (Fig. 5).

## 4 Conclusion

Based on the study conducted, the present level of understanding of safety issues is below par. The presently available tool for hazard communication, MSDS, is neither understandable nor accessible for majority of workers, who require this information on a daily basis. The Hazardous Material Information System acts as an accessible medium but its understandability is limited with the use of standardized English language, which many stakeholders do not understand. A translated HMIS sheet would be an improvised alternative. MHMIS is the best tool among the three in terms of understandability. But, it has a drawback when it comes to accessibility due to equipment cost and accessibility issues lack of computer knowledge among low-level workers. Thus, MHMIS becomes an effective hazard communication tool especially during hazard training sessions where a trained professional will operate the software.

## References


1. Adane, L., Abeje, A.: Assessment of familiarity and understanding of chemical hazard warning signs among university students majoring chemistry and biology: a case study at Jimma University, Southwestern Ethiopia. World Appl. Sci. J. **16**(2), 290–299 (2012)

2. Takala, J., Pesonen, J., Kulikov, I., Jäppinen, H.: Machine translation for chemical safety information. J. Hazard. Mater. **27**, 213–230 (1991)
3. Winder, C., Azzi, R., Wagner, D.: The development of the globally harmonized system (GHS) of classification and labelling of hazardous chemicals. J. Hazard. Mater. **A125**, 29–44 (2005)
4. Silk, J.C.: Development of a globally harmonized system for hazard communication. Int. J. Hyg. Environ. Health. **206**(4–5), 447–452. (2003). (Ta, G.C.)
5. Clarke, S., Probst, T.M., Guldenmund, F.W., Passmore, J.: Handbook of the Psychology of Occupational Safety and Workplace Health. Wiley Blackwell (2012)
6. Côté, R., Davis, H., Dimock, C., Korpan, M., Loewen, K., Segal, I.M.: Regul. Toxicol. Pharmacol. **27**, 61–74 (1998)
7. Banda, S.F., Sichilongo, K.: Analysis of the level of comprehension of chemical hazard labels: a case for Zambia. Sci. Total Environ. **363**(1), 22–27 (2006)
8. Su, T-S., Hsu, I-Y.: Perception towards chemical labeling for college students in Taiwan using Globally Harmonized System. Saf. Sci. **46**(9), 1385–1392 (2008)
9. Herring, B.E., Stauffer jr, J.L: Automated hazardous material information retrieval system for fire departments. Computers Ind. Eng. **9**, 103–123 (1985)
10. Ta, G.C. et al.: Analysis of the comprehensibility of chemical hazard communication tools at the industrial workplace. Ind. Health. **48**(6), 835–844 (2010)
11. ISO 3864 Safety Colours and Safety Signs. International organization for standardization, Geneva. (2002)

# Quality Assessment of Groundwater Using Water Quality Index at Yamunanagar, Haryana

**Abhishek Tyagi, Prasenjit Mondal and N. A. Siddiqui**

## 1 Introduction

As we all know that groundwater is the only source of fresh water, which we are using for fulfilling our basic needs. Groundwater is water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations [1]. However, lack of discipline and weak legislations for conservation of water is resulting in indiscriminate use and pollution of ground water, rendering it harmful for human consumption. Consequently, a number of waterborne diseases, which causes health hazards, increased. So, it is necessary to monitor water quality regularly to observe the demand and level of pollution in groundwater [2].

Main objectives of present study were to analyze the quality of groundwater at different location in Yamunanagar city and calculation of water quality index to conclude the exact quality whether fit for drinking or not.

### *1.1 Study Area*

Figure 1 shows the district is mainly drained by the rivers Yamuna, Markanda, and its tributaries. Markanda is tributary of river Ghaggar and drains major part of the district.

Yamuna acts as basin boundary between west flowing rivers of Indus system and east flowing rivers of Ganga Basin. River Yamuna drains eastern part of the district and acts as boundary between Haryana and Uttar Pradesh states [3].

A. Tyagi (✉) · P. Mondal · N. A. Siddiqui
University of Petroleum and Energy Studies, Dehradun, India
e-mail: Abhishektyagi34@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_36

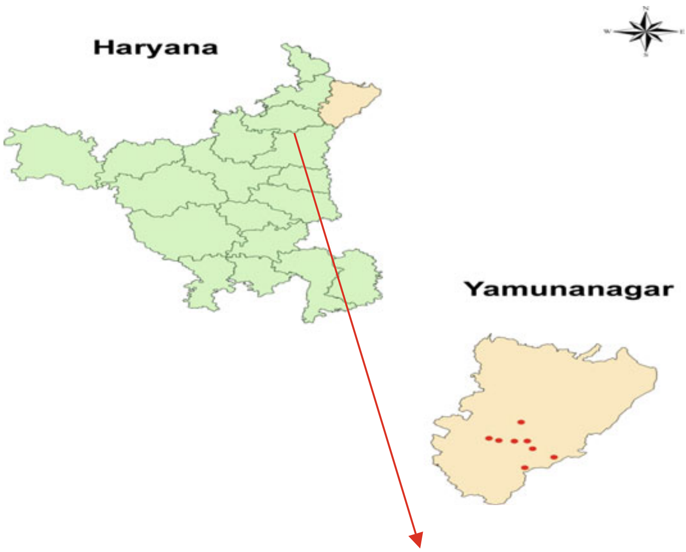



**Fig. 1** Location of the study area

Physio-graphically, it is divided as Yamunanagar Siwalik; Sadaura Plain, Yamunanagar Plain, Yamunanagar Khadar and Bet Yamunanagar. Yamunanagar (Fig. 2).

### 1.2 Demography

Yamunanagar is thickly populated district, and density of population is 589 persons per $km^2$, which is higher than state average of 478 persons per $km^2$. The population of the district is 10, 42,000 as per 2001 census [4].

## 2 Materials and Methods

Total 18 groundwater samples were collected from eight different selected sites and analyzed for six physiochemical parameters. All samples were collected in polyethylene bottles, which were prewashed with acid and soaked in deionized water. Care was taken to properly preserve the samples before transportation to the laboratory and analysis, in the chemical testing laboratory, which was done as per the standard [5].

The WQI was determined using the standard given by the World Health Organization (WHO), Bureau of Indian Standards (BIS), and Indian Council for

