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Paradigms in Pollution Prevention

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ISSN 2191-5547 ISSN 2191-5555 (electronic)
SpringerBriefs in Environmental Science
ISBN 978-3-319-58414-0 ISBN 978-3-319-58415-7 (eBook)
DOI 10.1007/978-3-319-58415-7

Library of Congress Control Number: 2017944135

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

The age old tradition of the use of our air, land and water resources as disposal media for our waste products is now being questioned by the public, government, industry and elected officials. The environmental protection paradigm centred on controlling pollution after it has been created is being challenged by an emerging view rooted in preventing pollution at its source. The regulatory paradigm based on emission limits and extensive government inspection programmes is now widely recognized as incomplete, inadequate, too costly and a significant barrier to enhanced trade relations among nations.

Increasingly, a pollution prevention paradigm is being substituted which focuses on reducing the overall cost of pollution control by changing production and distribution processes. This results in more responsibility for pollution control in the private sector and shifts the focus of regulation from substantive improvements in environmental quality to procedural efficiency concerns.

By integrating pollution control in the private sector, the pollution prevention paradigm not only cuts the overall cost of regulation, it also harmonizes standards and increases compliance both nationally and internationally.

It is important to understand that implementation of the preventive paradigm depends much more on people as consumers, workers, managers and professionals than does traditional, reactive environmental management. But, by and large, most people have poor environmental literacy. Without detailed environmental knowledge, resistance to change may be severe.

Pollution prevention as social, cultural and economical change means that large numbers of people must cooperate. Ordinary environmental concerns that are fed by the popular press coverage of environmental issues may not be capable of sustaining long-term personal and occupational commitment to preventive actions. Practicing prevention, in other words, requires more mature environmental responsibility than most people have thus far experienced. The preventive strategy requires a high level of personal commitment, responsibility and habitual behaviour.

Solving the current environmental problems and preventing future environmental pollution requires new ways of thinking. We have much to learn from our successes and failures, but we must shift from some of the old paradigms, enhance others and produce new ones where appropriate.

This book serves as an excellent medium for the readers from which they can explore new approaches and change their thinking so as not to be condemned to repeat the environmental mistakes, mishaps and misdeeds.

The chapters in this book hold many lessons for pollution prevention programmes. The goal is to place some of the many environmental events in a context in which they can be scrutinized objectively, systematically and passionately.

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Preface

As the stride of industrial activity strengthened and the understanding of collective effects grew, a pollution control paradigm became the dominant approach to environmental management. This new paradigm of pollution prevention will serve as the epoch of state and local environmental dogmas. The challenge is to switch from past environmental regulations based on pollution control and government authorized regulations to future environmental procedures which would be based on pollution prevention, source reduction, recycling and waste minimization. It will require a new social setup amongst environmental, industrial and regulatory interests.

The current approach has failed to prevent global contamination and environmental damage because it underestimates the scale, complexity and diversity of the hazards of chemical pollution. There exists an urgent need for fundamental shifts in the mode of chemical assessment and policies.

A new framework should focus on chemical classes rather than individual substances, and the conversion of industrial processes to prevent the production and use of persistent and bioaccumulative substances. The default state of pollution policy must be shifted in the face of uncertainty from permission to restriction.

To preserve public health, environmental strategies must be developed to understand pollution prevention ethics and eliminate or minimize waste production. Preventing pollution, rather than devising more costly control methods, is key to industrial competition and environmental health and sustainability.

The advantages of pollution prevention include improving the effectiveness of managing reduced waste streams, minimizing the uncertainty associated with the environmental impact of released pollutants, avoiding transfers of released pollutants and protecting natural resources. Prevention of pollution also educates the public on matters of waste management, and promotes regulatory inspections of industrial waste management practices.

For any comprehensive system to work, governments must encourage and participate in recycling, consumption of recycled products and investment in recycling technologies. With this perspective, the paradigm associated with environmental protection has been changing. Educational programs and training activities must be available to prepare people for this coming paradigm shift.

This book will provide insight to readers on various types of pollution affecting our environment, its health hazards on our living system and preventive ways to keep a check on the proliferating menace of pollution. It discusses diverse topics on pollution prevention and waste minimization leading towards zero discharge.

We thank Amity University and Hon'ble Founder President for providing the platform and infrastructure to organize this workshop and continuous support to bring out the publication in a presentable form. We would like to express our deepest appreciation to the scientists, faculties and research scholars who have contributed their chapters for the development of the book. In particular, Dr. J. S. Pandey, Dr. Abhishek Chauhan, Dr. Charu Gupta, Dr. Renu Khedkar, Dr. Monika Thakur, Dr. Pallavi Saxena and Dr. Khushbu Gulati played an important role in the formation of the book. Several anonymous reviewers provided helpful comments that improved the presentation of the material in the book.

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Abstract

The book is a compilation of some related presentations at a national conference entitled 'Pollution Prevention Paradigm' held on May 11, 2012, at Amity University, Noida, Uttar Pradesh, India.

Environmental pollution prevention programs and policies cover all aspects of pollution and involve coordination among areas such as industrial development, city planning, water resources development and transportation policies; their implications and priorities may vary.

As environmental pollution control technologies have become more sophisticated and more expensive, there has been a growing interest in ways to incorporate prevention in the design of industrial processes with the objective of eliminating harmful environmental effects while promoting the competitiveness of industries. Among the benefits of pollution prevention approaches, clean technologies and toxic use reduction also have the potential for eliminating worker exposure to health risks.

Pollution prevention is a pragmatic program capable of constantly and speedily addressing pollution issues as they arise. It is arguable that traditional control measures have reached their limit and only the implementation of comprehensive pollution prevention programs will be capable of addressing the next phase of environmental protection in a practical and effective way.

Pollution prevention programs now have an extraordinary opportunity to evolve and make a unique contribution to homeland security and provide a new driver for pollution prevention implementation. The time to design and implement a more preventive, risk reduction approach based on pollution prevention protecting human health, the environment and community is now in this new arena of environmental security.

Continued support is necessary to expand our pollution prevention program's efforts to reduce generation of wastes, use toxic chemicals, improve resource conservation and management and expand environmental security through pollution prevention.

A more proactive approach is demanded which suggests that pollution must be prevented, not just controlled. The more pollution is prevented from ever being produced, the less money has to be spent controlling it. The pollution prevention approach focuses directly on the use of processes, practices, materials and energies that avoid or minimize the creation of pollutants and wastes, and not on 'add-on' abatement measures.

In the future, it will become gradually more important for pollution prevention programs and organizations to recognize that it is more effective to prevent environmental damage and prove there is no safer way of proceeding with production when adopting a guiding principle of cleaner production. This will require a unified approach for resource use and consumption and an understanding that environmental risks cannot be shifted among workers, consumers or media, i.e. land, air and water. This multimedia approach to pollution prevention will ensure the source reduction of wastes. For example, no longer will pollution control techniques remove air pollutants only to place them in water or solid waste streams.

Topics include the benefits as well as the health hazards related to food industry waste, the measurement of volatile organic compounds (VOCs) indicating their importance and role in photochemical smog formation, the need for sustainable treatment systems to clean up of lakes and rivers of India, the combined effect forces of global dimming and global warming, the beneficial role of microbes in our environment, green building, energy efficiency, carbon, ecological foot printing, lifestyle solutions and the environmental pollution and public health studies in relation to increasing cases of asthma in rural and urban India. Featuring a collection of informative and descriptive chapters, this book is essential reading for environmental scientists, environmental toxicologists and people from allied fields.

Chapter 1
Green Building, Energy Efficiency, Carbon and Ecological Footprinting (CF and EF), and Life Style Solutions (LSS)

J.S. Pandey and Vaibhav Pandey

Abstract Ultimate solutions to climate change problems lie in regulating and controlling the three key sectors: production, consumption, and lifestyle. In fact, the third one automatically takes care of the first two because our production and consumption patterns and trends depend directly on our lifestyles. This boils down to the fact that key to climate change mitigation lies in our lifestyles. Food, clothing, and shelter are our primary requirements, and they all contribute significantly to increasing concentrations of greenhouse gases (GHGs) and ultimately to climate change problem. This chapter illustrates some model development exercises based on realistic and relevant parameters, which are easy to measure and monitor in the residential sector. Subsequently, the chapter also shows what kind of researches need to be pursued in various educational and research institutions so as to gradually make every citizen of the society environmentally aware and responsible. In short, the presentation discusses and recommends the kind of activities which need regular pursuance, refinement, modification, and application in regard to evolving site-specific, region-specific, and ecosystem-specific environmental management plans that are aimed at combating the climate-regulated environmental crisis which is unfolding before us every day with a newer dimension.

Keywords Carbon footprint • Ecological footprint • Life style solutions • Climate change

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7_1

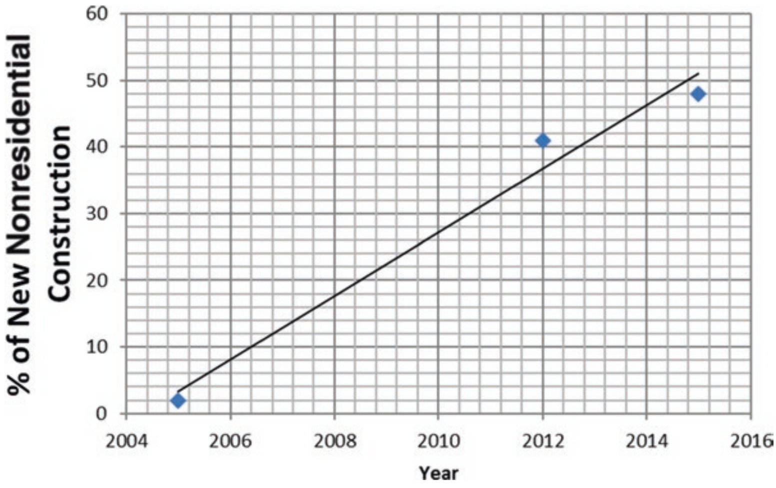

Fig. 1.1 Construction trend

1 Introduction

Buildings, in particular, have a significant contribution to make in terms of environmental impact as they are strongly dependent on highly energy-intensive materials like cement and steel. According to some estimates, they contribute to about 43% of the world's GHG-emissions (http://www.narucmeetings.org/Presentations/2009_Weston_Carbon.pdf). Also, it is worth noting that the waste from the construction material accounts for roughly 40% of landfill materials. Moreover, it is estimated that in the USA this year about 40–48% construction would be green. In economic terms, this opportunity is worth $120–145 billion (http://www.usgbc.org/articles/green-building-facts). This trend over last one decade can be seen clearly in Fig. 1.1.

"Green building" or "sustainable building" essentially aims at increasing the efficiency of energy, water, and material consumption, while simultaneously reducing the adverse impacts on ecosystem and human health. This necessitates appropriate and better design for the building construction, operation, maintenance, and waste disposal. In short, green buildings reduce the overall negative impact on the environment by way of:

- Efficiently using energy, water, and other material resources
- Protecting and improving occupants' health and productivity
- Reducing waste and pollution generation and load

Ultimate solutions to climate change problems (Adger et al. 2005) lie in regulating and controlling the three key sectors: production, consumption, and lifestyle. In fact, the third one automatically takes care of the first two because our production and consumption patterns and trends depend directly on our lifestyles. This boils down to the fact that key to climate change mitigation lies in our lifestyles. Food, clothing, and shelter are our primary requirements, and they all contribute significantly to increasing concentrations of greenhouse gases (GHGs) (USEPA 2005; Pandey et al. 1997) and ultimately to climate change problem.

This chapter illustrates some model development exercises based on realistic and relevant parameters, which are easy to measure and monitor in the residential sector. Subsequently, the chapter also shows what kind of researches need to be pursued in various educational and research institutions so as to gradually make every citizen of the society environmentally aware and responsible.

In short, the presentation discusses and recommends the kind of activities which need regular pursuance, refinement, modification, and application in regard to evolving site-specific, region-specific, and ecosystem-specific environmental management plans aimed at combating the climate-regulated environmental crisis which is unfolding before us every day with a newer dimension.

2 Carbon Footprinting (CF) and Ecological Footprinting (EF)

Carbon footprinting (CF) and ecological footprinting (EF) (http://www.ecologicalfootprint.com; Rees and Wackernagel 1996, 1999; Mishra et al. 2008) are some of the recent environmental impact assessment tools, which not only help in understanding and quantifying impacts due to various activities like solid waste disposal, wastewater treatment, air pollution control etc. but also help in evolving appropriate cost-effective environmental management plans. Awareness has now significantly increased in respect of greenhouse gases (GHGs), global warming, climate change, and carbon footprints (CFs). Institutions like US Environmental Protection Agency (USEPA) and Water Utility Climate Alliance are already working vigorously in this direction. CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), and fluorinated gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are the main GHGs, which contribute significantly to total CF. These GHGs have widely different global warming potentials according to the Intergovernmental Panel on Climate Change (IPCC 2006).

Activities that lead to GHG-emissions are said to be ***carbon-positive***, while those which remove GHGs from the environment are known as ***carbon-negative*** or carbon-sinks. When GHG-emissions equal GHG-assimilation or absorption, the activities are known as ***carbon-neutral.***

GHG-emissions can be of the following kinds:

- Direct
- Indirect
- Operational
- Embodied emissions

Combustion of fossil fuels, vehicular emission, and ***methane emission from wetlands*** come under the category of direct emissions. Indirect emissions include electricity use/purchase, transportation of people, goods, material (chemical), and waste. Operational and embodied emissions are also used alternatively in place of direct and indirect emissions, respectively.

3 CF (Carbon Footprint):Calculators

In developed countries like America, where consumers are directly responsible for about 40% of GHG-emissions, CF-calculators are very frequently being used for estimating their GHG (CO_2-e) emissions. There are mainly two lifestyle components which are responsible for citizen's GHG-emissions: household activities and transportation.

However, not all CF-calculators give same or similar results. The differences amongst them could be as high as five to six million MT per year per individual. Some of the most popular CF-calculators can be listed as follows:

- American Forests (http://www.americanforests.org/resources/ccc/)
- Be Green (http://www.greennow.com/)
- BEF (Bonneville Environmental Foundation) (https://www.greentagsusa.org/GreenTags/calculator_intro.cfm)
- Carbon Counter.org (http://www.carboncounter.org)
- Chuck Wright (http://www.chuck.wright.com/calculators/carbon.html)
- Clear Water (http://www.clearwater.org/carbon.html)
- The Conservation Fund (http://www.conservationfund.org/gozeroFund)
- EPA (http://www.epa.gov/climatechange/emissions/ind_calculator.html)
- Safe Climate (http://www.safeclimate.net/calculator/)
- TerraPass (http://www.terrapass.com/)

Generally, the kind of inputs these CF-calculators require can be summarized as follows:

- Electricity/energy/oil/natural gas/propane/kerosene/wood consumption and related emission factors
- Waste generation and related emission factors
- Number of individuals/institutions/activities (as the case may be)
- Distance covered in transportation (flight/rail/road) and related emission factors
- Number of vehicles and their emission factors
- Use of air conditioners and their emission factors

And, the variations in CF-results are normally attributed to the following factors:

- Methodologies
- Individual behavioral features
- Conversion and emission factors
- Lack of transparency

The greatest uncertainty, however, is associated with emission (conversion) factors. Most of the calculators do not display or explicitly explain the methodologies behind these factors. As a result, they have used significantly different emission factors. These variations cannot be ignored in view of the fact that ultimately these calculators are supposed to influence and guide the citizens and policy makers for taking appropriate pollution (carbon) reduction measures and strategies.