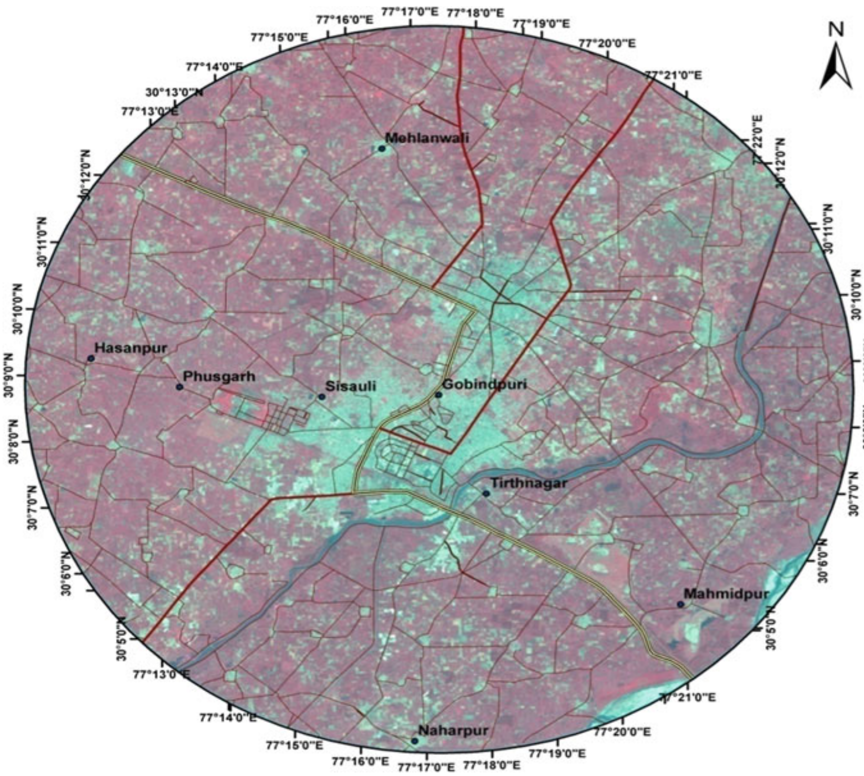



**Fig. 2** Villages selected for study

**Table 1** Rating of water quality based on the value of WQI [9]

| WQI ranges | Quality of water |
|---|---|
| 0–25 | Excellent |
| 26–50 | Good |
| 51–75 | Poor |
| 76–100 | Very poor |
| >100 | Non-drinkable |

Medical Research (ICMR) for six different important parameters [6, 7]. In this study, the weighted arithmetic index method (Brown et.al.) was adopted for calculation of WQI [8]. (Tables 1 and 2)

$$\mathrm{WQI} = \frac{\sum q_n W_n}{\sum W_n} \tag{1}$$

**Table 2** Standards (drinking water) and their respective agencies (All values are in ppm except pH and conductivity)

| S. no. | Parameters | Standards | Recommended agency |
|---|---|---|---|
| 1. | pH | 6.5–8.5 | BIS/IS |
| 2. | Electrical conductivity | 300 | ICMR |
| 3. | Total hardness | 200 | BIS/IS |
| 4. | Chloride | 250 | BIS/IS |
| 5. | Total alkalinity | 120 | ICMR |
| 6. | Dissolved oxygen | 5 | BIS/ICMR |

where

$q_n$ is quality rating ($n$th Water quality parameter) and $n = 1, 2, \ldots 6$.
$W_n$ is unit weight of $n$th parameters.

Now,

$$q_n = \frac{100(V_n - V_{i0})}{(S_n - V_{i0})} \tag{2}$$

where

$V_n$ is the estimated value ($n$th parameter).
$S_n$ is the permissible value ($n$th parameter).
$V_{i0}$ is the ideal value ($n$th parameter for pure water).

where

$$\begin{aligned} V_{i0} &= 7.0\,(\text{for pH}) \\ &= 14.6\,(\text{for DO}) \\ &= 0\,(\text{for all other parameter}) \end{aligned}$$

And,

$$W_n = \frac{K}{S_n} \tag{3}$$

where

$K$ is proportionality constant.
Now, $K = 1/\sum(1/S_n)$.

**Table 3** Physiochemical analysis of different samples

| S. no. | Sample | pH | Conductivity (mS) | Salinity (ppt) | DO (ppm) | Total hardness (ppm) | Chloride (ppm) | Alkalinity (ppm) |
|---|---|---|---|---|---|---|---|---|
| 1. | Govindpuri | 7.29 | 0.862 | 0.645 | 1.2 | 0.54 | 58.98 | 282 |
| 2. | Mehlanwali-I | 7.54 | 0.692 | 0.520 | 2.1 | 0.48 | 16.99 | 416 |
| 3. | Mehlanwali-II | 7.44 | 0.40 | 0.307 | 0.8 | 0.32 | 12.99 | 274 |
| 4. | Mehlanwali-III | 7.42 | 0.762 | 0.563 | 0.5 | 0.56 | 27.98 | 416 |
| 5. | Sisauli-I | 7.49 | 0.594 | 0.445 | 1.6 | 0.76 | 20.99 | 344 |
| 6. | Sisauli-II | 7.50 | 0.510 | 0.379 | 1.2 | 0.52 | 19.99 | 296 |
| 7. | Sisauli-III | 7.45 | 0.815 | 0.610 | 0.7 | 1.86 | 53.97 | 428 |
| 8. | Sisauli-IV | 7.39 | 0.563 | 0.384 | 0.7 | 0.8 | 13.99 | 320 |
| 9. | Pushgarh-I | 7.30 | 0.563 | 0.424 | 1.0 | 0.94 | 13.99 | 362 |
| 10. | Pushgarh-II | 7.37 | 0.476 | 0.356 | 1.3 | 0.42 | 13.58 | 300 |
| 11. | Hasanpur-I | 7.29 | 0.566 | 0.420 | 1.1 | 0.68 | 12.99 | 340 |
| 12. | Hasanpur-II | 7.38 | 0.596 | 0.448 | 1.8 | 0.62 | 9.99 | 368 |
| 13. | Tirthnagar-I | 7.80 | 0.455 | 0.341 | 1.7 | 1.16 | 37.98 | 190 |
| 14. | Tirthnagar-II | 7.70 | 0.298 | 0.224 | 1.4 | 1.22 | 48.99 | 170 |
| 15. | Tirthnagar-III | 8.10 | 0.671 | 0.501 | 1.7 | 0.86 | 43.97 | 288 |
| 16. | Mehmoodpur | 7.90 | 0.808 | 0.605 | 2.3 | 3.00 | 58.97 | 276 |
| 17. | Naharpur-I | 7.20 | 0.241 | 0.181 | 2.7 | 2.24 | 11.99 | 134 |
| 18. | Naharpur-II | 7.20 | 1.73 | 1.31 | 2.4 | 1.24 | 51.34 | 194 |

**Table 4** Calculated values of $W_n$ and $V_{i0}$ for various parameters

| | pH | Conductivity (mS) | DO (ppm) | Total hardness (ppm) | Chloride (ppm) | Alkalinity (ppm) | |
|---|---|---|---|---|---|---|---|
| Standard value | 7.5 | 0.3 | 5 | 300 | 250 | 120 | Total $W_n$ |
| $W_n$ | 0.219 | 0.371 | 0.372 | 0.0062 | 0.0074 | 0.0155 | 0.9914 |
| $V_{i0}$ | 7 | 0 | 14.6 | 0 | 0 | 0 | |

## 3 Results and Discussion

The values of various physiochemical parameters of groundwater in the selected sites are summarized in Tables 3, 4, and 5 (Fig. 3).

Industries being voraciously consumer of natural resources brought in pollution of air, water, and soil environment. Rapid industrialization is degrading the water quality by discharging large amount of effluent in the surrounding water bodies as well as into the groundwater. As of today, the city is industrial hub for all kind of large and small industries—large-scale sugar factory, paper mill, and a thermal power plant.

**Table 5** Calculated values of water quality index for different location

| Sample | pH | $q_n$ (pH) | Conductivity (mS) | $q_n$ (Conductivity) | DO (ppm) | $q_n$ (DO) | Total hardness (ppm) | $q_n$ (TH) | Chloride (ppm) | $q_n$ (Chloride) | Alkalinity (ppm) | $q_n$ (Alk) | WQI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Govindpuri | 7.29 | 58 | 0.862 | 287.3,333,333 | 1.2 | 139.58333 | 0.54 | 0.18 | 58.98 | 23.592 | 282 | 235 | 176.5643 |
| Mehlanwali-I | 7.54 | 108 | 0.692 | 230.6666667 | 2.1 | 130.20833 | 0.48 | 0.16 | 16.99 | 6.796 | 416 | 346.67 | 164.5062 |
| Mehlanwali-II | 7.44 | 88 | 0.4 | 133.3333333 | 0.8 | 143.75 | 0.32 | 0.10667 | 12.99 | 5.196 | 274 | 228.33 | 126.8831 |
| Mehlanwali-III | 7.42 | 84 | 0.762 | 254 | 0.5 | 146.875 | 0.56 | 0.18667 | 27.98 | 11.192 | 416 | 346.67 | 174.2231 |
| Sisauli-I | 7.49 | 98 | 0.594 | 198 | 1.6 | 135.41667 | 0.76 | 0.25333 | 20.99 | 8.396 | 344 | 286.67 | 151.1015 |
| Sisauli-II | 7.5 | 100 | 0.51 | 170 | 1.2 | 139.58333 | 0.52 | 0.17333 | 19.99 | 7.996 | 296 | 246.67 | 141.9998 |
| Sisauli-III | 7.45 | 90 | 0.815 | 271.6666667 | 0.7 | 144.79167 | 1.86 | 0.62 | 53.97 | 21.588 | 428 | 356.67 | 181.6146 |
| Sisauli-IV | 7.39 | 78 | 0.563 | 187.6666667 | 0.7 | 144.79167 | 0.8 | 0.26667 | 13.99 | 5.596 | 320 | 266.67 | 146.0008 |
| Pushgarh-I | 7.3 | 60 | 0.563 | 187.6666667 | 1 | 141.66667 | 0.94 | 0.31333 | 13.99 | 5.596 | 362 | 301.67 | 141.3996 |
| Pushgarh-II | 7.37 | 74 | 0.476 | 158.6666667 | 1.3 | 138.54167 | 0.42 | 0.14 | 13.58 | 5.432 | 300 | 250 | 131.6571 |
| Hasanpur-I | 7.29 | 58 | 0.566 | 188.6666667 | 1.1 | 140.625 | 0.68 | 0.22667 | 12.99 | 5.196 | 340 | 283.33 | 140.651 |
| Hasanpur-II | 7.38 | 76 | 0.596 | 198.6666667 | 1.8 | 133.33333 | 0.62 | 0.20667 | 9.99 | 3.996 | 368 | 306.67 | 145.989 |
| Tirthnagar-I | 7.8 | 160 | 0.455 | 151.6666667 | 1.7 | 134.375 | 1.16 | 0.38667 | 37.98 | 15.192 | 190 | 158.33 | 145.1128 |
| Tirthnagar-II | 7.7 | 140 | 0.298 | 99.33333333 | 1.4 | 137.5 | 1.22 | 0.40667 | 48.99 | 19.596 | 170 | 141.67 | 122.0557 |
| Tirthnagar-III | 8.1 | 220 | 0.671 | 223.6666667 | 1.7 | 134.375 | 0.86 | 0.28667 | 43.97 | 17.588 | 288 | 240 | 186.6046 |
| Mehmoodpur | 7.9 | 180 | 0.808 | 269.3333333 | 2.3 | 128.125 | 3 | 1 | 58.97 | 23.588 | 276 | 230 | 192.4056 |
| Naharpur-I | 7.2 | 40 | 0.241 | 80.33333333 | 2.7 | 123.95833 | 2.24 | 0.74667 | 11.99 | 4.796 | 134 | 111.67 | 87.19701 |
| Naharpur-II | 7.2 | 40 | 1.73 | 576.6666667 | 2.4 | 127.08333 | 1.24 | 0.41333 | 51.34 | 20.536 | 194 | 161.67 | 275.0037 |

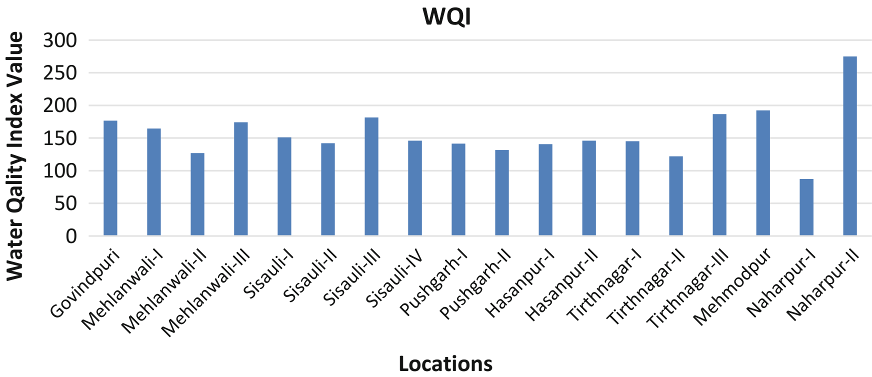



**Fig. 3** Water quality index values for different locations

The WQI calculations have shown that the quality of groundwater is degrading day by day due to large-scale industrialization, and the values of various water quality parameters were found to be higher than the prescribed standard values at some sites.

## 4 Conclusion

It is very difficult to understand the water quality based on values of various water quality parameters, as the values of some parameters may fall within the permissible limits, while some other parameters may be off the permissible limits. Thus, calculation of water quality index, which provides a single value indicative of the water quality, makes it easy to judge whether the water is safe or unsafe for domestic and drinking purposes.

The WQI for various sites in Yamunanagar, Haryana, was calculated using experimental data for six different water quality parameters. It was found that WQI values were higher than 100 for seven of the eight villages selected for the study, which means that the water is unsuitable for drinking. Only at one of the eight sites, the WQI was found to be less than 100, but the calculated WQI value indicates very poor quality water.

## References

1. Goell, E., et al.: Sustainable Cities in Egypt Learning from Experience: Potentials and Preconditions for New Cities in Desert Areas. The Egyptian Cabinet Information and Decision Support Center-Center for Future Studies, Cairo (2009)

2. Baker, A.: Fluorescence properties of some farm wastes: implications for water quality monitoring. Water Res. **36**(1), 189–195 (2002)
3. Rai, R.K., et al.: The Yamuna River Basin: Water Resources and Environment, vol. 66. Springer Science & Business Media, Berlin (2011)
4. Goel, P.: Water Pollution: Causes, Effects and Control. New Age International, New Delhi (2006)
5. American Public Health Association APHA: Standard Methods for the Examination of Water and Wastewater. American Public Health Association, USA, CD-ROM (2005)
6. American Public Health Association APHA, et al.: Standard Methods for the Examination of Water and Wastewater, vol. 2. American Public Health Association, USA (1915)
7. Singh, V.K., Singh, K.P., Mohan, D.: Status of heavy metals in water and bed sediments of river Gomti–a tributary of the Ganga river, India. Environ. Monit. Assess. **105**(1), 43–67 (2005)
8. Brown, R.M., et al.: A water quality index-crashing the psychological barrier. Ind. Environ. Qual. **1**(1), 173–178 (1972)
9. Chatterjee, C., Raziuddin, M.: Determination of Water Quality Index (WQI) of a degraded river in Asansol industrial area (West Bengal). Nat. Environ. Pollut. Technol. **1**(2), 181–189 (2002)

# Impact of Information Technology and Sedentary Lifestyle on Occupational Health

**Shuchi Upadhyay Tiwari and Rajeev Tiwari**

## 1 Introduction

From the last six decades of the twenty-first century, the concept and nature of job has been changing. 1970–1980 was the introduction of information technology basically computer in a few workplaces [1]. This was followed in the 1990–2000 with great transformation and understanding of technology. In 2000, revised structure of work started to take place. Organization in different countries affected by recession reduced the number of employees to survive. There is high growth of information technology and zero paperwork in workplace of different government and private sectors; the globalization and privatization of industries affect the individual health and performance. This is good for environment but give adverse effect to human body. Over the last 69 years, many changes have occurred in the work culture and structure because of the use of information technology.