Notwithstanding the uncertainty in their emission-estimates, these calculators do, however, generate awareness amongst common masses about environmental protection and conservation. This way they not only enhance their acceptability, but also become amenable to public understanding.

4 Ecological Footprint

The ecological footprint (EF) [http://www.ecologicalfootprint.com/] is a broad measure of resource use which highlights the areas where consumption is exceeding environmental limits. It mainly depends on the following parameters, which can be selected according to the options indicated before them (http://steppingforward.org.uk/calc/) (Table 1.1):

5 GHG-Emission from Transportation Sector

There are mainly three variables on which the GHG-emission from transportation is dependent: distance travelled in a given time period, the vehicle-specific fuel efficiency, and the presence/absence of air conditioner in the vehicle. In transportation sector, the differences in emissions could accrue mainly because of the differences in vehicle-specific emission factors chosen by different CF-calculators. For instance, Be Green's emission factor (Padgett et al. 2008) for air travel is 0.15 kg/km, whereas the factor used by BEF is 4.0 kg/km of CO_2-equivalent. Some CF-calculators like American Forests (AF) include emissions from even motorcycles, taxis, rail, buses, etc.

6 Residential Emissions

Residential emissions depend essentially on the following factors:

- Electricity consumption
- Household fuel use
- Solid waste disposal

Households are normally divided into three categories: single-family home, town-home, and apartments. The energy to CO_2-eq. Conversion factors vary from

Table 1.1 Parameters for assessing ecological footprint

S. no.	Parameters	Available options
1.	Travelling (transport)	• Car (average use)
		• Car (heavy use)
		• Car (light use)
		• Bus/train
		• Motorbike
		• Walking/cycling
2.	Living space (residential	• Large house
		• Medium-sized house
		• Small house
		• Flat/apartment
		• Zero emission development zone
3.	Sharing of apartment (lifestyle)	• No other person
		• With one other person
		• With two other person
		• With three other person
		• With four other person
		• With five other person
		• With six other person
		• With more than six other person
4.	Heating/cooling bills (energy/electricity consumption)	• Low
		• Normal
		• High
5.	Use of electricity (type)	• Renewable
		• Nonrenewable
6.	Energy conservation measures	• Adequate
		• Not adequate
7.	Food habits	• Regular meat eater
		• Occasional meat eater
		• Heavy meat eater
		• Vegetarian
8.	Food imports/exports	• Locally produced food
		• Food items imported from different states
		• Food items imported from neighboring countries
		• Food items imported from distant countries
9.	Waste generation	• Average
		• Below average
		• Above average

(continued)

Table 1.1 (continued)

S. no.	Parameters	Available options
10.	Type of waste	• Recyclable
		• Nonrecyclable

0.25 (kg CO_2-e/kWh) used by clear water to 0.90 (kg CO_2-e/kWh) used by Chuck Wright. Bonneville Environmental Foundation (BEF) includes even transmission losses, while calculating their emission (conversion) factor [0.63 (kg CO_2-e/kWh)]. Some calculators like TerraPass have used monthly (temporal) variations too.

As far as emission factors for natural gas, fuel oil, and propane are concerned, there are large variations. For natural gas, the highest conversion factor is used by Safe Climate, which is about 1.33 times higher than the factor used by Clear Water (the lowest emission factor for natural gas). For fuel oil, Safe Climate uses the highest emission factor, which is approximately 1.36 times higher than the value used by Clear Water. Clear Water uses the lowest emission factor for fuel oil also. For propane, American Forests (AF) uses the lowest emission factor and Clear Water (CW) uses the highest emission factor (which is 7.1 times higher than that of AF) (https://www.greenbiz.com/sites/.../EIARVol28Issue2-3pgs106-115.pdf).

7 Climate Change and Green Buildings

According to an American estimate, energy use in commercial buildings accounts for 17% of US-GHG emission (http://www3.epa.gov/climatechange/ghgemissions/sources/electricity.html). Buildings have significant environmental impacts as they utilize and consume sizable amounts of natural resources like forest and mining products iron, steel, cement, limestones, water, etc. over their entire life cycle. This adds to further depletion of natural resources, which already are under serious threat due to excessive industrialization and commercialization. Therefore, while designing a green building, one has to keep in mind that this kind of resource depletion and the consequent environmental impacts are minimized.

Enhancing energy efficiency and reducing consumption at every step are the core issues while adopting appropriate mitigation approaches aimed at combating various kinds of environmental impacts. In other words, the same thing can be looked at as "bringing in lifestyle changes." It gives rise to the need for innovative model development exercises aimed at delineating appropriate "environmental management plans" based on those parameters for which data can be easily collected in the residential complexes.

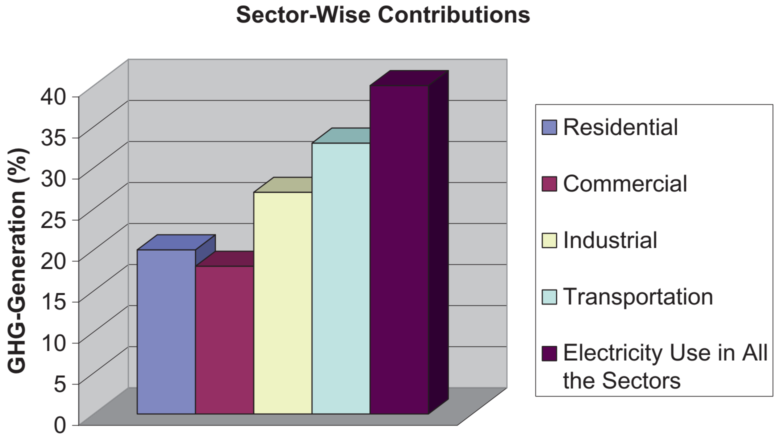

Fig. 1.2 Sector-wise CO_2-emissions

8 Models Representing Temporal Trends and Interdependence of CF and EF

Figure 1.2 provides the percentage contribution from various sectors (industrial, commercial, residential, and transportation) towards GHG-generation. In the same diagram is also shown the summed-up contribution from all these sectors (http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html#emissions).

When we look at the temporal trend of carbon footprint [Fig. 1.3], we find that its gradient, which was less than 25 (million metric tons of carbon/year) during 1900–1940 had a steep rise (gradient of 116 million metric tons of carbon/year) during 1940–2000, i.e., during the period of industrialization. Under the circumstances, it can be safely concluded that the intensity of material consumption had increased almost fourfold—thereby raising concerns regarding sustainability of the conventional development-framework (http://petrolog.typepad.com/climate_change/2010/01/cumulative-emissions-of-co$_2$.html).

Global ecological footprint (Fig. 1.4) has also almost the similar trend during the same period, its gradients being 0.007 and 0.013 (Number of Earths per year) during the periods 1900–1940 and 1940–2000, respectively. (Figures 1.3 and 1.4 suggest that while during 1940–2000, there was a fourfold increase in carbon dioxide emissions (measured as carbon footprint (CF)), the overall impact on the environment (measured in terms of global ecological footprint (EF) was only twofold). When we tried to study the correlation (www.footprintnetwork.org) between EF and CF (Fig. 1.5), we found that its best representation ($R^2 = 0.944$) is through the equation $CF = 2540.5(EF)^2 + 3817.4(EF) - 77.797$ ($R^2 = 0.944$). Subsequently, we had also analyzed the per capita CF and EF values and studied their correlations (Fig. 1.6). These per capita correlations could be best represented in the form of $CF = 2.6855e^{0.2399(EF)}$ ($R^2 = 0.9186$).

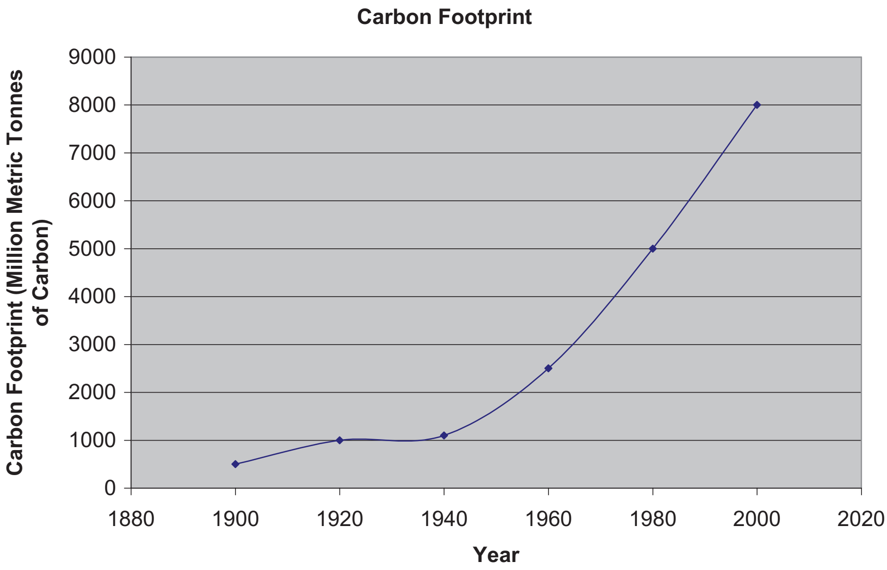

Fig. 1.3 Carbon footprint—temporal trend

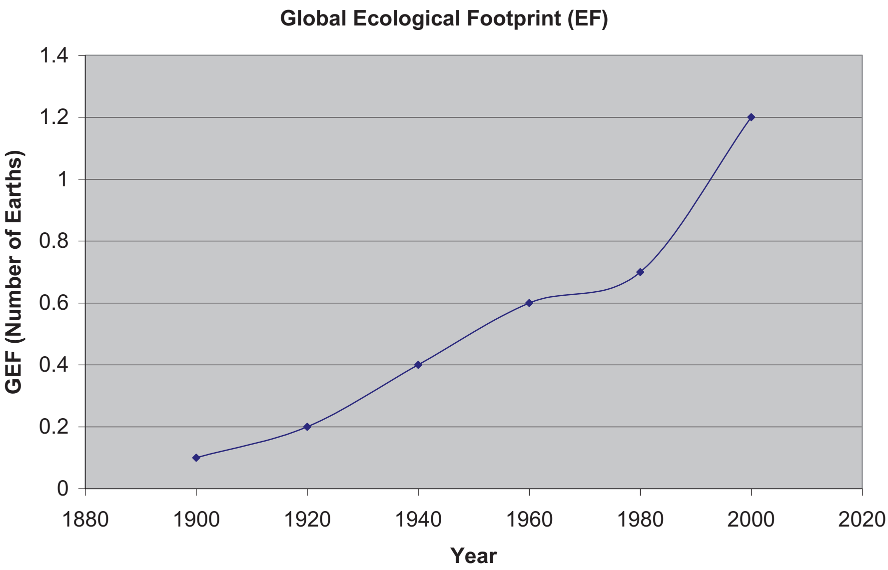

Fig. 1.4 Global ecological footprint

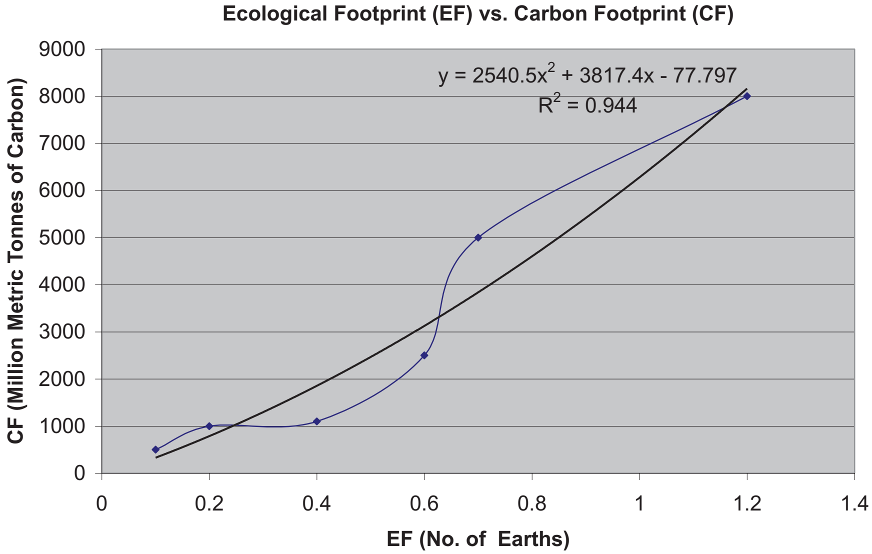

Fig. 1.5 EF vs. CF

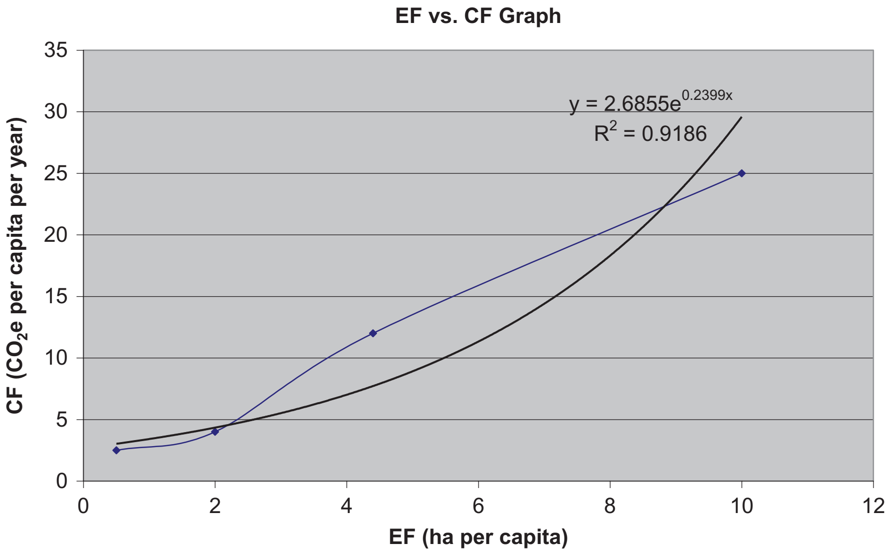

Fig. 1.6 Per capita EF vs. per capita CF

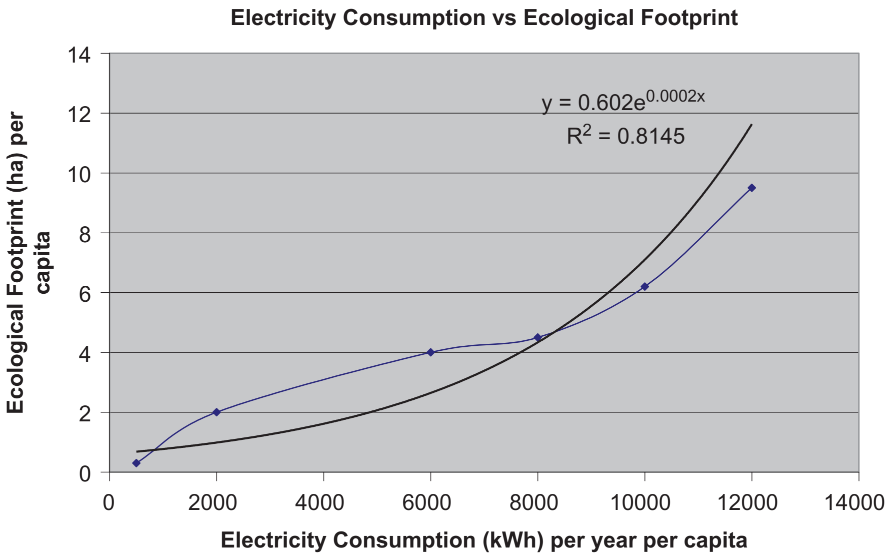

Fig. 1.7 Electricity consumption and ecological footprints

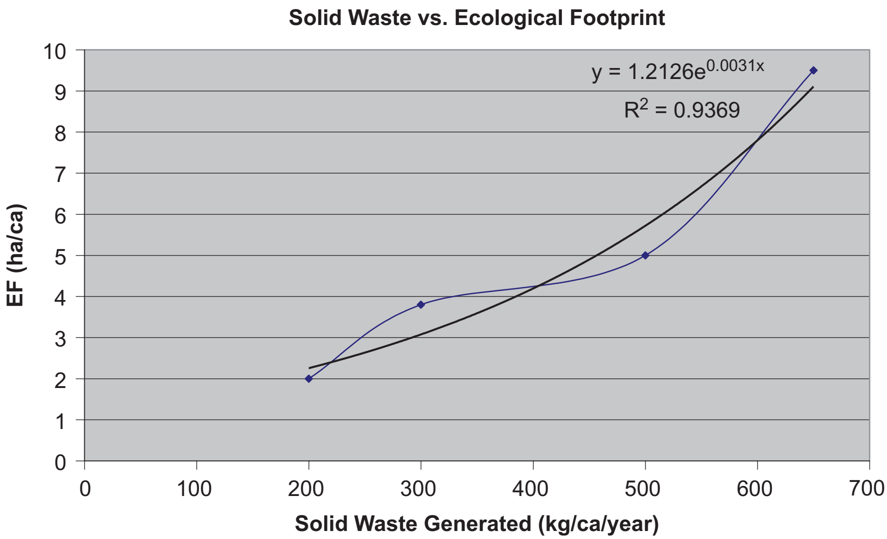

Fig. 1.8 Solid waste generated and ecological footprints

Our next attempt was to see if the concepts of CF and EF could be used for ranking of green buildings. Of all the parameters which we studied, we found that the maximum contribution to the EF and CF comes from electricity generation as has also been illustrated earlier (Fig. 1.2) and solid waste generation (Pandey 2009a, b; Pandey et al. 2009).