More computer based work leads towards more sitting and bad posture too, which gives central obesity and high blood pressure. Prevalence of cervical spondylosis, neck pain, arm and shoulder pain has been seen in computer professionals.

Cervical spondylosis and back pain are common lifestyle and degenerative disease in adult age group (30–50 years) [1]. Upper limb, cervical spondylitis and neck pain are common causes of neuromuscular disease. It effects work style and increase burden on employees for their work and health. The shoulder is known as very important joint in human body [2]; all pain and discomfort of shoulder are related with number of associated problem and other condition [3]. The problems of

S. U. Tiwari
Department of Food Technology, Uttaranchal University, Prem Nagar, Dehradun, India
e-mail: shuchi.diet@gmail.com

R. Tiwari (✉)
CIT, University of Petroleum and Energy Studies, Dehradun, India
e-mail: rajeev.tiwari@ddn.upes.ac.in



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_37

neck are connected with tension, such neck pains may further spread in suprascapular and upper dorsal regions, and such pains are named after the place of their origin like nerve root or spinal source pain [4]. There are various defined names used to describe these uncomfortable situations, e.g. cervico-brachial syndrome [5], neck and upper limb disorder, [6] neck shoulder problem [7].

Mostly symptoms are on mechanical grounds and etiological factors are poorly understood [8] which gives adverse effects including anxiety, poor posture, depression, neck strain or occupational activities are responsible for same [9]. When mechanical factors are dominant, the problem is usually referred to as cervical spondylosis. Chronic neck pains are due to mechanical and degenerative factors. Due to degenerative changes in cervical spondylosis, intervertebral discs osteophyte formation starts and involves adjacent soft tissue structures.

## 2 Material and Method

All study samples were obtained from different teaching and non-teaching sectors of Dehradun (Uttarakhand) through clinical survey method. Out of 4000 professionals of different sectors, only 289 cases have been selected for this study. All candidates of this study group were working professional for at least last two years, and none of the group members had a neck or cervical injury in recent past. All data was divided in groups as per the profession of the sampled population. Groups were representing as O1 to O6. The diagnosis of such problems like spondylosis was based on X ray and CT scans [10]. In the upper limb, neck, knees and hips pain was reported from last one day to one week as per questioner asked.

Supplementary questions were included to identify neurological problems. Each question in the questionnaire was assessed by calculating chi-square and $p$ value.

## 3 Questionnaire

The questionnaire and personal interviews were used to collect information. The queries in questionnaire ranged from general in nature to very specific. All points of questionnaire were pretested among the professionals. Questionnaire was then customized according to pretest conducted on candidates. The standardized Nordic questionnaire [11] has been used to assess musculoskeletal complaints in the non-teaching IT professionals and teaching professionals. The questionnaire was specifically structured but some of the questions were also asked spontaneously. All information was collected on the basis of questionnaire which covered prevalence of symptoms and interference. Modification of Nordic questionnaire was as per requirement. It distinguishes between the different disease possibilities in group of IT professionals with musculoskeletal and other diagnoses. The questionnaire included queries on age, weight, duration of occupation, computer/laptop working hours, the nature of muscle related problems—type of musculoskeletal problem, pain in upper neck, pain in lower limb, type of pain, severity of pain, complaints in body region: neck, arm, shoulder, back, spinal and thighs, etc. musculoskeletal problem defined as a discomfort in different body parts.

**Data collection**: data was also collected through direct interaction and personal meet with each subject. Reports of different problems and discomforts were identified and finalized with tests and prescription reports of orthopaedic and neurologist [12]. All samples of data were from age group of 30 years to 50 years. All the members of the sampled population were from middle-income group.

**Data analysis**: all collected information was finally verified, checked, edited and categorized as per their discomfort; statistical calculation and analysis were performed by SPSS. Statistical association was investigated using coefficient and chi-square test. The data was considered statistically significant of $\rho < 0.06$.

## 4 Results

A total 289 of adult males in the age group 30–50 years were studied for the shoulder, cervical or back pain. 58.4% of the sampled population was aged below 40 years; all of them were working 8–9 h daily. Table 1 describes the demographic characteristic of different samples.

Out of total population studied, cervical spondylosis was found in 11%, and similarly 21% of the cases had problem of lower back pain. 25% of the total sampled population had poor vision, and 17.3% were found to have upper back pain. 18% of the sampled population were found to have shoulder pain.

All the 289 males complained of indigestion and acidity due to sedentary lifestyle and poor eating habits. Out of total 289 cases, 38% were having central obesity. Low physical activity and fast food intake is the root cause of high blood pressure. 29% of the cases were found to have high blood pressure (hypertension). Table 2 summarized the various problems identified in the various occupational groups analysed in the present study.

**Table 1** Demographic view of study sample

| S. no. | Gender | Occupation | Number | Mean age (year) | Group |
|---|---|---|---|---|---|
| 1 | Male | Teaching professionals | 79 | 35 | O1 |
| 3 | Male | Manager | 88 | 51 | O2 |
| 5 | Male | Office workers | 37 | 35 | O3 |
| 6 | Male | IT Engineer | 22 | 35 | O4 |
| 7 | Male | Consultant | 32 | 45 | O5 |
| 8 | Male | Researcher | 31 | 35 | O6 |

**Table 2** Different occupational problems in study sample

| S. no. | Occupational group | Cervical spondylosis | Lower back pain | Poor vision (eye problem) | Upper back pain | Shoulder pain | High blood pressure | Central obesity | Normal |
|---|---|---|---|---|---|---|---|---|---|
| 1 | O1 | 8 | 16 | 22 | 11 | 13 | 21 | 33 | 12 |
| 2 | O2 | 5 | 14 | 19 | 12 | 9 | 18 | 29 | 13 |
| 3 | O3 | 4 | 12 | 8 | 13 | 11 | 17 | 22 | 10 |
| 4 | O4 | 4 | 7 | 9 | 6 | 8 | 9 | 7 | 6 |
| 5 | O5 | 6 | 3 | 7 | 2 | 6 | 8 | 8 | 5 |
| 6 | O6 | 5 | 10 | 9 | 6 | 7 | 11 | 11 | 6 |
| Total | | 32 | 62 | 74 | 50 | 54 | 84 | 110 | 52 |

**Table 3** Combined occupational discomfort in different groups

| Occupational group | Both lower back pain + central obesity | Both poor vision + central obesity | Both cervical spondylosis + central obesity | Both cervical spondylosis + blood pressure | Total |
|---|---|---|---|---|---|
| O1 | 16 | 18 | 17 | 13 | 64 |
| O2 | 15 | 18 | 12 | 11 | 56 |
| O3 | 13 | 10 | 6 | 14 | 43 |
| O4 | 5 | 8 | 4 | 7 | 24 |
| O5 | 4 | 6 | 5 | 6 | 21 |
| O6 | 8 | 8 | 5 | 8 | 29 |

Table 3 gives results for males having two or more than two occupational health problem. Out of total study sample of 289, 18% were normal free from any neuromuscular problem and 82% have occupational discomfort. Out of 237 samples having different problems, 25.7% were having lower back pain with central obesity. Similarly, 28.6% of the population, identified with one or more musculoskeletal problems, had poor vision with central obesity. 20.6% had cervical spondylosis with central obesity, and 24.8% were having cervical spondylosis with high blood pressure.