Information on electricity consumption for various countries was collected (https://yearbook.enerdata.net/) for which values of EF were reported (www.footprintnetwork.org). These values were subsequently correlated (Fig. 1.7). Similar exercise was done for solid waste generation (http://www.nationmaster.com/graph/env_mun_was_gen-environment-municipal-waste-generation) (Fig. 1.8). Correlation with electricity consumption was of the type EF (per capita) = $0.602e^{0.0002(\text{Electricity consumed per capita})}$ (R^2 = 0.8145), while the same w.r.t. solid waste generation was EF(ha/ca) = $1.2126e^{0.0031(\text{solid waste generated per capita})}$ with R^2 = 0.9369. This exercise was done in order to explore the possibility of using these correlations for doing a quick assessment of the environmental impact due to an activity or an event.

9 Energy-Efficient Buildings (EEB): Climate Change Solutions (CCS)

Buildings contribute well over one third of global energy use and associated greenhouse gas emissions. Thus, they have a huge potential to achieve drastic emission reductions at various levels. Indirectly it means that energy-efficient buildings would result in significantly reducing the impacts and risks of climate change. For example, landmark structures such as New York City's Empire State Building, with 102 stories and 242,000 m^2 could help in achieving emission-reduction targets considerably [http://www.ittefaq.com/issues/2009/12/14/news0794.htm].

The current climate footprint from buildings is equivalent to 8.6 billion tons of CO_2 per year. It is further predicted to almost double to 15.6 billion tons of CO_2 by 2030. Additionally, there is continuously the pressure for constructing new housing complexes—so as to combat population growth, urbanization, and modernization. This is bound to lead to an almost doubling of existing building stock in developing countries by 2050.

In South Africa, the building sector accounts for 23% of greenhouse gas emissions. Moreover, investment in new buildings is expected to grow at the rate of around 2% per year. This would automatically result in a multifold increase in greenhouse gas emissions. Therefore, in terms of immediate solutions what is urgently needed is using improved building designs, technologies, and policy instruments. This would, inter alia, enhance energy efficiency up to 40–50% in new buildings.

10 Need for Urgency

The following areas need immediate attention:

- In order to achieve national GHG-emission reduction targets, buildings need to be given the highest priority.

- Nationally Appropriate Mitigation Actions (NAMA) should focus on enhancing energy efficiency as the most important means for reducing GHG-emissions.
- Investment in energy-efficient building programmes in developing countries should need continuous and consistent support from well-developed countries.
- Continuous monitoring and energy/environment audits are the most important segments of any well-intentioned and effective environmental management plan.

11 Cost Implications of Mitigation Measures

Many of the CF-calculators provide many mitigation measures as well as costs involved in implementing those mitigation measures. Some of the mitigation measures suggested by them are related to tree plantation. And the cost estimates include two important factors: (1) GHG-mitigation, which on an average works out to be per tree (0.3–4.0 tons GHG per tree) and (2) cost of every tree (approx. $1–5). Other mitigative measures could be subsidizing energy through renewable (wind and solar) energy. These mitigation measures can, therefore, be grouped under the following categories:

- Restoration
- Renewable energy
- Energy efficiency

However, prices for mitigation may vary between 3 and 30 USD per ton of GHG.

12 Conclusion

Inter alia, the chapter deals with the kind of research, which is needed in the area of Climate Change. Side by side, these researches need to be extended and pursued further so as to strike a balance between ecology and economy. Future exercises are needed, which should aim at the dynamics of Ecological Footprints (Pandey and Joseph 2001; Pandey et al. 2001a); analysis of Environmental Risks by way of developing models which deal with the issues like Temporal Risk Gradients (TRG) (Pandey et al. 2001b); and Ecological Economics of Natural Resources (Pandey et al. 2004). There is also a need for quantifying region-specific emission factors for different GHGs (Pandey et al. 2007). On the basis of these emission factors, region-specific ecosystem health (Pandey and Khanna 1992a) and human health risk assessment (Pandey and Khanna 1992; Pandey et al. 1992, 1993, 1994, 2005) can be carried out. Subsequently, appropriate region-specific environmental management plans can be developed. Ecology works very much on the concepts of species-specific, ecosystem-specific, and process-specific bio-rhythms (Pandey and Khanna 1995). It has a perfect analogy with the way a musical concert or consortia works or in terms of Electronics Engineering, the way an integrated circuit (IC) works. All these features form a portion of Ecological Engineering.

Acknowledgement The authors are grateful to all those sources of information including discussions, discourses, workshops, and conferences, which have helped in shaping this chapter by way of a systematic data analysis and appropriate synthesis and conversion of the information into useful models. The views expressed are those of the authors (mainly) and their respective institutions may or may not share the same views.

References

Adger WN, Arnell NW, Tompkins ET (2005) Successful adaptation to climate change across scales. Glob Environ Chang 15:77–86

IPCC (2006) IPCC. In: Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

Mishra AP, Tembhare MW, Pandey JS, Kumar R, Wate SR (2008) Carbon footprint: where India stands in global scenario. Souvenir: international conference on recent trends in environmental impact assessment (RTEIA-2008), NEERI, Nagpur, India, November 23–25, p 34

Padgett JP, Steinmann AC, Clarke JH, Vandenbergh MP (2008) A comparison of carbon calculators. Environ Impact Assess Rev 28:106–115

Pandey JS (2009a) Inter-disciplinarity of issues connected with climate change, food security and energy alternatives. Int J Clim Chang Impacts Responses 1(4):17–22

Pandey JS (2009b) Invited lecture: role of carbon and ecological foot-printing (CF and EF) in the context of innovative technologies and sustainable development. In: Proceedings: seminar on environmental issues of Jharkhand June 5, 2009, Organized by Jharkhand State Pollution Control Board, Ranchi, India

Pandey JS, Khanna P (1992a) Speed-dependent modeling of ecosystem exposures from vehicles in the near-road environment. J Environ Syst 21(2):185–192

Pandey JS, Khanna P (1995) Development of plant function types for studying impact of green house gases on terrestrial ecosystems. J Environ Syst 23(1):67–82

Pandey JS, Joseph V (2001) A scavenging-dependent air-basin ecological risk assessment (SABERA)—model applied to acid rain impact around Delhi City, India. J Environ Syst 28(3):193–202

Pandey JS, Pimparkar S, Khanna P (1992) Micro-environmental zones and occupancy factors in Jharia coal-field: PAH-health exposure assessment. J Environ Syst 21(4):349–356

Pandey JS, Pimparkar S, Khanna P (1993) Health exposure assessment and policy analysis. Int J Environ Health Res 3:161–170

Pandey JS, Mude S, Khanna P (1994) Comparing indoor air pollution health risks in India and United States. J Environ Syst 23(2):179–194

Pandey JS, Deb SC, Khanna P (1997) Issues related to greenhouse effect, productivity modelling and nutrient cycling: a case study of Indian wetlands. Environ Manag 21(2):219–224

Pandey JS, Khan S, Joseph V, Singh RN (2001a) Development of a dynamic and predictive model for ecological foot printing (EF). J Environ Syst 28(4):279–291

Pandey JS, Khan S, Khanna P (2001b) Modelling and quantification of temporal risk gradients (TRG) for traffic zones of Delhi City in India. J Environ Syst 28(1):55–69

Pandey JS, Joseph V, Kaul SN (2004) A zone-wise ecological-economic analysis of Indian wetlands. Environ Monit Assess 98:261–273

Pandey JS, Kumar R, Devotta S (2005) Health risks of NO_2, SPM and SO_2 in Delhi (India). Atmos Environ 39:6868–6874

Pandey JS, Wate SR, Devotta S (2007) Development of emission factors for GHGs and associated uncertainties. In: Proceedings: 2nd international workshop on uncertainty in greenhouse gas inventories. International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria, 27–28 September, 2007

Pandey JS, Wate SR, Chakrabarti T. (2009) Invited lecture: carbon and ecological foot-printing in the residential, commercial and industrial context with particular emphasis on designing green buildings. In: Proceedings: seminar on green building 23rd January, 2009, Organized by Chief Engineer Bareilly Zone under the Aegis of Chief Engineer Central Command, Military Engineer Services, Bareilly, UP India

Rees WE, Wackernagel M (1996) Urban ecological footprints: why cities cannot be sustainable—and why they are a key to sustainability. Environ Impact Assess Rev 16:223–248

Rees WE, Wackernagel M (1999) Monetary analysis: turning a blind eye on sustainability. Ecol Econ 29:47–52

USEPA (2005) Global anthropogenic non-CO2 greenhouse gas emission: 1990–2020. http://www.epa.gov/methane/pdfs/global_emissions.pdf

Chapter 2
Microbes: "A Tribute" to Clean Environment

Charu Gupta, Dhan Prakash, and Sneh Gupta

Abstract Due to industrial development, the amount and variety of hazardous substances added to the environment has increased drastically. Bioremediation is the process of using microorganisms or other life forms to consume and breakdown environmental pollutants in comparatively safe products. Because bacteria have a fast rate of population growth and are constantly evolving, they can adapt to live off materials and chemicals that are normally poisonous to other species. Some bacteria can remove chlorine from carcinogenic materials, digest pesticides, and have the ability to decolorize various xenobiotic dyes through microbial metabolism. Other microbes used for biological decolorization are red yeasts like *Rhodotorula rubra, Cyathus bulleri, Cunninghamella elegans,* and *Phanerochaete chrysosporium, Actinobacteria, Cyanobacteria, Flavobacteria, Deinococcus-thermus, Thermotogae, Firmicutes*, *Staphylococcus*, and *Proteobacteria*. Construction of strains with broad spectrum of catabolic potential with heavy metal-resistant traits makes them ideal for bioremediation of polluted environments in both aquatic and terrestrial ecosystems. The transfer of genetic traits from one organism to another paves way in creating Genetically Engineered Microorganisms (GEMs) for combating pollution in extreme environments making it a boon to mankind by cleaning up the mess that has created in nature.

Keywords Pollution • Nano-bioremediation • Clean environment • Designer microbes • Microbial cleaners

1 Introduction

Over the last 150 years, the number of organic chemicals released into the environment has increased dramatically (Schwarzenbach et al. 2010) leaving an unprecedented chemical footprint on earth. Many groundwater contaminations result from

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7_2

point sources, originating from accidents or contaminations at industrial sites. These contaminations typically form plumes with high concentrations of pollutants (μg/L to mg/L range). Alternatively, chemicals may enter groundwater through widespread application in agriculture or release from sewage treatment into rivers. Here, pesticides, pharmaceuticals, or consumer care products are introduced as nonpoint sources and typically occur in much smaller concentrations (micropollutants in ng/L to μg/L range) (Richardson and Ternes 2011).

Biodegradation is one of the most favored and sustainable means of removing organic pollutants from contaminated aquifers but the major steering factors are still surprisingly poorly understood. Microorganisms play a fundamental role in the environment. Their role is the result of complex biogeochemical processes by consortia of microorganisms and the function of individual species is not clear in many cases (OECD 2015).

2 Rationale of Using Microbes for Clean Environment

Microbes are ubiquitous in nature and are being exposed to the continuous release of more and more recalcitrant xenobiotic compounds into the environment. These microbes inhabiting polluted environments are armed with various resistance and catabolic potentials. The catalytic potential of microbes in nature is enormous, and this is advantageous to mankind for a cleaner and healthier environment through bioremediation.

The contamination cleanup strategy called bioremediation using naturally occurring or genetically modified microbes to clean up dirt and pollution is gaining importance, as scientists devise new ways to use bugs against mercury, oil spills, radioactive waste, and more.

In general, potential microbes with broad spectrum of activities from their native habitat have been screened, characterized, genetically modified, and released back to their native habitat for better performance. By such studies, the core problem of pollution is tactfully attacked and benefits of decontamination add healthy atmosphere to mankind.

The overall rationale for using any microbes is similar for all types of products. Living microbes are capable of enzymatically degrading substances associated with soil and/or bad odor. Thus, products containing spores (dormant microbes) have to allow for a germination step first to the vegetative state to become physiologically active. Microbial action is aimed at controlling odor and to support the cleaning action of detergents (Kumar and Gopal 2015).

Some microorganisms produce a broad range of extracellular enzymes including proteases, cellulases, amylases, and ureases which can degrade organic high molecular weight substances in soil. As opposed to cleaners with added enzymes, microbes can further metabolize some of these degradations products. Substances creating odor problems such as NH_3 can be metabolized, or the formation of H_2S may be avoided by transforming SO_3 into S_2. The purified degrading enzymes, nitrilase, azoreductases, and organophosphate hydrolases could be effectively used in industry for the treatment of effluents. The systems developed are eco-friendly and economical and hence could effectively be integrated with physicochemical methods for pollution control.

The microbes used in the cleaning products are also claimed to outcompete unwanted microorganisms in colonizing surfaces by using up the nutrients provided in the soil and from polluted surfaces. Other microbes can directly inhibit the growth of unwanted microbes, for example, by lowering the pH. Producers claim a long-term effect because microorganisms will stay on the treated surface (as spores) and hinder recolonization by unwanted microbes.

In this direction, a new terminology named "microbial cleaners" is coming into play. Microbial cleaners are the specially designed groups of bacteria and fungi that are capable of cleaning the polluted sites (Spök 2009).

In commercial contexts, microbial cleaners are mainly applied for odor control in cases where conventional cleaners are considered less efficient. The rationale is that microbes causing problems in hospitals are outcompeted by the microbes used in the cleaner which would render disinfection unnecessary. Besides hard surface cleaning, these products are also used for cleaning carpets and upholstery. Specialty products are used for cleaning drains, pipes, and grease traps in order to remove deposits, and also in industrial production in the washing of machine parts, as well as for oil spills on masonry or concrete.

Products based on Effective Microorganisms (EM®) represent a special type in terms of product design, producer, production process, and marketing. An inoculum including a combination of bacteria and fungi is manufactured by licensed companies mainly based in Japan and marketed worldwide by specialized EM vendors and health food shops.

The same and similar combinations of microbes are used for various outdoor and indoor purposes including soil enhancement, composting, as a feed additive and for cleaning. EM cleaners are not only applied in all the areas described above but recommended for a much broader range of indoor cleaning applications including tiling, stove, refrigerator, pots and pans, bio-waste container, living spaces, wooden floors, closets, wardrobes, shoe cabinets, leather clothes, glass doors, washing machines, dishwashers, doormats, cars, and even as laundry detergent (Spök 2009).

Microbial cleaners are covered under Environment and Health Legislation by EU Directive 2000/54/EC which regulates the minimum requirements for the protection of workers from risks related to biological agents.

Employers (e.g., manufacturers and blenders of microbial products, professional cleaning service companies, other companies employing cleaning personnel) are required to conduct a risk assessment, including the classification of the microorganisms used into one of four risk groups based on the pathogenic potential. Potential allergenic or toxigenic effects and exposures also have to be considered (Directive 2000).

Only microbes which belong to risk group 1 are not considered to pose any hazards to human health. The use of microbes classified in risk group 2 or higher requires notification to the national competent authorities and preventive measures by the employer. The type of risk mitigation measures largely depends on the particular risk group and exposure scenario.

Manufacturers claim that microbes classified into risk group 2 or higher are neither used nor considered for application in cleaners.

The microorganisms that are considered as biocides include two *Bacillus* spp. including *B. subtilis* which is frequently used in microbial cleaners. These microbes are listed as biocides in the Annex to Regulation 1451/2007.

Microbial cleaners are environmentally sound. Most microbial cleaner products contain much lower levels of acids and surfactants. Microbial products used in commercial and industrial contexts for cleaning drains, pipes, and grease traps are less alkaline and indicate a potential for reducing the amount of organic solvents used. This is also true for solvent-free microbial degreasing of parts in industrial manufacturing. According to manufacturers, the preventive character of microbial action is also potentially beneficial for the environment as microbes are being active as long as there is sufficient nutrients and water on the surface. When lacking nutrients or water, certain microbes can survive as spores which can germinate and become physiologically active again if nutrients and water becomes available to them. If used on a regular basis, for instance, in grease traps and drain pipes the formation of sediments and odor is reduced which renders the need to use environmentally harmful cleaning products unnecessary.

The most frequently used microbes are members of the genus group*Bacillus, Bifidobacterium, Lactobacillus, Rhodopseudomonas*, and *Saccharomyces*. Some producers are specialized on combinations of different *Bacillus* sp. spores instead of using vegetative cells; as spores allow for a longer shelf life up to 1 year (Spök 2009).

3 Bioremediation Through Genetic Engineering of Microbes

Bioremediation involves using genetically altered living organisms that give them taste for toxins to eat the contaminants. Bioremediation explores gene diversity and metabolic versatility of microorganisms (Fulekar 2009). Such microbes are deployed to purge sites of contaminants such as polychlorinated biphenyls (PCBs), oil, radioactive waste, gasoline, and mercury.

Microbes play a very important role in the mineralization of pollutants either by natural selection or through recombinant DNA technology making bioremediation process an extension of normal microbial metabolism. The recombinant DNA technology explores PCR, anti-sense RNA technique, site-directed mutagenesis, electroporation, and particle bombardment techniques.

The major advantage of developing genetically engineered microbes is that the modified organism has a higher degradative capacity and can even degrade the recalcitrant molecules. It is an effective, safe, and economical technique for bioremediation (Singh et al. 2014).

In a recent study, researchers developed a modified *E. coli* bacterium that allowed it to not only survive in mercury but also to remove it from waste sites. The genes produce proteins called metallothionein and polyphosphate kinase that allow the bacterial cells to develop a resistance to mercury and to accumulate large amounts of the heavy metal within the organism. Mercury is a toxic heavy metal and can be converted into methylmercury, a more toxic form; and no natural organism can bioremediate it. These transgenic bacteria sequester mercury contamination before the natural bacteria converts it into toxic methylmercury. These transgenic microbes are used in the form of filters and are added (bio-augmentation) at the contaminated and polluted site to remove the toxic metal (Kumar and Gopal 2015).

Thus, bio-augmentation is a type of bioremediation that involves adding organisms directly to the open environment. The microbes that are not able to adapt the environment die quickly and simply provide more nutrients for the indigenous bacteria to feed on.

There are some microbes that develop special proteins to protect themselves from potentially toxic nanoparticles in their own environment. These microbial proteins can be used to improve water quality on a large scale. In another study, bacteria were isolated from an abandoned mine excrete proteins that cause metal nanoparticles to aggregate. The bacteria bind and immobilize the metals in the form of nanoparticles which are potentially toxic to the bacteria.

Similarly, S-reducing bacteria can cause the precipitation of zinc metal and form nanoparticles. These nanoparticles are able to move freely because they are so small (2–6 nm diam.) and can redissolve if conditions change (Dixit et al. 2015).

Microbes such as bacteria, fungi, and algae play an important role in the bioremediation of xenobiotic compounds like dyes and plastic including pesticides and insecticides like morpholine, methyl parathion, organophosphorus compounds, and benzimidazoles (Tang et al. 2007).

In a study, different pure isolates of *Pseudomonas* sp. were characterized for complete and partial mineralization of morpholine, methyl parathion, and other organophosphorus pesticides and fungicides that causes oil hydration by both aromatic and aliphatic hydrocarbon degradation. There are some other bacteria such as *Serratia* sp. and *Bacillus* sp. that have been characterized for their ability to degrade benzimidazole compounds and effectively decolorize distillery and textile mill effluents, respectively. The other species, *Pseudomonas A3, Pseudomonas putida, P. aeruginosa,* and *Serratia marinorubra*, have been used for complete mineralization of broad-spectrum fungicides in soil.

These microbes including *Trichoderma viridae* are also capable of degradation of commercial textile mill azo reactive dyes like Black B, Turq Blue GN, Yellow HEM, Red HEFB, Navy HER, number of mono, bi, poly azo dyes, and triphenylmethane dyes like Methyl red, Acid black, Acid brown, Acid green, Sudan black, and Crystal violet to name a few.

For the detoxification of heavy metal and biosorption, *Bacillius* sp. was found to be effective in reducing hexavalent chromium to its nontoxic trivalent form. The cultures of *Azotobacter* sp. and *Leuconostoc* sp. are cloned for their extracellular polysaccharide (EPS) production for biosorption of many heavy metals like cadmium, zinc, arsenate, and chromium from polluted samples.

Likewise, aliphatic and aromatic hydrocarbons including crude oil and nitroaromatic compounds are also successfully degraded by a wide range of *Pseudomonas* sp. and *Raulstonia* sp. All these specialized bacteria are encoded with a catabolic plasmid which encoded the genes for hydrocarbon degradation.

Microbes are also capable of decolorization and deodorization of highly polluted river water. There are various potential bacteria and fungi that have been isolated, characterized, and effectively used for bioremediation. The treated water can be used for agriculture, industry, and aquarium and for other household purpose (Kumar and Gopal 2015). Thus, till date bioremediation is the most reliable and eco-friendly technique for the treatment of hazardous waste effluents.

4 Microbes Causing Bioremediation

These include a diverse array of microbes isolated from various environmental habitats. Some of them are identified as active members of consortium including *Acinethobacter, Actinobacter, Acaligenes, Arthrobacter, Bacillins, Berijerinckia, Flavobacterium, Methylosinus, Mycrobacterium, Mycococcus, Nitrosomonas, Nocardia, Penicillium, Phanerochaete, Pseudomonas, Rhizoctomia, Serratio, Trametes*, and *Xanthofacter.* Each of these individual microbes is not capable of complete biodegradation but these works synergistically for the complete mineralization under both aerobic and anaerobic conditions (Singh et al. 2014).

4.1 Use of Microbes in Cleaning Products

Chemical-based cleaning products are commonly used throughout the world in both industrial and domestic use. Some of the common examples of the synthetic cleaning solutions are sodium hypochlorite, sodium hydroxide, and ammonium hydroxide. Since they are highly reactive, they are not environmental friendly and can affect human health. Some studies have reported that mixing of these products liberates toxic chlorine and ammonia gas that cause acute poisoning and illness (Nazaroff and Weschler 2004).

To overcome the environmental health hazard, microbial-based cleaning products are recently developed and used in many developed countries like the UK, the USA, etc. These products contain various strains of microorganisms as active ingredients in place of synthetic chemicals. These products would be in great demand in the near future and the global market may reach up to USD 9.32 billion dollars by the year 2017 PR Web (2011).

Both the vegetative cells and the spores are used in the cleaning products and treatment applications. The most common microbial species used are *Bacillus* sp.

like *B. subtilis, B. licheniformis*, and *B. amyloliquefaciens. B. polymyxa* strains have also been used as production organisms for topical antibiotics (Adisesh et al. 2011; Gelmetti 2008).

The other bacterial genera used in cleaning agents are *Achromobacter*, *Actinobacter*, *Alcaligenes*, *Arthrobacter*, *Rhodopseudomonas*, *Rhodobacter*, and *Lactobacillus* sp. (Wassenaar and Klein 2008). Some of these bacteria degrade various xenobiotic compounds while others degrade textile azo dyes (Xingzu et al. 2008).

Some of the cleaning products also use fungal species like *Saccharomyces* and *Candida* species. They have the potential to be effectively used in the biodegradation of variety of hazardous chemicals (Xiuyan et al. 2011; Harms et al. 2011).

Besides, microbial metabolites such as enzymes like amylases, proteases, and lipases are also used in detergent products. This is done to improve their activity at lower water temperature and more alkaline pH levels (Kirk et al. 2002). For example, *B. subtilis* strains have been engineered to express some of these modified genes and a number of recombinant lipase enzymes have been produced using engineered-*Bacillus* and *Aspergillus* species (Hasan et al. 2010).

5 Mechanism of Microbial Mineralization: Biodegradation

During biodegradation, the breakdown and transformation of insoluble organic toxic constituents into the less toxic soluble inorganic compounds takes place with the help of microbial enzymes. Bioremediation is a step-wise process where the intermediate compounds are converted into carbon-di-oxide, water, and other inorganic compounds. The biodegradation takes place under both aerobic and anaerobic conditions. Under aerobic conditions, oxygen acts as a terminal electron acceptor whereas under anaerobic metabolism, nitrate, sulfate, and bicarbonate acts as a terminal electron acceptor.

There are several factors that affect the rate of biodegradation such as soil moisture, oxygen availability, soil pH, availability of nutrients, contaminant concentration, and the presence of suitable microbes. The optimum conditions of these factors enhance the rate of biodegradation by microbes. Oxygen plays a critical role in the bio-degradative process. Research studies have shown that aerobic indigenous microorganisms play a key role in degradation of petroleum oils (Cai et al. 2013).

5.1 Xenobiotic Compounds: Aerobic Biodegradation Pathway

In the bacterial respiration, oxygen is the most common electron acceptor. In aerobic biodegradation of aromatic compounds, oxygen plays an important dual role: firstly, it acts as an electron acceptor for the aromatic pollutants, and secondly it activates the substrate with the help of oxygenation reactions. Some polluted environments are often noxious such as aquifers, aquatic sediments, and submerged soils and require alternative electron acceptors such as nitrate, Fe(III), and sulfate (Cao et al. 2009).

Some of the common xenobiotic compounds include petroleum hydrocarbons, chlorinated aliphatics, benzene, toluene, phenol, naphthalene, fluorine, pyrene, chloroanilines, pentachlorophenol, and dichlorobenzenes. All these compounds are rapidly and potentially degraded by the aerobic degradation process and finally release carbon-di-oxide, water, residues along with some biomass. Many bacterial consortia capable of growing on these chemicals degrade toxic compounds to non-toxic compounds (Shimao 2001).

Alkanes consisting of long carbon chain and straight structures are more prone to aerobic biodegradation. Aerobic degradation pathway of alkane degradation is basically the oxidation of the terminal methyl group into a carboxylic acid through an alcohol intermediate, and finally completes mineralization through β-oxidation pathway (Zhang and Bennett 2005).

The aerobic degradation process of aromatic compound involves their oxidation by molecular oxygen, and then it enters into Krebs cycle and β-oxidation (Wilson and Bouwer 1997). During aerobic respiration, microorganisms use oxygen to hydroxylate the benzene ring, resulting in the subsequent fission of the ring. The enzymes involved in these processes are mono- and di-oxygenase that incorporate one or two atoms of oxygen, respectively, into the ring.

5.2 Anaerobic Biodegradation Pathway

The anaerobic biodegradation pathway is followed by the microorganisms when the pollutants are highly recalcitrant (increase in halogenation) and cannot be mineralized by aerobic pathways. Under anaerobic conditions, the biodegradation of xenobiotic compound produces carbon-di-oxide, methane, water, residues, and biomass (Jayasekara et al. 2005). Some examples of recalcitrant molecules include polychlorinated biphenyls (PCBs), chlorinated dioxins, and some pesticides like DDT.

Anaerobic bacteria perform reductive dehalogenation either by a gratuitous reaction or by a new type of anaerobic respiration. This process reduces the degree of chlorination and makes the product more accessible for mineralization by aerobic bacteria (Van Agteren et al. 1998).

During anaerobic degradation, reductive dehalogenation is the first step of degradation of PCBs (Poly chlorinated biphenyl); dehalogenation is done under anaerobic conditions where organic substrates act as electron donors. PCBs accept electrons to allow the anaerobic bacteria to transfer electrons to these compounds. Anaerobic bacteria are capable of degrading xenobiotics that are present in various anaerobic habitats.

The major groups of anaerobic bacteria responsible for degrading xenobiotic compounds include *Acidovorax, Bordetella, Pseudomonas, Sphingomonas, Variovorax, Veillonella alkalescens, Desulfovibrio* spp., *Desulfuromonas michi-*

ganensis, Desulfitobacterium halogenans, D. oleovorans, G. metallireducens, and *D. acetonicum*. Anaerobic sulfate-reducing and methanogenic condition can be applied to isolate pure culture of anaerobic bacteria (Zhang and Bennett 2005). Anaerobes can also utilize substituted and complex aromatic compounds in the way that do not perturb the benzene nucleus itself. The list of selected xenobiotic compounds and their degrading bacterial species are presented in Table 2.1.