**Discussion**: in a fast growing economy, people are depended on new technology which increases work efficiency and decreases energy consumption [13]. Technology is good for economics but all teaching, non-teaching and other professionals tend to have same lifestyle which tends to be a sedentary lifestyle, with less physical activity and heavy documentation and computer work. 11% of the total population, analysed in the present study, complained of cervical spondylosis, which shows use of wrong posture during working hours. Neck pain and back pain resulting from prolonged sitting were found to be more prominent in group O2 (managers), compared to other groups. Asian and other developing countries are given very less attention on the health problem of employees especially on occupational health of employees. Many degenerative diseases are associated with ageing and working style and are more common in male as compared to female [14].

## 5 Conclusion and Suggestion

A total of 287 males were sampled to analyse the occupational problems faced by them. It was found that prolonged working hours and wrong working postures and poor ergonomics at workplace results in central obesity and affects the physical, muscular and neurological well-being of individuals. High blood pressure and cervical spondylosis were seen in desk work employees because of lack of movement and flexibility. All the results point to adverse impacts of wrong work culture on well-being of working professionals in different sectors. Yoga class, aerobic classes or mini-fitness gym should be provided to the employees to stop or control the increase in number of employees with occupational health problems.

## References

1. Jumah, K.B., Nyame, P.K.: Relationship between load carrying on the head and cervical spondylosis in Ghanaians. West Afr. J. Med. **13**, l81–182 (1994)
2. Kapandji, I.A.: The shoulder: measurement of joint movement. Clin. Rheum. Dis. **8**, 595–616 (1982)
3. Kessel, L., Watson, M.: The painful arc syndrome: clinical classification on a guide to management. J. Bone Jt. Surg. (Br) **59**, 166–172 (1977)

4. Friedenberg, A.B., Miller, W.T.: Degenerative disc disease of the cervical spine. J. Bone Jt. Surg. (Am) **45**, 1171–1183 (1963)
5. Ohara, H., Itani, T., Aoyama, H.: Prevalence of occupational cervico-brachial disorder among different occupational groups in Japan. J. Hum. Ergol. **11**, 55–63 (1982)
6. Westerling, D., Jonsson, B.G.: Pain from the neck shoulder region and sick leave. Scand. J. Soc. Med. **8**, 131–136 (1980)
7. Winkel, J., Ekblorn, B., Hagberg, M., Jonsson, B.: The working environment of cleaners: evaluation of physical strain in mopping and swabbing as a basis for jobredesign. In: Kvilseth, T.O. (ed.) Ergonomics of Workstation Design. Butterworths, London (1980)
8. Binder, A.I.: Neck pain syndromes. Clin. Evid. (Search date December 2006)
9. Binder, A.I.: Cervical pain syndromes. In: Isenberg, D.A., Maddison, P.J., Woo, P., Glass, D. N., Breedveld, F.C. (eds.) Oxford Textbook of Rheumatology, 3rd edn, pp. 95–1185. Oxford Medical Publications, Oxford (2004)
10. Canadian Chiropractic Association, Canadian Federation of Chiropractic Regulatory Boards, Clinical Practice Guidelines Development Initiative, Guidelines Development Committee (GDC): Chiropractic clinical practice guideline: evidence-based treatment of adult neck pain not due to whiplash. J. Can Chiropr. Assoc. **49**, 158–209 (2005)
11. Kuorinka, I., Jonsson, B., Kilbom, A., et al.: Standardised, nordic questionnaire for the analysis of musculoskeletal, symptoms. Appl. Ergon. **18**, 233–237 (1987)
12. Hagberg, M., Wegman, D.H.: Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. Br. J. Ind. Med. **44**, 602–610 (1987)
13. Pallis, G., Jones, A.M., Spillane, J.D.: Cervical spondylosis. Incidence and complication. Brain **77**, 274 (1954)
14. Jager, H.J., Gordon-Harri, L., Mehring, U.M., Goetz, G.F., Mathias, K.D.: Degenerative changes in the cervical spine and load-carrying on the head. Skeletal Radiol. **26**, 475–481 (1997)

# Effect of Finite Dimension of the Substrate on the Performance of Microstrip Antenna

**R. K. Chaurasia and V. Mathur**

## 1 Introduction

Present wireless communication systems needed high gain, low profile, low volume, low fabrication cost, easy to implement, high-efficiency antenna. A microstrip antenna can provide all these mentioned features [1]. A microstrip antenna consists of four elements. The conducting patch that acts as radiator, substrate that acts as base material, conducting ground plane and strip line that provide interface between source and antenna. The prime disadvantage of the microstrip antenna is narrow bandwidth, which restricts it for many applications, where wider bandwidth is required [2]. Therefore, the big challenge designing of microstrip antenna is to increase the bandwidth. Various methods have been studied [3, 4] and reported to increase the antenna's bandwidth. The effect of slots is also presented in many literatures [5, 6]. The substrate has a vital role in the characteristic of microstrip antenna. The height of substrate with low dielectric constant offers good efficiency and wide bandwidth, but it need larger element [7] and hence increases the size of antenna. Simplicity in structure and of the antenna finds many wireless applications for X-band frequency range.

## 2 Microstrip Antenna Design

The first step in the design of a microstrip antenna is the selection of resonant frequency, the second step is the selection of substrate, and third step is the calculation of dimension of radiating patch, ground plane, and feedline. In the present study, the chosen geometry of the antenna is rectangular. The calculation of the

R. K. Chaurasia (✉) · V. Mathur
Faculty of Science & Technology, The ICFAI University, Jaipur, India
e-mail: Chaurasia.rajk@gmail.com



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_38

width, $W$, and length, $L$, of rectangular patch is done by using the following equations [8].

$$W = \frac{c}{2f} \times \sqrt{\frac{2}{(\varepsilon_{r+1})}} \tag{1}$$

$$L = \frac{c}{2f}\left(\frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{\left[1 + 12\frac{h}{W}\right]}\right)^{-1/2} - 2\Delta L \tag{2}$$

where $f$ and $c$ are resonant frequency and the speed of electromagnetic waves. The effective dielectric of duroid substrate is calculated by using the equation

$$\varepsilon_e = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\sqrt{\left[1 + 12\frac{h}{W}\right]} \tag{3}$$

where $\varepsilon_r$ and $h$ are the dielectric and height of the substrate.