Table 2.1 List of xenobiotic compounds and their degrading bacterial species (Agrawal and Shahi 2015)

Target compounds	Bacteria degrading the compounds
PAH (polycyclic aromatic hydrocarbons) compounds	
Naphthalene	*Streptomyces* spp. isolates AB1, AH4, and AM2, strain QWE-35
	Pseudomonas sp. CZ2 and CZ5
	Pseudomonas stutzeri strain B1SMN1
	Achromobacter sp.
	Enterobacter sp.
	Geobacillus sp. SH-1
	Rhodococcus
	Pseudomonas putida S2
	Bacillus fusiformis (BFN)
	Paenibacillus
	Novosphingobium naphthalenivorans sp.
	Polaromonas naphthalenivorans sp. nov.Strain CJ2
	Bacillus naphthovorans strain MN-003
	Staphylococcus sp. strain MN-005 and *Micrococcus* sp.
	Neptunomonas naphthovorans
Phenanthrene	*Pseudomonas* sp. Ph6
	Massilia sp. Strain Pn2
	Sphingobium sp. Strain PNB
	Sphingomonadaceae PHPY *and Rhodobacteraceae* SK
	Mycobacterium sp.
	Brevibacillus sp. PDM-3
	Vibrio parahaemolyticus
Anthracene	*Microbacterium* sp. *strain SL10*
	Martelella sp. *AD3*
	Ochrobactrum sp. VA1
	Rhodococcus opacus 412
	Ps. aeruginosa and Ps. citronellolis
PCP (pentachlorophenol)	*Kocuria* sp. CL2
	Comamonas testosteroni CCM 7530
	Sphingobium sp. UG30
	Bacillus cereus (DQ002384), *Serratia marcescens strain*
	Sphingomonas chlorophenolica

Table 2.1 (continued)

Target compounds	Bacteria degrading the compounds
Chloroaniline	*Acinetobacter baylyi*
	Delftia tsuruhatensis H1
	Acinetobacter baumannii CA2
	Pseudomonas putida CA16
	Klebsiella sp. CA17
Phthalate	*Achromobacter denitrificans*
	Arthrobacter sp. C21
	Agrobacterium sp. JDC-49
	Ochrobactrum sp. JDC-41
	Enterobacter sp. T5
	Rhodococcus sp. L4
Pesticides	
Endosulfan compounds	*Paenibacillus* sp. *ISTP10*
	Achromobacter xylosoxidans strain C8B
	Stenotrophomonas maltophilia and Rhodococcus erythropolis
	Klebsiella oxytoca KE-8
	Klebsiella pneumonia
2,4-D (2,4-dichlorophenoxyacetic acid)	*Maribacter* sp.
	Delftia sp.
	Pseudomonas putida
	Comamonas koreensis
DDT (Dichlorodiphenyltrichloroethane)	*Pseudoxanthobacter liyangensis* sp. nov
	Novosphingobium arabidopsis sp. nov.
	Alcaligenes sp.
	Serratia marcescens DT-1P
Halogenated organic compounds	
Vinyl chloride	*Micrococcus species*
	Sphingopyxis sp.
	Pseudomonas aeruginosa
Herbicides	
Atrazine	*Raoultella planticola*
	Bacillus subtilis
	Rhodococcus sp.
	Arthrobacter sp.
	Nocardioides sp.
Propanil	*Xanthomonas* sp., *Acinetobacter calcoaceticus*
	Rhodococcus sp., and *Pseudomonas* sp.
Petroleum products	*Acinetobacter* sp.
	Pseudomonas, Achromobacter, Bacillus, and *Micromonospora*
	Dietzia strain
	Flavobacterium sp. *Acinetobacterium calcoaceticum*, and *Pseudomonas aeruginosa*

(continued)

Table 2.1 (continued)

Target compounds	Bacteria degrading the compounds
Azo dyes	*Morganella* sp.
	Sphingomonas sp.
	Proteus hauseri
	Staphylococcus arlettae

The sulfate reducing bacteria play a major role in degrading crude oil (Barton and Hamilton 2007). These groups of bacteria are obligate anaerobes that utilize sulfate as final electron acceptor during anaerobic respiration and generate hydrogen sulfide from the reduction of sulfate (Sahrani et al. 2008).

The process of conversion of biodegradable materials to gases like carbon dioxide, methane, and nitrogen compounds is called mineralization. Mineralization process is completed, when all the biodegradable biomass is consumed and all the carbon is converted into carbon dioxide (Kyrikou and Briassoulis 2007).

Rhodococcus RHA1 and *Arthrobacter keyseri* 12B bacteria play a major role in the degradation of 3,4-dihydroxybenzoate (Hara et al. 2007). For the degradation of chlorinated compounds, bacteria take several paths simultaneously for the removal of five chlorine atoms leading to the formation of phenol and finally mineralization to methane and carbon-di-oxide. Biogas usually methane is generated from anaerobic digestion (Holm-Nielsen et al. 2009).

6 Mechanisms of Bioremediation

There are various mechanisms of bioremediation like biosorption, metal–microbe interactions, bioaccumulation, bio-mineralization, biotransformation, and bioleaching. Microorganisms remove the heavy metals from soil by using chemicals for their growth and development. They are capable of dissolving metals and reducing or oxidizing transition metals. The different methods used by microbes to restore environment are oxidation, binding, immobilization, volatilization, and transformation of heavy metals. The microbes protect themselves from the toxic chemical pollutants through developing self-defense mechanisms including formation of outer cell-membrane protective material including hydrophobic or solvent efflux pumps. For instance, plasmid-encoded and energy-dependent metal efflux systems involving ATPases and chemiosmotic ion/proton pumps are reported for As, Cr, and Cd resistance in many bacteria (Roane and Pepper 2000).

6.1 Bioremediation Through Adsorption

Microorganisms can remove the heavy metals by the mechanism of bio-adsorption. The microbes have unique binding sites at their cellular structure without the use of energy. Amongst the various reactive compounds associated with bacterial cell walls, the extracellular polymeric substances have significant effects on acid-base properties and metal adsorption (Guiné et al. 2006). Studies on the metal-binding behavior of extracellular polymeric substances (EPS) revealed a great ability to complex heavy metals through various mechanisms, which include proton exchange and micro-precipitation of metals (Comte et al. 2008; Fang et al. 2010).

6.2 Bioremediation Through Physio-Bio-Chemical Mechanism

Biosorption is a process of involving higher affinity of a biosorbent towards any sorbate usually metal ions, and this process is continued till equilibrium is established between the two phases or components (Das et al. 2008). There are some microbes like *Saccharomyces cerevisiae* that acts as a biosorbent for the removal of Zn(II) and Cd(II) through the ion exchange mechanism (Talos et al. 2009). *Cunninghamella elegans* emerged as a promising sorbent against heavy metals released by textile wastewater (Tigini et al. 2010). Heavy metal degradation is an energy expenditure process.

Some fungi such as *Klebsiella oxytoca*, *Allescheriella* sp., *Stachybotrys* sp., *Phlebia* sp. *Pleurotus pulmonarius*, and *Botryosphaeria rhodina* have metal-binding potential (D'Annibale et al. 2007). Pb(II) contaminated soils can be biodegraded by fungal species like *Aspergillus parasitica* and *Cephalosporium aphidicola* with biosorption process (Akar et al. 2007). In a study, mercury-resistant fungi (*Hymenoscyphus ericae, Neocosmospora vasinfecta*, and *Verticillum terrestre*) were able to bio-transform a Hg(II) state to a nontoxic state (Kelly et al. 2006).

Many of the contaminants are hydrophobic and are absorbed by the microbes through the secretion of some biosurfactant and direct cell-contaminant association. Biosurfactants form stronger ionic bonds with metals and form complexes before being desorbed from soil matrix to water phase due to low interfacial tension (Thavasi 2011).

Microbes mobilize the heavy metals from the contaminated sites by leaching, chelation, methylation, and redox transformation of toxic metals. Heavy metals can never be destroyed completely, but the microbial process transforms their oxidation state or organic complex, so that they become water-soluble, less toxic, and precipitated (Garbisu and Alkorta 2001). Microorganisms use heavy metals and trace elements as terminal electron acceptors and reduce them through the detoxification mechanism. Microorganisms remove heavy metals through the mechanisms which they employ to derive energy from metals redox reactions to deal with toxic metal through enzymatic and non-enzymatic processes.

Microorganisms adopt different defense systems like exclusion, compartmentalization, complex formation, and synthesis of binding protein and peptides to reduce the stress developed by toxic metals (Gómez Jiménez-T et al. 2011). Heavy metal accumulation by microorganisms can be studied by the expression of metal-binding protein and peptides (phytochelatins and metallothionein) (Cobbett and Goldsbrough 2002).

Synechococcus sp. (cynobacterial strains) has been reported with the expression of the smtA gene and production of metal-binding protein. *Ralstonia eutropha* has been genetically modified to express mouse metallothionein on the cell surface and decrease the toxic effect of the Cd(II) in the contaminated sites. Expression of different proteins and peptides by the *Escherichia coli* regulates the range of accumulation of cadmium (Mejare and Bulow 2001).

6.3 Molecular Mechanisms in Bioremediation

There are various mechanisms involved in the removal of heavy metals by microorganisms. A genetically engineered bacterium *Deinococcus geothermalis* reduces mercury at high temperatures due to the expression of mer operon from *E. coli* coded for Hg^{2+} reduction (Brim et al. 2003). Another mercury-resistant bacteria *Cupriavidus metallidurans* strain MSR33 was genetically modified by introducing a pTP6 plasmid that provided genes (merB and merG) regulating mercury biodegradation along with the synthesis of organomercurial lyase protein (MerB) and mercuric reductase (MerA) (Rojas et al. 2011)). Modification of *Pseudomonas* strain with the pMR68 plasmid with novel genes (*mer*) made that strain resistant to mercury (Sone et al. 2013). Two different mechanisms for mercury degradation by bacteria (*Klebsiella pneumonia* M426) are mercury volatilization by reduction of Hg(II) to Hg(0) and mercury precipitation as insoluble Hg due to volatile thiol (H_2S) (Essa et al. 2002). Genetic engineering of *Deinococcus radiodurans* which naturally reduces Cr(IV) to Cr(III) has been done for complete toluene (fuel hydrocarbon) degradation by cloned genes of *tod* and *xyl* operons of *Pseudomonas putida* (Brim et al. 2006). Microbial metabolites like metal bound coenzymes and siderophores are mainly involved in the degradation pathway (Penny et al. 2010).

7 Designer Microbes: Biotechnological Intervention in Bioremediation

Genetic engineering offers an advantage of constructing microbial strains which can withstand adverse stressful situations and can be used as bioremediators under various complex environmental conditions. A recent development in this field is "microbial biosensors" that measures the degree of contamination in contaminated sites quickly and accurately.

A list of selected genetically engineered bacteria for removal of heavy metals is presented in Table 2.2.

Table 2.2 Selected genetically engineered bacteria for remediation of heavy metals (Divya and Kumar 2011)

GEB	Heavy metal	Removal efficiency (%)
E. coli strain	As	100
E. coli JM109	Hg	96
Methylococcus capsulatus	Cr^{6+}	100
P. fluorescens 4F39	Ni	80

GEB genetically engineered bacteria, *As* arsenic, *Hg* mercury, *Cr* chromium, *Ni* nickel

Till date various biosensors have been designed to evaluate heavy metal concentrations like mercury (Hg), cadmium (Cd), nickel (Ni), copper (Cu), and arsenic (As) (Verma and Singh 2005; Bruschi and Goulhen 2006). Besides, genetic engineering of endophytes and rhizospheric bacteria for plant-associated degradation of pollutants in soil is also considered to be one of the most promising new technologies for remediation of metal contaminated sites (Divya and Kumar 2011). Bacteria like *Escherichia coli* and *Moreaxella* sp. expressing phytochelatin 20 on the cell surface have been shown to accumulate 25 times more Cd or Hg than the wild-type strains (Bae et al. 2003). However, one major obstacle for utilizing these GEMs in hostile field conditions is sustaining the recombinant bacteria population in soil, with various environmental conditions and competition from native bacterial populations (Wu et al. 2006).

Further, the molecular approaches have been applied to only limited bacterial strains like *Escherichia coli*, *Pseudomonas putida*, *Bacillus subtilis*, etc. This means other microorganisms need to be explored for their application in heavy metal bioremediation through molecular intervention.

8 Nano-bioremediation: Recent Approach

The nanoparticles that enhance microbial activity to remove toxic pollutants are called "nano-bioremediation." Another concept of "bio-nanotechnology" is defined as the bio-fabrication of nano-objects or bifunctional macromolecules that are used as tools to construct or manipulate nano-objects.

The major advantage of using nano-based technologies is that they reduce both the costs of cleaning up contaminated sites at a large scale and the process time. Wide physiological diversity, small size, genetic manipulability, and controlled cultivability make microbial cells ideal producers of nanostructures. They may range from natural products, such as polymers and magnetosomes, to engineered proteins or protein constructs, such as virus-like proteins (VLP) and tailored metal particles (Sarikaya et al. 2003).

Deinococcus radiodurans, a radioactive-resistant organism, has the ability to withstand radiation well beyond the naturally occurring levels, thus it is used in radioactive waste cleanup initiatives in the USA (Brim et al. 2000).

Nanoscale modified biopolymers have now replaced the metal-chelating polymers that require toxic solvents for their synthesis and ultrafiltration for their separation.

Here, the polymers can be recovered by changing the environmental surrounding like pH, temperature, etc. These are manufactured by genetic and protein engineering of microorganisms, and their size can be controlled at the molecular level (Vishwanathan 2009). This innovative technique would be a promising tool to address the escalating problem of heavy metal as well as organic contaminants in the environment (Dixit et al. 2015).

9 Conclusions

There is a lot of research going on for combating the pollution throughout the globe. Microbes represent an effective tool for bioremediation and for clean-up environment. They can degrade almost all types of pollutants, heavy metals, industrial effluents, xenobiotics, and other recalcitrant molecules of complex nature. There are numerous biotechnological tools like genetic engineering, nano-bioremediation, bio-nanotechnology, and nanoscale modified biopolymers that can be used to further improve the efficacy of microbial cells in cleaning up the waste from the environment. Construction of strains with broad spectrum of catabolic potential with heavy metal-resistant traits makes them ideal for bioremediation of polluted environments for both aquatic and terrestrial ecosystems. The transfer of genetic traits from one organism to another paves way in creating Genetically Engineered Microorganisms (GEMs) for combating pollution in extreme environments making it a boon to mankind by cleaning up the mess that has created in nature.

Acknowledgements Authors are grateful to Dr. Ashok K. Chauhan, Founder President and Mr. Atul Chauhan, Chancellor, Amity University UP, Noida, India for the encouragement, research facilities, and financial support.

Conflict of interest: Authors hereby declare no conflict of interest.

References

Adisesh A, Murphy E, Barber CM et al (2011) Occupational asthma and rhinitis die to detergent enzymes in healthcare. Occup Med 61(5):364–369

Agrawal N, Shahi SK (2015) An environmental cleanup strategy-microbial transformation of xenobiotic compounds. Int J Curr Microbiol App Sci 4(4):429–461

Akar T, Tunali S, Cabuk A (2007) Study on the characterization of lead (II) biosorption by fungus *Aspergillus parasiticus*. Appl Biochem Biotechnol 136:389–406

Bae W, Wu CH, Kostal J et al (2003) Enhanced mercury biosorption by bacterial cells with surface-displayed MerR. Appl Environ Microbiol 69:3176–3180

Barton LL, Hamilton WA (2007) Sulphate reducing bacteria: environmental and engineered system. Cambridge University Press, Cambridge, p 558

Brim H, McFarlan SC, Fredrickson JK et al (2000) Engineering *Deinococcus radiodurans* for metal remediation in radioactive mixed waste environments. Nat Biotechnol 18:85–90
Brim H, Venkateshwaran A, Kostandarithes HM et al (2003) Engineering *Deinococcus geothermalis* for bioremediation of high temperature radioactive waste environments. Appl Environ Microbiol 69:4575–4582
Brim H, Osborne JP, Kostandarithes HM et al (2006) *Deinococcus radiodurans* engineered for complete toluene degradation facilities Cr(IV) reduction. Microbiology 152:2469–2477
Bruschi M, Goulhen F (2006) New bioremediation technologies to remove heavy metals and radionuclides using Fe(III)-sulfate- and sulfur reducing bacteria. In: Singh SN, Tripathi RD (eds) Environmental bioremediation technologies. Springer, New York, pp 35–55
Cai M, Yao J, Yang H et al (2013) Aerobic biodegradation process of petroleum and pathway of main compounds in water flooding well of Dagang oil field. Bioresour Technol 144:100–106
Cao B, Nagarajan K, Loh KC (2009) Biodegradation of aromatic compounds: current status and opportunities for biomolecular approaches. Appl Microbiol Biotechnol 85:207–228
Cobbett C, Goldsbrough P (2002) Phytochelatins and metallothioneins: role in heavy metals detoxification and homeostatis. Annu Rev Plant Biol 53:159–182
Comte S, Guibaud G, Baudu M (2008) Biosorption properties of extracellular polymeric substances (EPS) towards Cd, Cu and Pb for different pH values. J Hazard Mater 151:185–193
D'Annibale A, Leonardi V, Federici E et al (2007) Leaching and microbial treatment of a soil contaminated by sulphide ore ashes and aromatic hydrocarbons. Appl Microbiol Biotechnol 74:1135–1144
Das N, Vimala R, Karthika P (2008) Biosorption of heavy metals—an overview. Indian J Biotechnol 7:159–169
Directive 2000/54/EC of the European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work (seventh individual directive within the meaning of Article 16(1) of Directive 89/391/EEC). OJ L 262, 1710.2000, pp 21–45
Divya B, Kumar DM (2011) Plant-microbe interaction with enhanced bioremediation. Res J Biotechnol 6:72–79
Dixit R, Wasiullah, Malaviya D et al (2015) Bioremediation of heavy metals from soil and aquatic environment: an overview of principles and criteria of fundamental processes. Sustainability 7:2189–2212
Essa AMM, Macaskie LE, Brown NL (2002) Mechanisms of mercury bioremediation. Biochem Soc Trans 30:672–674
Fang LC, Huang QY, Wei X et al (2010) Microcalorimetric and potentiometric titration studies on the adsorption of copper by extracellular polymeric substances (EPS), minerals and their composites. Bioresour Technol 101:5774–5779
Fulekar MH (2009) Bioremediation of fenvalerate by *Pseudomonas aeruginosa* in a scale up bioreactor. Romanian Biotechnol Lett 14(6):4900–4905
Garbisu C, Alkorta I (2001) Phytoextraction: a cost-effective plant-based technology for the removal of metals from the environment. Bioresour Technol 77:229–236
Gelmetti C (2008) Local antibiotics in dermatology. Dermatol Ther 21:187–195
Gómez Jiménez-T R, Moliternib E, Rodríguezb L et al (2011) Feasibility of mixed enzymatic complexes to enhanced soil bioremediation processes. Procedia Environ Sci 9:54–59
Guiné V, Spadini L, Sarret G et al (2006) Zinc sorption to three Gram-negative bacteria: combined titration, modeling and EXAFS study. Environ Sci Technol 40:1806–1813
Hara H, Eltis LD, Davies JE et al (2007) Transcriptomic analysis reveals a bifurcated terepthalate degradation pathway in *Rhodococcus* sp. strain RHA1. J Bacteriol 189:1641–1647
Harms H, Schlosser D, Wick LY (2011) Untapped potential: exploiting fungi in bioremediation of hazardous chemicals. Nat Rev Microbiol 9:177–192
Hasan F, Shah AA, Javed S et al (2010) Enzymes used in detergents: lipases. Afr J Biotechnol 9(31):4836–4844
Holm-Nielsen JB, Al Seadi T, Oleskowicz-Popiel P (2009) The future of anaerobic digestion and biogas utilization. Bioresour Technol 100:5478–5484

Jayasekara R, Harding I, Bowater I et al (2005) Biodegradability of selected range of polymers and polymer blends and standard methods for assessment of biodegradation. J Polym Environ 13(3):231–250

Kelly DJA, Budd K, Lefebvre DD (2006) The biotransformation of mercury in pH-stat cultures of micro-fungi. Can J Bot 84:254–260

Kirk O, Borchert TV, Fuglsang CC (2002) Industrial enzyme applications. Curr Opin Biotechnol 13:345–351

Kumar BL, Gopal DVR (2015) Effective role of indigenous microorganisms for sustainable environment. Biotech 5:867–876

Kyrikou J, Briassoulis D (2007) Biodegradation of agricultural plastic films: a critical review. J Polym Environ 15:125–150

Mejare M, Bulow L (2001) Metal binding proteins and peptides in bioremediation and phytoremediation of heavy metals. Trends Biotechnol 19:67–73

Nazaroff WW, Weschler CJ (2004) Cleaning products and air fresheners: exposure to primary and secondary air pollutants. Atmos Environ 38:2841–2865

OECD (2015) Biosafety and the environmental uses of micro-organisms: conference proceedings. OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264213562-en

Penny C, Vuilleumier S, Bringel F (2010) Microbial degradation of tetrachloromethane: mechanisms and perspectives for bioremediation. FEMS Microbiol Ecol 74:257–275

Richardson SD, Ternes TA (2011) Water analysis: emerging contaminants and current issues. Anal Chem 83:4614–4648

Roane TM, Pepper IL (2000) Microorganisms and metal pollution. In: Maier RM, Pepper IL, Gerba CP (eds) Environmental microbiology. Academic, London, p 55

Rojas LA, Yanez C, Gonzalez M et al (2011) Characterization of the metabolically modified heavy metal-resistant *Cupriavidus metallidurans* strain MSR33 generated for mercury bioremediation. PLoS One 6:e17555

Sahrani FK, Ibrahim Z, Yahya A et al (2008) Isolation and identification of marine sulphate reducing bacteria, *Desulfovibrio* sp. and *Citrobacter freundii* from Pasir Gudang, Malaysia. Science 47:365–371

Sarikaya M, Tamerler C, Jen AK et al (2003) Molecular biomimetics: nanotechnology through biology. Nat Mater 2:577–585

Schwarzenbach R, Egli T, Hofstetter TB et al (2010) Global water pollution and human health. Annu Rev Environ Res 35:109–136

Shimao M (2001) Biodegradation of plastics. Curr Opin Biotechnol 12:242–247

Singh R, Singh P, Sharma R (2014) Microorganism as a tool of bioremediation technology for cleaning environment: a review. Proc Int Acad Ecol Environ Sci 4(1):1–6

Sone Y, Mochizuki Y, Koizawa K et al (2013) Mercurial resistance determinants in *Pseudomonas* strain K-62 plasmid pMR68. AMB Express 3:Article 41

Spök A (2009) Environmental, health and legal aspects of cleaners containing living microbes as active ingredients. IFZ–Inter-University Research Centre for Technology, Work and Culture Schlögelgasse 28010 Graz, Austria

Talos K, Pager C, Tonk S et al (2009) Cadmium biosorption on native *Saccharomyces cerevisiae* cells in aqueous suspension. Acta Univ Sapientiae Agric Environ 1:20–30

Tang CY, Criddle QS, Fu CS et al (2007) Effect of flux and technique. Biol Med 1(3):1–6

Thavasi R (2011) Microbial biosurfactants: from an environment application point of view. J Bioremed Biodegr 2:Article 104e

Tigini V, Prigione V, Giansanti P et al (2010) Fungal biosorption, an innovative treatment for the decolourization and detoxification of textile effluents. Water 2:550–565

Van Agteren MH, Keuning S et al (1998) Handbook on biodegradation and biological treatment of hazardous organic compounds. Kluwer, Dordrecht

Verma N, Singh M (2005) Biosensors for heavy metals. J Biometals 18:121–129

Vishwanathan B (2009) Nanomaterials. Narosa Publishing House Pvt Ltd., New Delhi

Wassenaar TM, Klein G (2008) Safety aspects and implications of regulation of probiotic bacteria in food and food supplements. J Food Prot 71:1734–1741

Wilson L, Bouwer E (1997) Biodegradation of aromatic compounds under mixed oxygen/denitrifying conditions: a review. J Ind Microbiol Biotechnol 18:116–130
Wu CH, Wood TK, Mulchandani A et al (2006) Engineering plant-microbe symbiosis for rhizoremediation of heavy metals. Appl Environ Microbiol 72:1129–1134
Xingzu W, Xiang C, Dezhi S et al (2008) Biodecolorization and partial mineralization of reactive black 5 by a strain of *Rhodopseudomonas palustris*. J Environ Sc 20:1218–1225
Xiuyan L, Ji Z, Jiandong J et al (2011) Biochemical degradation pathway of reactive blue 13 by *Candida rugopelliculosa* HXL-2. Int Biodeter Biodegr 65:135–141
Zhang C, Bennett GN (2005) Biodegradation of xenobiotics by anaerobic bacteria. Appl Microbiol Biotechnol 67:600–618

Chapter 3
Food Industry Waste: A Panacea or Pollution Hazard?

Renu Khedkar and Karuna Singh

Abstract The food-processing industry produces large volumes of wastes, both solids and liquids, generated from the production, preparation, and consumption of food. These wastes pose increasing disposal and potentially severe pollution problems and represent a loss of valuable biomass and nutrients. Due consideration to proper utilization and disposal of solid waste is the need of the hour for sustainable industrial development. Industrial waste management techniques can be classified into three options: source reduction by processing plant modification, waste recovery, recycle or waste treatment for value-added products and eco-friendly detoxification or neutralization of the undesirable components. Efficient management of waste can bring down the cost of production of processed foods and minimize the pollution hazard.

Concept of 4-R, comprising Reduce, Reuse, Recycle, and Recover, is the ultimate goal to optimize utilization of solid waste while minimizing environmental problems. Extraction of pectin, essential oils from the citrus peels, and whey protein concentrate from whey are some of the examples of by-product utilization from food-processing industry. The by-products of fruits and vegetables are also found to be good sources of antioxidants and antimicrobial compounds. Microbial synthesis of single cell protein, amino acids, and vitamins is also possible by the use of whey, molasses, etc. The ultimate goal of green productivity could be achieved through zero discharge, zero emission, zero pollution, cost-effective processing, and application of clean production technology.

The waste from food-processing industry is not a waste in a real sense but can be converted and utilized as food, feed, and fodder. The regulatory agencies and the food-processing industries can work hand in hand to develop new processes for waste management and utilization which are commercially viable.

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7_3

Keywords Waste management • Reduce • Reuse • Recycle • By-product • Nutrient

1 Introduction

India's food-processing sector covers fruits and vegetables; meat and poultry; milk and milk products, alcoholic beverages, fisheries, plantation, grain processing, and other consumer product groups like confectionery, chocolates and cocoa products, soya-based products, mineral water, high protein foods, etc. The most promising sub-sectors include soft-drink bottling, confectionery manufacture, fishing, aquaculture, grain-milling and grain-based products, meat and poultry processing, alcoholic beverages, milk processing, tomato paste, fast food, ready-to-eat breakfast cereals, food additives, flavors, etc. Health food and health food supplement is another rapidly rising segment of this industry, which is gaining vast popularity amongst the health conscious.

India is ranked fifth in the world in terms of production, consumption, and export of processed food. It is a leading producer of quite a few agriculture-based and dairy-based items. It is ranked first in the world in production of rice, milk (fresh, whole, buffalo milk), pulses, ginger, chick pea, and fruits such as banana, guava, papaya, and mango. India also holds second position in the world in production of wheat, potato, garlic, cashew nut, ground nut, dry onion, green pea, pumpkin, guard, and cauliflower. A good agricultural and dairy produce enables India to expand its food-processing industry and meet the global demand easily after satisfying the domestic needs.

The food industry is now facing increasing pressure to ensure that their company's activities are environmentally sensitive, but there is also increased internal pressure to maintain or increase profitability in the face of fierce competition.

"Food waste" refers to food that is of good quality and fit for human consumption but that does not get consumed because it is discarded—either before or after it spoils. Food waste typically, but not exclusively, occurs at the retail and consumption stages in the food value chain and is the result of negligence or a conscious decision to throw food away (FAO 2013). Food loss and waste have many negative economic and environmental impacts. Economically, they represent a wasted investment that can reduce farmers' incomes and increase consumers' expenses. Environmentally, food loss and waste inflict a host of impacts, including unnecessary greenhouse gas emissions and inefficiently used water and land, which in turn can lead to diminished natural ecosystems and the services they provide.

Food loss and waste can occur at each stage of the food value chain. Some examples of how they can occur at each stage are:

- During production or harvest in the form of grain left behind by poor harvesting equipment, discarded fish, and fruit not harvested or discarded because they fail to meet quality standards or are uneconomical to harvest
- During handling and storage in the form of food degraded by pests, fungus, and disease

- During processing and packaging in the form of spilled milk, damaged fish, and fruit unsuitable for processing
- Processed foods may be lost or wasted because of poor order forecasting and inefficient factory processes
- During distribution and marketing in the form of edible food discarded because it is noncompliant with esthetic quality standards or is not sold before “best before” and “use-by” dates
- During consumption in the form of food purchased by consumers, restaurants, and caterers but not eaten

The food-processing industry has special concerns about the health and safety of the consumer. Key resources used by the food-processing industry include the water, raw materials, and energy. The key environmental issues for the food industry include the following:

Wastewater: Primary issues of concern are biochemical oxygen demand (BOD); total suspended solids (TSS); excessive nutrient loading, namely nitrogen and phosphorus compounds; pathogenic organisms, which are a result of animal processing; and residual chlorine and pesticide levels.

Solid Waste: Primary issues of concern include both organic and packaging waste. Organic waste, that is, the rinds, seeds, skin, and bones from raw materials, results from processing operations. Inorganic wastes typically include excessive packaging items that are plastic, glass, and metal. Organic wastes are finding ever-increasing markets for resale, and companies are slowly switching to more biodegradable and recyclable products for packaging. Excessive packaging has been reduced and recyclable products such as aluminum, glass, and high-density polyethylene (HDPE) are being used where applicable.

Some Glaring Facts

- India, the world’s second largest fruit and vegetable producer, encounters a waste of close to 18% worth INR 44,000 crore ($7 billion) of produce (Anonymous 2012).
- The latest DIPP paper on Foreign Direct Investment (FDI) in retail estimated that against a production of 180 million metric tons a year of fruits, vegetables, and perishables. India has a capacity of storing only 23.6 million metric tons in 5386 cold storages across the country (Anonymous 2013).
- The Saumitra Chaudhuri Committee in 2012 indicated 61.3 million tonnes of cold storage requirement in the country against the present capacity of around 29 million tonnes.
- The country lost INR 45 crore ($7.2 million) worth of food grain in the past 5 years (Baweja 2013).
- A report by the Institution of Mechanical Engineers reveals that each year 21 million tonnes of wheat which is equivalent to Australia’s annual grain production is wasted in India.
- Food Corporation of India (FCI) reports show that food grain worth Rs. 120.29 crore ($19.2 million) was lost in storage, while Rs. 106.18 crore ($17 million)

Table 3.1 Percentage of losses estimated for major produces

Crop	Cumulative wastage (per cent)
Cereals	4.65–5.99
Pulses	6.36–8.41
Oil seeds	3.08–9.96
Fruits and vegetables	4.58–15.88
Milk	0.92
Fisheries (Inland)	5.23
Fisheries (Marine)	10.52
Meat	2.71
Poultry	6.74

Source: CIPHET Study on post-harvest losses, 2016

worth of grain was lost in transit. The remaining Rs. 9.85 crore ($1.5 million) worth of food grains were not fit for human consumption (Thomas 2013).