The length and width of the substrate also change the antenna characteristic. Normally, the length and width of the finite substrate is more than the length and width [7] of the patch because the patch along with the microstrip feedline is etched over the substrate. Therefore, overall dimension of the substrate is such that it completely covers the patch and feedline. As a thumb rule, the minimum length ($L_G$) and the width ($W_G$) of the substrate is dependent on the dimension of the patch and height of the substrate is given as:

$$W_G = W + 6h \text{ and } L_G = L + 6h \tag{4}$$

## 3 Results and Discussion

To optimize the performance of the proposed microstrip antenna HFSS antenna simulator has been used. Using above set of equations, the length and width of the patch comes out to be 7.9 and 9.1 mm, respectively. Considering the better impedance matching [8, 9] with microstrip line, the final length and width of the rectangular patch is kept at 8.0 and 15.5 mm, respectively. The height of the duroid substrate is taken as 1.5 mm. The dimension of the microstrip feedline is taken as 7 mm × 2.25 mm.

In the all case of observation, the dimension of the patch and the height of the substrate are fixed. From Eq. 4, the initial width and length of the substrate is found to be 24.5 and 17 mm. The first case of observation of the proposed antenna is done with a substrate width of 24 mm and length of 17 mm. The Simulation result, return loss over the frequency range 8–12 GHz, is shown in Fig. 1. Here, a bandwidth of 2.1 GHz with return loss of at −22.5 dB is observed.

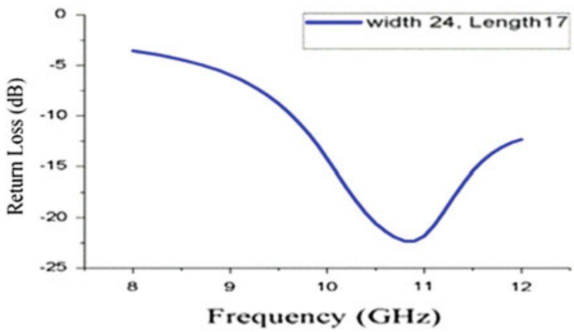



**Fig. 1** First observation with width 24 mm and length 17 mm

In the second case of observation, the width of substrate is kept as same as the first observation, whereas its length is increased from 17 to 18 mm. It also led to increase the length of strip line by 1 mm. The result is shown in Fig. 2. It gives a bandwidth of 1.5 GHz with a return loss of −19.1 dB. The performance is not as good as the first one.

In the third case of observation, the width of substrate is decreased to 23 mm and its length is kept at 17 mm. The strip line length is at 7 mm and no change in the width of strip line. The return loss plot is shown in Fig. 3. It gives a bandwidth of 2.2 GHz with a high return loss at −37.5 dB.

The last is done with the width of substrate at 23 mm and length at 18 mm. The length of strip line would also change from to 8 mm. The result is shown in Fig. 4. Here, a low bandwidth of 1.7 GHz with a return loss of −18.3 dB is observed.

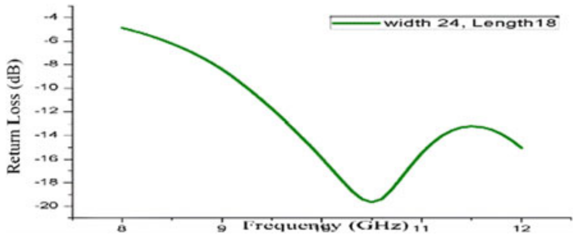



**Fig. 2** Second observation with width 24 mm and length 18 mm

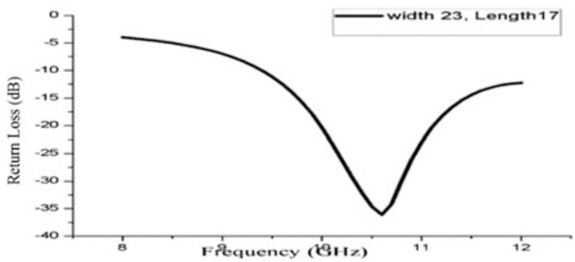



**Fig. 3** Third observation with width 23 mm and length 17 mm

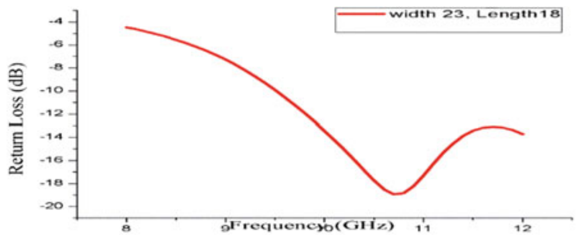



**Fig. 4** Fourth observation with width 23 mm and length 18 mm

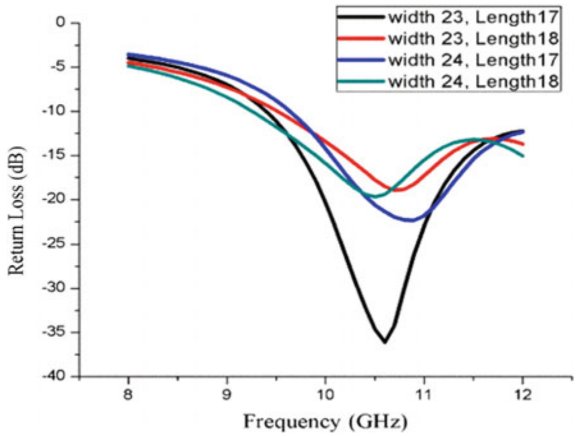



**Fig. 5** Congruent observation with the four aforesaid observations

From all the above observations, it has been seen that the effect of changing width and length of substrate of the microstrip antenna changes its performance (bandwidth and return loss). The combined result of all these observations is plotted in Fig. 5. The best result (wide bandwidth) is obtained in with the substrate dimension of 23 mm by 17 mm. This dimension not only the return loss is quite high but the bandwidth is also enhanced.

## 4 Conclusions

The performance in terms of bandwidth enhancement of the microstrip antenna with the dimension of the substrate is demonstrated for covering X-band application. With a patch dimension of 8 mm × 15.5 mm, and substrate dimension of 23 mm × 17 mm × 1.5 mm, a high bandwidth of 2.2 GHz is obtained along with a high return loss of −37 dB. Hence, by choosing the right dimension of substrate gives antenna a wider bandwidth.

## References

1. Balanis, C.A.: Antenna Theory and Design, 3rd edn. Willey (2005)
2. Garg, R., Bhatia, P., Bahl, I., Ittipiboon, A.: Microstrip Antenna Design Handbook, Artech-House, Balanis C.A., Antenna Theory and Design, 3rd edn. Willey (2005)
3. Garg, R., Bhatia, P., Bahl, I., Ittipiboon, A.: Microstrip Antenna Design Handbook, Artech-House, (2001)
4. Mishra, R.: An overview of microstrip antenna. HCTL Open Int. J. Technol. Innovations Res. (IJTIR) **21**(2), August (2016)
5. Mishra, R., Jayasinghe, J., Mishra, R.G., Kuchhal, P.: Design and performance analysis of a rectangular microstrip line feed ultra-wide band antenna. Int. J. Sig. Process. Image Process. Pattern Recogn. SERSC Publications, **9**(6), 419–426, July (2016). http://dx.doi.org/10.14257/ijsip.2016.9.6.36
6. Kumar, R., Praveen, V.N., Kamble, V., Krishna, R.R.: Simulation, design of compact multi-band microstrip slot antennas for WiMAX/WLAN and UWB applications. Wirel. Pers. Commun. **80**(3), 1175–1192 (2015)
7. Kuo, J.S., Wong, K.L.: A compact microstrip antenna with meandering slots in the ground plane. Microw. Opt. Technol. Lett. **29**(2), 95–97 (2001)
8. Mishra, R.G., Mishra, R., Kuchhal, P.: Design of broadband monopole microstrip antenna using rectangular slot. In: Proceeding of International Conference on Intelligent Communication, Control and Devices, Volume 479 of the series Advances in Intelligent Systems and Computing, pp. 683–688, ISBN: 978-981-10-1707-0. http://dx.doi.org/10.1007/978-981-10-1708-7_78
9. Mishra, R., Mishra, R.G., Kuchhal, P.: Analytical study on the effect of dimension and position of slot for the designing of Ultra Wide Band (UWB) microstrip antenna. In: 5th IEEE International Conference on Advances in Computing