As per a study conducted by the Central Institute of Post-Harvest Engineering & Technology (CIPHET), Ludhiana (published in 2016). Post-harvest losses of major agricultural commodities including fruits and vegetables at national level was estimated to the tune of about Rs. 92,651 crore per annum at 2014 wholesale prices. The cumulative wastage in fruits and vegetables is estimated in the range of 4.58–15.88% (Wastage of Agricultural Produce 2016) (Table 3.1).

2 Pollution from Food Processing

2.1 Fruit and Vegetable Food-Processing Sector

The primary steps in processing fruits and vegetables include:

1. General cleaning and dirt removal
2. Removal of leaves, skin, and seeds
3. Blanching
4. Washing and cooling
5. Packaging
6. Clean-up

Wastewater and solid wastes are the primary area of pollution control within the fruit and vegetable food-processing industry.

Wastewater is high in suspended solids, organic sugars, starches, and may contain residual pesticides.

Solid wastes include organic materials from mechanical preparation processes, i.e., rinds, seeds, and skins from raw materials.

2.2 Meat, Poultry, and Seafood Sector

The primary steps in processing livestock include:

1. Rendering and bleeding
2. Scalding and/or skin removal
3. Internal organ evisceration
4. Washing, chilling, and cooling
5. Packaging
6. Clean-up

Meat, poultry, and seafood facilities offer a more difficult waste stream to treat. The killing and rendering processes create blood by-products and waste streams, which are extremely high in BOD. These facilities are very prone to disease spread by pathogenic organisms carried and transmitted by livestock, poultry, and seafood.

Waste streams generalized into the following: process wastewaters; carcasses and skeleton waste; rejected or unsatisfactory animals; fats, oils, and greases (FOG); animal faeces; blood; and eviscerated organs.

2.3 Beverage and Fermentation Sector

The primary steps in processing beverages are

1. Raw material handling and processing
2. Mixing, fermentation, and/or cooking
3. Cooling
4. Bottling and packaging
5. Clean-up

Wastewater and solid waste are the primary waste streams for the beverage and fermentation sector. Solid wastes result from spent grains and materials used in the fermentation process. Wastewater volume of "soft-drink processes" is lower than in other food-processing sectors, but fermentation processes are higher in BOD and overall wastewater volume compared to other food-processing sectors.

2.4 Dairy Sector

A majority of the waste milk in dairy wastewaters comes from start-up and shutdown operations performed in the high-temperature, short time (HTST) pasteurization process. This waste is pure milk raw material mixed with water.

Another waste stream of the dairy sector is from equipment and tank-cleaning wastewaters. These waste streams contain waste milk and sanitary cleaners and are one of the principal waste constituents of dairy wastewater.

Over time, milk waste degrades to form corrosive lactic and formic acids. Approximately 90% of a dairy's wastewater load is milk.

2.5 Can Cooker Products

Water plays a role in most of the problems associated with metal food containers after processing. Whether steam, hot water or cold water, each can serve as the vehicle to transport undesirable substances.

2.6 Food Packaging Waste

The role of packaging is to protect the food between processing and usage by the consumer. After the usage, packaging needs to be dealt with in an environmentally responsible manner (Marsh and Bugusu 2007). Packaging contributes significantly to the waste. Food packaging accounts for two-thirds of total packaging waste by volume (Hunt et al. 1990).

3 Techniques to Protect Environment

Concept of 4-R, comprising Reduce, Reuse, Recycle, and Recover, is the ultimate goal to optimize utilization of solid and liquid waste while minimizing environmental problems.

- Since food is such an incredibly valuable resource that can be used to protect our soil and water or grow our next generation of crops, there are so many better uses for it to consider before putting in a landfill or incinerator.
- If food is anaerobically digested for renewable energy production, then the residuals (digestate) can, and should, be put to beneficial use to then feed the soilnot landfills.

Various methods to protect environment from food industry waste can be:

3.1 Source Reduction

Source reduction is the most effective method of environmental protection to decrease the volume of waste material and by-products generated in the production process. Source reduction should be the most logical starting point for reducing disposal. Examples of source reduction include:

(a) Use brooms and scrapers to clean floors and equipment while they are dry before washing them down with water.
(b) Use high-pressure spray washes during clean-up to conserve water.
(c) Dedicate mixing lines to certain products to reduce changeover clean-ups.
(d) Minimize spills and leaks on the production line to prevent raw materials from becoming wastes.

3.2 *Food Waste Management Alternatives*

Many alternatives exist for managing the food waste. They include:

3.2.1 Using the Food By-Product as an Animal Feed

Feeding food by-products directly to livestock allows for former wastes to be useful again. In addition, the quantity of liquid and solid waste is reduced when by-products are fed to livestock rather than being disposed of in landfills or wastewater treatment plants.

3.2.2 Composting or Land Spreading the Food By-Product

With proper management, food by-products can be kept out of the landfill and instead be composted and added to the soil at appropriate rates.

Benefits of compost to the food industry are:

(a) Reduces solid waste disposal fees
(b) Ends wasting large quantities of recyclable raw ingredients
(c) Educates consumers on the benefits of food waste composting
(d) Markets your establishment as environmentally conscious
(e) Markets your establishment as one that assists local farmers and the community
(f) Helps close the food waste loop by returning it back to agriculture
(g) Reduces the need for more landfill space

3.2.3 Food Packaging Waste Management

The integrated waste management approach involves source reduction, recycling, composting, combustion, and landfilling. By altering the design, manufacture, purchase, or use of the packaging materials, the reduction of impact of solid waste on environment can be achieved. It involves less packaging, designing long lasting products, and reusing the packaging materials. Recycling involves reprocessing the materials to new product. Plastic waste is used for plastic foot ware, box strapping.

PET is used in rugs, carpets, blankets, luggage, pillows, etc. Composting is a valuable alternative to organic waste disposal. Where the waste cannot be recycled or composted, combustion is an alternative.

3.2.4 Clean Technology Developments

Clean technologies are defined as "manufacturing processes or product technologies that reduce pollution or waste, energy use, or material use in comparison to the technologies that they replace."

Common source reduction methods employed at most plants include improving good housekeeping practices, making process modifications, substituting more environmentally friendly raw materials, and segregating waste streams. Some simple cost-effective means of achieving source reduction include installing automatic shut-off valves, using low-flow or air-injected faucets/spray cleaners, switching from chemical caustic peeling processes to mechanical peeling, and converting from water to mechanical conveyance of raw materials through a production line.

Advanced Wastewater Treatment Practices: The following is a listing of some technologies being used in advanced wastewater treatment:

(a) Membrane applications
(b) Disinfection
(c) Charge separation, e.g., electro-coagulation
(d) Other separation practices, e.g., air flotation system

4 Utilization of Waste Produced by Food Industry

4.1 Fruit and Vegetable Processing Waste

Waste generated from the organized sector of fruit and vegetable processing, packaging, distribution, and consumption in India, Philippines, China, and the United States is about 55 million tonnes. Most of the waste is dumped in landfills or in rivers, creating environmental hazards. Alternative to these methods could be to use the waste as manure, as livestock feed, as an alternative energy source, or for development of value-added products.

4.1.1 Utilization as Livestock Feed

Dried ripe banana peels and citrus peels can be incorporated along with wheat straw or broiler litter in the feed of lactating animals. Dried pineapple juice waste and pomace of bottle gourd juice can replace the roughage portion in the diets of ruminants. Fresh cauliflower and cabbage leaves with stems, empty pea pods being a rich source of proteins, sugars, and micronutrients can be used as such or after drying or ensiling with cereal straws in the diets of livestock. Cull carrots fed to dairy cows improves their reproductive system. Carrot flakes or dehydrated carrots are given to horses. Cull potatoes are used for lactating cows whereas dried tomato pomace can be fed to adult buffaloes (Wadhwa and Bakshi 2013).

4.1.2 Utilization for Extraction of Value-Added Products

Peels, pomace, and seeds are rich sources of sugars, minerals, organic acids, dietary fiber, and bioactive compounds. Pectin, a soluble dietary fiber, is extracted from citrus peels, apple pomace, and guava. It is used in processed foods and beverages. Essential oil extracted from citrus peels finds wide use in beverages, cosmetics, and pharmaceutical industry. The bioactive compounds from fruits and vegetables include phenolic compounds such as simple phenolics, phenolic acids, flavonoids, lignans, lignins, and tannins. Many of these compounds show antioxidant, antibacterial, anticancer, and antimutagenic activities. Apple pomace is a rich source of dietary fiber, polyphenols, and minerals. Major compounds isolated are catechins, hydroxycinnamates, phloretin glycosides, and quercetin glycosides. Wine making from grapes generate huge amount of waste. This waste can be used for production of grape seed oil, ethanol, citric acid, tartrates, hydrocolloids and dietary fiber, anthocyanins, etc. Anthocyanins, catechins, flavonol glycosides, phenolic acids, alcohols, and stilbenes are the principal phenolic constituents of grape pomace (Djilas et al. 2009).

4.2 Utilization of Cereal Processing Waste

The cereals like wheat, rice, barley, oat, and maize are milled in order to meet sensory expectations of consumers. The by-products of cereal processing pose a threat to the environment since the BOD and COD levels can reach 3.5×10^4–5×10^4 and 10^5–1.5×10^5 mg/L, respectively (ElMekawy et al. 2013). The processing of cereals generates by-products such as bran, germ, endosperm, husk, and broken kernels. The bran is a source of vitamins and minerals and is also used as dietary fiber in many refined foods. Oil extracted from rice bran is cardio protective. Starch is extracted from endosperm and is used as thickener in sauces and desserts. The husk has many uses from fuel and abrasive to packaging material (The Rice Association 2015). Corn undergoes either wet or dry milling. After removing germ and starch, the main by-product remaining is protein used as corn gluten.

The cereal by-products have been used in microbial fermentation to produce organic acids such as lactic and citric acid. Brewer's spent grain (BSG) was used in *Aspergillus niger* fermentation to produce citric acid. Corn steep liquor (CSL) and BSG have been tried in production of lactic acid.

Biopolymers are gaining attraction as petroleum-based polymers affect the environment negatively. Biopolymers like polyhydroxyalkonates (PHA), polyalcohols (e.g., xylitol), and polysaccharides (e.g., pullulan) are produced using biotechnological methods. BSG, CSL, and rice bran have been used in the production of xylitol, pullulan, and PHA, respectively.

Hydrogen gas is an eco-friendly fuel having high energy content. Biomass containing starch and cellulose are raw materials for bio-hydrogen production. Wheat starch and barley malt by-product have been used in the bio-hydrogen refinery.

Bioethanol is a substitute for fossil fuels. The main biomass for bioethanol production is starch-rich agro-industrial by-products such as wheat bran, rice hull, CSL, and other corn milling by-products.

Bioelectricity is produced by transformation of lignocellulosic biomass residues to electricity in a microbial fuel cell (MFC) (ElMekawy et al. 2013).

4.3 Utilization of Dairy Waste

Dairy industry is one of the major industries generating large volumes of wastewater. Wastewater is generated in milk-processing unit and in the production of butter, cheese, skim milk powder, ghee, etc. The major by-products of these processes are skim milk, butter milk, and whey. Edible casein is manufactured from skim milk. It has wide applications in dairy and food products. Casein is also used in glue textile fibers, rubber, paints, sizing, and in the production of caseinates and casein hydrolysates. Whey is the largest by-product of dairy industry. It is produced during the manufacture of cheese, chhana, paneer, and casein (Gupta 2008). Discharging of whey as waste creates severe pollution problems due to its high BOD (35–40 g/L). This high BOD is due mainly to the lactose, which is present at concentrations between 4.5 and 5%.

Whey proteins and lactose have gained a lot of importance. Whey is used in different ways and can be classified in three categories:

- Fermentation: production of ethyl alcohol, lactic acids, vitamins, SCP, Baker's yeast, xanthan gum
- Concentration: whey protein, dried whey, production of lactose
- Pasteurization: whey cream and pasteurized sweet whey

Whey derivatives with different functional and nutritional properties are produced using modern industrial membrane processing techniques such as ultrafiltration, reverse osmosis, electrodialysis. Ultra-filtration (UF) is generally used for whey utilization to separate the proteins from the permeate containing mostly lactose. Applications of UF and RO for concentrating the whey solids have gained an importance. Whey protein concentrate is an item of worldwide commerce due to its nutritious composition.

Whey has also been widely used for the production of single cell protein (SCP). It has advantages since the process is simple, the BOD is considerably reduced and lactose is converted into yeast biomass.

Recovery of sugars, proteins, and minerals in the waste effluents by crystallization, evaporation, and spray drying are practiced in many dairy plants (Gupta 2008).

4.4 Utilization of Meat, Fish, and Poultry Waste

India ranks first in the livestock wealth. The contribution of livestock industry is >12% GDP. Efficient utilization of by-products can have direct impact on economy and environmental pollution. Non-utilization of animal by-products can create major health problems.

In the meat industry, most of the waste comes from slaughter houses. Hides and skin are the valuable by-products of animals. It finds use in leather industry, athletic equipment, cosmetics, edible gelatin, and glue. Animal organs and glands are used either as food or has medicinal applications. Organs and bones are also used in the production of meat meal and bone meal. Bones are also used in the manufacture of gelatin. Brain, nervous system, and spinal cord are source of cholesterol which is a raw material for vitamin D3. Liver extract from pigs and cattle is a source of vitamin B12 and is used in nutritional supplements. Insulin is extracted from pancreas and is used in the treatment of diabetes.

Fish waste is a source of proteins, minerals, and fats. Fish protein hydrolysate and fish oil apart from the chemicals like chitosan are valuable products obtained from fish waste.

Feathers are produced in large quantities as the by-products of poultry industry. If not treated, they become a source of pollution hazard. They find multiple uses in animal feed, erosion control, thermal insulation, filtration units, biodegradable composites, and fabrics. Hydrolyzed poultry feathers also find use in the production of biofuel (Jayathilakan et al. 2012).

5 Future Trends

The exploitation of by-products of fruit and vegetable processing as a source of functional compounds and their application in food is a promising field, which requires interdisciplinary research of food technologists, food chemists, nutritionists, and toxicologists. In the near future, we are challenged to respond to the following research needs:

- Food-processing technology should be optimized in order to minimize the amounts of waste arising.

- Methods for complete utilization of by-products resulting from food processing on a large scale and at affordable levels should be developed. Active participation of the food and allied industries with respect to sustainable production and waste management is required.
- Natural and anthropogenic toxins such as solanin, patulin, ochratoxin, dioxins, and polycyclic aromatic hydrocarbons need to be excluded by efficient quality control systems. Minimization of potentially hazardous constituents, e.g., solanin, amygdalin, and optimization of valuable compounds such as carotenoids and betalains may also be achieved by plant breeding.
- There is a need for specific analytical methods for the characterization and quantification of organic micronutrients and other functional compounds.
- The bioactivity, bioavailability, and toxicology of photochemical need to be carefully assessed by in vitro and in vivo studies.