# Performance Enhancement of Rectangular Microstrip Antenna by Inserting Notches and Slits

**Raj Gaurav Mishra, Ranjan Mishra, Piyush Kuchhal and N. Kumari**

## 1 Introduction

In recent years, the wireless communication society has been grown very rapidly. Antenna, as one of key components, finds an intensive research and development to sustain the growth. In communication using wireless systems, the information signals are radiated in space as an electromagnetic wave by using an antenna and the radiated signal is intercepted by a receiving antenna. An antenna serves as a device that is used for radiating or receiving electromagnetic waves [1].

Microstrip antennas, being the one of the suitable and useful for this, find many hopeful claims in this area [2]. Its utility and usefulness lies in its potential attractive features [3]. However, the wide use is also restricted by its low bandwidth (around 5%) and low efficiency. This main disadvantage of microstrip antenna possesses its inadequacy for various wideband applications nowadays. In its simple form, a microstrip antenna comprises of a radiating patch and a ground plane, both are of conductor, along with a dielectric substrate in between them. The shape of the upper surface is of various regular geometrical forms. Recently, various methods have reported for improving the performance of the impedance bandwidth of microstrip antenna. The report includes the effect by inserting slots on the radiating structure [4–7]. Besides these parasitic element [8], partial ground plane [9], open-loop resonator effect [10] are also reported. Recently, researchers included broadband optimization by inserting slot on planer rectangular antenna [11, 12].

The outline of the paper is comprised of four sections: The introduction is presented in Sect. 1; Sect. 2 is regarding the antenna structure and its dimension; a

R. G. Mishra (✉) · R. Mishra · N. Kumari
Department of Electronics, Instrumentation and Control, CoES,
University of Petroleum and Energy Studies, Dehradun, India
e-mail: rgmishra@ddn.upes.ac.in

P. Kuchhal
CoES, University of Petroleum and Energy Studies, Dehradun, India



N. A. Siddiqui et al. (eds.), *Advances in Health and Environment Safety*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-10-7122-5_39

brief analysis of the impedance calculation antenna is carried out in Sect. 2; results are discussed in Sect. 3, and the conclusion is carried out in Sect. 4.

## 2 Antenna Structure and Design

The structure of the rectangular antenna is dependent on three parameters. These are operating frequency ($f$), dielectric constant of the substrate material ($\varepsilon_r$), and its height ($h$). In the present discussion, the mid-operating frequency is 8 GHz, dielectric constant of the FR4 epoxy substrate is 4.4, and the height is 1.6 mm. The upper range in the height of the substrate is taken because this adds on the bandwidth and also avoids any bulkiness in the structure of the antenna [13]. Length and width of the rectangular antenna are calculated by the set of equations [1, 2]. Consider the impedance matching with the line, the length and width are come out to be 12 and 16 mm, respectively, after slight optimization. The analysis is performed in advanced design software (ADS) using method of moment.

In this present study, the inductive effect is done by inserting notches and slits on the radiating structure. These have been sliced out normal to the axis of resonating length. The notches are the structure at the corners, and the slits are over the length. The structure of them is also rectangular in shape. The analysis is carried out by varying the dimensions of these structures, and in the report, the suitable size is kept which present the best result. The dimension of these structures is symmetrical in nature. The dimensions of notches and slits are 2 mm by 0.5 mm. The feeding to the antenna is provided by microstrip line having a 50 Ω load for good impedance matching. A symbolic structure of the antenna with notches and slits are shown in Fig. 1.

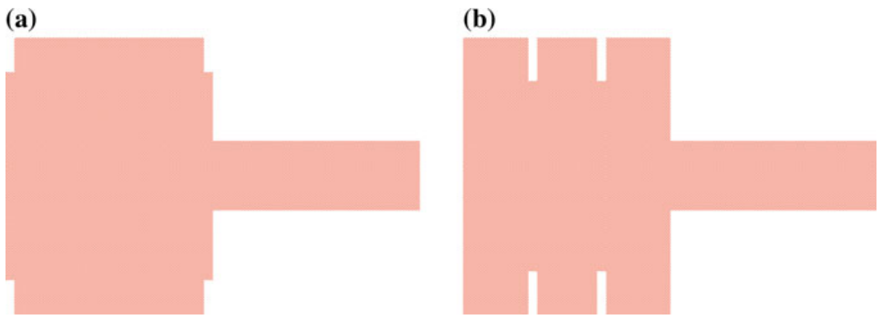



**Fig. 1** Planer structure of rectangular microstrip antenna with **a** notches and **b** slits

## 3 Results and Discussion

The effect of notches and slits on the microstrip antenna is observed and analyzed separately with reference to the plain microstrip antenna of same dimensions. The microstrip antenna is of dimension 15 mm × 12 mm × 1.5 mm with FR4 epoxy substrate and is fed with microstrip line of dimension 12 mm × 4 mm. This feeding is the most suitable for compact structure [3]. The plain structure gives a low return loss of the order of 20% and bandwidth of 19%. The next observation and analysis is with notches. A notch is a small grove cut along the corner of the edge. A symmetrical notch structure is chosen. The most significant result is observed with four notches at four corners. The dimension of each symmetrical notch is 2 mm × 0.5 mm. The impedance bandwidth has been significantly enhanced to 37% with this. This rise in bandwidth is quite noteworthy. Also the return loss has been in excess of −30 dB. Return loss plot ($S_{11}$ plot) with this structure is shown in Fig. 2. The maximum of return loss is at the frequency of 8 GHz with the −10 dB bandwidth of 1.5 GHz.

The final analysis is done by observing the effect of slits on the radiating surface. Here, the best result is obtained with four symmetrical slits, two each on the radiating edges of the antenna. Here too, a good return loss and increases in the bandwidth with respect to planer structure is obtained. Also the slit shifts the central frequency to around 9 GHz; this is due to slight overall change in the radiating dimension of the antenna.

The $S_{11}$ (return loss) plot with both notches and slits is shown in Fig. 2. In both cases, with notches and slits, an enhancement in the return loss and bandwidth is achieved with respect to the planer structure. Only the gain is marginal low and this

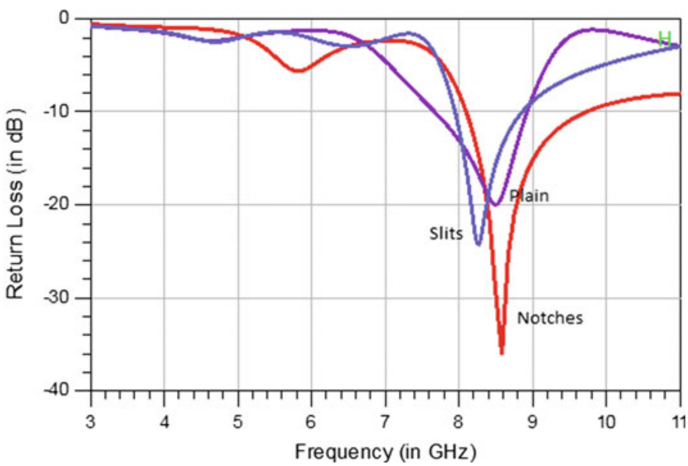



**Fig. 2** Return loss plot showing bandwidth

**Table 1** Performance parameter with different structure

| | Plain | Notch | Slit |
|---|---|---|---|
| Efficiency | 28.71 | 37.31 | 34.48 |
| Directivity (dB) | 7.47 | 7.41 | 7.42 |
| Gain (dB) | 2.37 | 2.08 | 1.92 |
| Bandwidth (%) | 19 | 37 | 37 |

reduction in gain is due to the increase in the bandwidth. A summarization and comparison with various parameters is shown in Table 1.

The current distribution over the patch with notches and slits is shown in Fig. 3 below.

Fig. 3 reveals that a noteworthy amount of current is present at the junction portion of radiating surface of the microstrip antenna and the microstrip line. In case of slit-loaded antenna, current flow is minimum at the corners of the edges, and the same low current is along the non-radiating far edge of the antenna. But with the introduction of notches, it is found that in the junction point, there is a drop in the distribution of the current flow, whereas it increases at the four edges. This results a better impedance matching and ultimately and enhancement in the bandwidth and good return loss with notches. There is a weak current flow at the edges with the slits, but it is high at the portion where the slits engraved the radiating portion. Therefore, an introduction of small slit of proper length increases the flow of current over the radiating portion of the antenna. This causes an enhancement in the bandwidth and the return loss. This enhancement is more than the plain structure but slight less than with the notches. The radiation pattern for the two aforesaid cases is shown in Fig. 4.

The radiation pattern reveals a broad distribution of the energy on the two side lobes. Since the gain with notches and slits is more than those obtained with planar structure, an identical radiation pattern is observed.

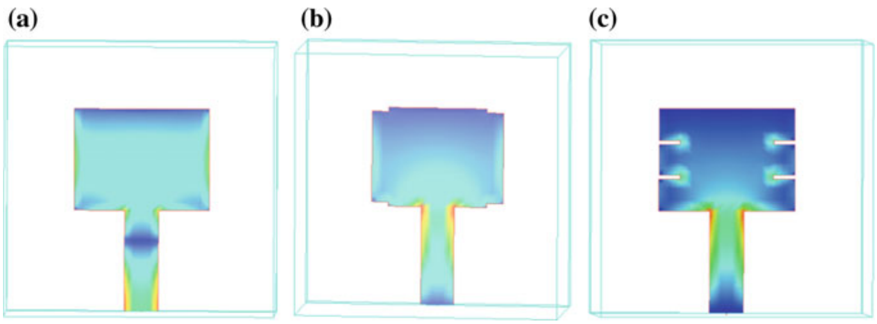



**Fig. 3** Current distribution in **a** plain microstrip antenna **b** notches loaded microstrip antenna **c** slits loaded microstrip antenna

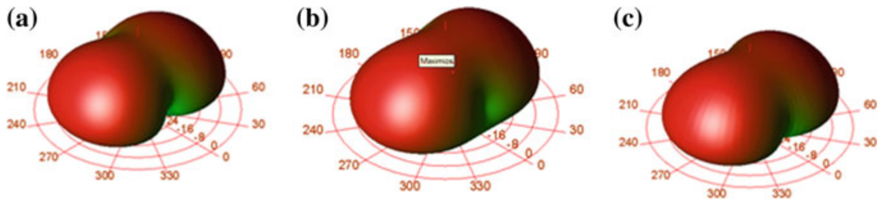



**Fig. 4** Radiation pattern of **a** plain microstrip antenna **b** notches loaded microstrip antenna **c** slits loaded microstrip antenna

## 4 Conclusions

The rectangular microstrip antenna has been analyzed with the insertion of symmetrical notches and slits on the radiating surface. It is established that there is an enhancement in the performance of the antenna parameter especially the bandwidth up to the order of 37%. It has also seen that the insertion of notches has more profound effect than the slits. Hence, it is concluded that an appropriate selection of the dimension and position of the notches and slits effectively enhanced the performance and the antenna can be a good choice for various wideband applications in the lower frequency range of X-band and finds useful application in earth observation.

## References

1. Balanis, C.A.: Antenna Theory and Design, 3rd edn. Willey (2005)
2. Garg, R., Bhatia, P., Bahl, I., Ittipiboon, A.: Microstrip Antenna Design Handbook, Artech-House, (2001)
3. Mishra, R.: An overview of microstrip antenna. HCTL Open Int. J. Technol. Innovations Res. (IJTIR), **21**(2), August (2016)
4. Mishra, R., Jayasinghe, J., Mishra R.G., Kuchhal, P.: Design and performance analysis of a rectangular microstrip line feed ultra-wide band antenna. Int. J. Sig. Process. Image Process. Pattern Recogn. SERSC Publications, **9**(6), 419–426, July (2016). http://dx.doi.org/10.14257/ijsip.2016.9.6.36
5. Sadat, S., Fardis, M., Geran, F., Dadashzadeh, G.: A compact microstrip square-ring slot antenna for UWB applications. Prog. Electromagnet. Res. **67**, 173–179 (2007)
6. Guo, Zheng, et al.: Bandwidth enhancement of monopole UWB antenna with new slots and EBG structures. IEEE Antenna Wirel. Propag. Lett. **12**, 1550–1553 (2013)
7. Kumar, R., Praveen, V.N., Kamble, V., Krishna, R.R.: Simulation, design of compact multi-band microstrip slot antennas for WiMAX/WLAN and UWB applications. Wirel. Pers. Commun. **80**(3), 1175–1192 (2015)
8. Abbosh, A.M., Bialkowski, M.E.: Design of UWB planar bandnotched antenna using parasitic element. IEEE Trans. Antennas Propag. **57**, 796–799 (2009)
9. Kuo, J.S., Wong, K.L.: A compact microstrip antenna with meandering slots in the ground plane. Microw. Opt. Technol. Lett. **29**(2), 95–97 (2001)
10. Kelly, J.R., Hall, P.S., Gardner, P.: Band-notched UWB antenna incorporating a microstrip open-loop resonator. IEEE Trans. Antennas Propag. **59**, 3045–3048 (2011)

11. Mishra, R.G., Mishra, R., Kuchhal, P.: Design of broadband monopole microstrip antenna using rectangular slot. In: Proceeding of International Conference on Intelligent Communication, Control and Devices, Volume 479 of the series Advances in Intelligent Systems and Computing, pp.683–688, ISBN: 978-981-10-1707-0. http://dx.doi.org/10.1007/978-981-10-1708-7_78
12. Mishra, R., Mishra, R.G., Kuchhal, P.: Analytical study on the effect of dimension and position of slot for the designing of Ultra Wide Band (UWB) microstrip antenna. In: 5th IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI), 978-1-5090-2028-7, Sept (2016)
13. Mishra, R., Kuchhal, P., Kumar, A.: Effect of height of the substrate & width of the patch on the performance characteristics of microstrip antenna. Int. J. Electr. Comput. Eng. **5**(6), 1441–1445 (2015)