References

Anonymous (2012) 18% of fruit & veggies production goes waste in India. http://archive.indianexpress.com/news/18--of-fruit---veggies-production-goes-waste-in-india/945453/. Accessed 10 Sept 2014

Anonymous (2013) Reducing agri food waste—opportunity for startups. http://usf.vc/entrepreneur-info/reducing-agri-food-waste-opportunity-for-startups/. Accessed 6 Sept 2014

Baweja H (2013) India lost foodgrain worth Rs. 45 crore in 5 years. http://www.hindustantimes.com/delhi/india-lost-foodgrain-worth-rs-45-cr-in-5-years/story-Sk7MtpEu3wEXNu99j1gV9I.html. Accessed 5 Nov 2014

Chaudhuri S (2012) The committee on encouraging investments in supply chains including provision for cold storages for more efficient distribution of farm produce. Report by Development Policy Division, Planning Commission, Govt. of India, New Delhi, India. http://www.efresh-global.com/efresh/headers/pdfs/coldAccri/15%29%20Report%20from%20Planning%20commission.pdf. Accessed 23 Oct 2014

Djilas S, Čanadanović-Brunet J, Cetkovit G (2009) By-products of fruits processing as a source of phytochemicals. Chem Ind Chem Eng Q 15(4):191–202

ElMekawy A, Diels L, Wever HD, Pant D (2013) Valorization of cereal based biorefinery byproducts: reality & expectations. Environ Sci Tech 47(16):9014–9027

FAO, Food and Agriculture Organization of the United Nations (2013) Food wastage footprint. Impacts on natural resources. Summary Report. Rome

Gupta VK (2008) Overview of production, processing and utilization of dairy by-products in course compendium on short course on “Technological advances in the utilization of dairy by-products”. NDRI, Karnal, India.

Hunt RG, Sellers VR, Franklin WE, Nelson JM, Rathje WL, Hughes WW, Wilson DC (1990) Estimates of the volume of MSW and selected components in trash cans and land fills. Report prepared by the Garbage Project and Franklins Associates Ltd. for the Council for Solid Waste Solutions, Tucson, AZ

Jayathilakan K, Sultana K, Radhakrishna K, Bawa AS (2012) Utilization of by products and waste materials from meat, poultry and fish processing industries: a review. J Food Sci Technol 49(3):278–293

Marsh K, Bugusu B (2007) Food packaging and its environmental impact. http://www.ift.org/~/media/Knowledge%20Center/Science%20Reports/Scientific%20Status%20Summaries/Editorial/editorial_0407_foodpackaging.pdf. Accessed 16 Aug 2015

The Rice Association (2015) By products. www.riceassociation.org.uk/content/1/16/by-products.html. Accessed 10 Oct 2015

Thomas KV (2013) http://www.thehindubusinessline.com/economy/agri-business/foodgrains-worth-rs-23632-crore-lost-in-aprjune-kv-thomas/article4996074.ece

Wadhwa M, Bakshi MPS (2013). Utilization of fruit & vegetable waste as livestock feed and as substrates for generation of other value-added products. In: Makkar (ed) FAO document. www.fao.org/3/a-i3273e.pdf. Accessed 25 Sept 2015

Wastage of Agricultural Produce (2016) Ministry of food processing industries, GoI. http://pib.nic.in/newsite/PrintRelease.aspx?relid=148566. Accessed 24 Nov 2016

Chapter 4
Ranking of BTEX with Respect to Ozone Formation by Development of Ozone Reactivity Scale

Pallavi Saxena and Chirashree Ghosh

Abstract The high concentration of ground-level ozone is a serious problem in many areas. Ozone formation is non-linear process and is produced from the photochemical interactions of volatile organic compounds (VOCs) and oxides of nitrogen (NOx) in the troposphere. Generally, MIR (Maximum Incremental Reactivity) scale is one of the popular ones in the assessment of ozone formation potential of various VOC compounds. In this study, we have taken this scale into consideration for analysing the ranking of benzene, toluene, ethylbenzene and xylene (BTEX) at selected sites which are divided on the basis of near to traffic intersection and less vegetation (Site I) and away from traffic intersection with dense vegetation (Site II) during winter season (Nov'10–Feb'11). The results showed that the average concentration of ozone was found to be higher at Site I than Site II. As per MIR scale, irrespective of site and month, xylenes (*m*-/*p*-xylene plus *o*-xylene) are the most dominant contributor to ozone formation amongst BTEX. Toluene is the second largest contributor to ozone formation. Amongst all, ozone formation potential of benzene is least but it is the most hazardous and carcinogenic species amongst BTEX. Thus, this scale is very useful for examining the relative importance of VOC compounds for their role in photochemical smog formation including production of ozone.

Keywords Ozone • MIR • BTEX • Traffic intersection • Vegetation • VOC

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7_4

1 Introduction

With the increase in the rate of urbanization and industrialization all over the world, large amounts of volatile organic compounds (VOCs) are released into the air annually (Gee and Sollars 1998; Tonooka et al. 2001; Khoder 2007). The concentration of VOCs in the air is depicted by such processes as emissions, evaporation, deposition, and photochemical reactions under the sunlight. Benzene, toluene, ethylbenzene, and isomers of xylene (Meta, Ortho, and Para—Xylene) (BTEX) are public health concern; they are major components of automobile exhaust. VOCs are majorly responsible in the processes of smog formation and also act as precursor of ozone. Currently, traffic is a chief anthropogenic source of VOCs along with some indoor sources like tobacco smoke, household cleaning or degreasing, air freshening, domestic heating and cooking, painting, disinfecting, varnishing, etc. Amongst the BTEX compounds, benzene has been generally recognized as a human carcinogen and the others also possess high toxicity, especially to central nervous system in humans (Xianglu and Naeher 2006). Therefore, this group of VOCs has received much attention in exposure assessment studies. Control plans have been established to lower their levels in ambient air. Just like particulate matter, personal exposure of VOCs cannot be accurately estimated (Gonzalez-Flesca et al. 2000). Exposure data from stationary monitoring sites cannot give the real exposure profile in urban areas, since the level of traffic VOCs decreases drastically as the distance from the main traffic roads increases, causing high spatial variations in the distribution of VOCs. Indeed, the influence of industrial sources on VOC levels along traffic road seemed negligible (Batterman et al. 2002), indicating that air VOCs were so much limited to the small area around the source that even curb side levels were frequently found to have lower concentration of VOCs than the middle lanes of the main roads. In several studies comparing VOC exposures in various commuting modes, roughly the same conclusion was reached: private cars or taxis were exposed to higher levels of VOCs than buses or trains (Chan et al. 2003; Lau and Chan 2003). Such factors as traffic density, wind, temperature, and city buildings make the spatial variation even greater (Upmanis et al. 2001). Due to the difficulties in directly measuring these small-scale spatial variations, it is a promising job to investigate whether it is feasible to find some traffic indicators as surrogates for traffic-related VOCs and NO_2 exposures. Some good results have been produced but their potential for generalization needs to be validated in further studies (Carr et al. 2002). In one study, traffic volume and the percentage of traffic jam were able to account for 0.76–0.80 of the variability in concentration changes of benzene, toluene, and ethylbenzene. In addition, ambient VOC levels have clear seasonal variation and are higher in the winter season, as was observed in an exposure study in Greece (Kourtidis et al. 2002; Pankow et al. 2003). Traffic-related VOC pollution has frequently been demonstrated to be a more serious problem in the developing countries than in the United States and Europe, as indicated by the VOC data obtained in Karachi, Pakistan

(Barletta et al. 2002), a VOC exposure study in India which gave very high levels of VOCs (Mukherjee et al. 2003), and data on BTEX ambient air levels in three cities in Southern China (Wang et al. 2002). A study in Mexico City gave different levels of benzene at different monitoring sites, some of which were rather high (Bravo et al. 1991). Ten year fixed-site monitoring data of VOCs in Mexico City (Arriaga-Colina et al. 2004) showed that total VOC levels in the city may have a decreasing trend due to the effective emission control measures though it was still higher than in many other cities in the world. A personal exposure measurement campaign carried out amongst service station attendants, street vendors, and office workers discovered that BTEX exposures amongst service station attendants were the highest (310/680/110/490 μg/m^3, respectively) (Romieu et al. 1999). Study in Australia also reported very high in-vehicle benzene exposures (Duffy and Nelson 1997). A study conducted in the United States on traffic-related exposures amongst highway patrol troopers found low levels of VOC exposures (Riediker et al. 2003). It has to be pointed out that most of these monitoring data are from fixed-site monitoring, while traffic-related exposure in traffic environment may be higher and pose a more serious threat to commuters and traffic-exposed workers. BTEX compounds take part in photochemical processes, even in areas distant from primary emissions. They have a high photochemical ozone creation potential in the atmosphere. The main process of chemical removal of BTEX from the atmosphere is through reaction with the OH radical during daytime. Typical atmospheric lifetimes with respect to reaction with OH radical are 225 h (benzene), 50 h (toluene), 40 h (ethylbenzene), 20 h (*o*-xylene), 12 h (*m*-xylene), and 19 h (*p*-xylene) for a 24-h average OH concentration of 1×10^6 cm^{-3}. The xylenes (*m*,*p*-xylene plus *o*-xylene) are reported to be the dominant contributors to ozone formation amongst BTEX (Tsujino and Kuwata 1993; Na et al. 2005). BTEX ratios can be useful as a tool to investigate photochemical processes (Tsujino and Kuwata 1993). The ratio between *m*,*p*-xylene and ethylbenzene (*m*,*p*-X/E) is used to investigate the extent of atmospheric photochemical reactivity and is a useful tool for estimating the photochemical age of an air mass (Nelson and Quigley 1984; Monod et al. 2001; Hsieh and Tsai 2003; Hsieh et al. 2011).

Delhi is one of the most polluted cities in the world due to its unrestricted growth (Khare and Kansal 2004). Urban transport, manufacturing industries, and thermal power plants (TPPs) are the major sources of anthropogenic pollution (CPCB 1995). As a consequence, the assimilative capacity of atmosphere is being stressed. To tackle the problem, a number of measures have been adopted in the past for the control of vehicular and manufacturing industry emissions. These include tightening vehicular emission limits, switching to cleaner fuels (i.e. unleaded gasoline, reduction of sulphur in diesel, reduction of benzene content in gasoline), phasing out of old vehicles and maintenance of in-use vehicles, conversion of all buses and public transport vehicles to natural gas, introduction of Metro Rail, and closing or relocating polluting industries and industries operating in non-conforming areas

(Khare and Kansal 2004). However, in spite of these measures, the ambient air quality of Delhi does not comply with National Ambient Air Quality Standards (NAAQS) (Kandlikar 2007). Emissions from diesel internal combustion engine were found to be a dominating source of VOCs in ambient air of Delhi ranging between 26 and 54% (Srivastava et al. 2005). Large number of diesel generator sets is used in Delhi in residential, commercial, and industrial areas as a backup to power supply. A recent study, although centred on urban atmosphere of Delhi, can be generalized for Indian climate, exhibit clear seasonal variations of the inter-species ratios indicating differential reactivity of the VOC species in different seasons (Srivastava 2005). Observed seasonal trends can be addressed by the seasonal characteristics of the prevailing meteorology, variations in the source strength and, most importantly, the availability of OH radical and insolation that take care of the removal process of the VOC species from the atmosphere. The meteorology in Delhi shows an explicit winter and summer characteristics. In the winter months, calm conditions and high stability of the atmosphere prevails, which hinder the pollutants from dissipating faster. Temperature inversion, which is a common phenomenon in the winter months and low mixing heights do restrict dilution process of the pollutants. Thus in the winter months, the pollutants generally show a higher level of concentration. An enhanced emission of aromatics is also reported due to cold start of gasoline powered vehicles in the winter months. In Indian cities during winter, slum dwellers ignite biomass including wood waste and other organic refuse for heating that also contribute to VOC loading of the atmosphere (Padhy and Varshney 2000). In contrast, the summer months in Delhi experience higher mixing height and an unstable atmosphere in addition to which there might be several occasions of sandstorm, locally known as ***andhi*** (Hoque et al. 2008). Meteorologically, these factors favour to better mixing and easy dissipation of the pollutants leading to their lower levels in the atmosphere. Delhi records more insolation during summers which helps in the photolysis of species like ozone, aldehydes, etc. and leading to the formation of OH radical. The reaction of terpene with ozone also leads to the formation of OH radical. Thus in the summer months, high level of OH concentration could prevail in the atmosphere of Delhi, which plays the key role in the atmospheric clean up and degradation process of the aromatic VOCs. The study shows a clear seasonal profile with a unimodal pattern for the summer months. In industrial areas, toluene and xylene profiles are bimodal indicative of enhanced evaporation of toluene from industrial units, vehicular service stations, electric motor winding, and waste decomposition at waste dumping lands around the sampling location in hotter months (Srivastava 2005). Thus, meteorological conditions and human activities are two important factors which have high impact on air quality in Delhi city. Therefore, the objectives of study are to (1) assess the concentrations of BTEX compounds at selected sites, viz., I and II in Delhi and (2) evaluate the ozone formation potential of BTEX species.

2 Materials and Methods

2.1 Study Area

Delhi is located at 28°61′N, 77°23′E, and lies in Northern India. The national capital territory (NCT) is stretched over an area of 1483 km^2. Delhi is located approximately 213–305 m above sea level. Delhi stands in the middle of the Indian subcontinent, between the Himalayas and Aravalli's range bordered by Haryana in East and by Uttar Pradesh across the river Yamuna. Yamuna enters Delhi near Palla village after covering a distance of about 400 km from its origin and exits from Delhi (NCT) at the village Jaitpur after traversing a distance of 50 km within the NCT (Report: Knowledge, Attitude, and Practice of Delhiities towards the River Yamuna). Two prominent features of Delhi's geography are **Yamuna flood plain** and **Delhi ridge**. The ridge forms the most dominant feature in this region. Aravallis extend from Gujarat through Rajasthan to Haryana up to Delhi. The spurs of Aravallis are popularly known as '**Delhi ridge in Delhi**', which is divided into Northern, Central, South central, and Southern ridge.

Delhi sprawls an area of 1500 km^2. Its east–west length is approximately 51.9 km and the northwest width approximately 48.48 km. The spread of Delhi is somewhat circular. The transportation network in Delhi is predominately road based. Delhi has the largest road length of 1284 km/100 km^2 of area in India. The road network in the city is 22,487 km long. Engineering, clothing, and commercial activities predominate although electrical goods are gaining importance. Most industries are located in the west, south, and southwest of the city. Delhi has two major thermal power plants, which are not sufficient to cater to the total power need of the city. Generator sets are thus used in commercial, residential, and industrial areas as backup power. Cooking, generator sets, various internal combustion engines, burning of organic wastes landfill, sewage treatment plants, slums, and open defecation are some of the sources of VOCs in Delhi.

2.2 Climatology of Delhi

Delhi features an atypical version of the humid subtropical climate. Summers are long and extremely hot, from early April to mid-October, with the monsoon season in between. Early March sees a reversal in the direction of wind, from the north-western direction, to the south-western. These bring the hot waves from Rajasthan, carrying sand and are a characteristic of the Delhi summer, known as '**loo**'. The months of March to May see a time of hot prickling heat. Monsoon arrives at the end of June, bringing some respite from the heat, but increasing humidity at the same time. The brief, mild winter starts in late November and peaks in January and is notorious for its heavy fog or 'smog' formation.

Table 4.1 MIR coefficient, BTEX-OH rate constant and ranking of BTEX compound concentrations, ozone formation potential, and reactivity with OH at Site I during winter season

Hydrocarbon	MIR coefficient	OH[a]	Conc. (μg/m^3)	Conc. (ppb)	OFP[b]	Reaction with OH[c]
Benzene	0.50	1.23	0.34	0.68	3.95	0.89
Toluene	7.7	5.5	1.23	2.46	60.90	9.65
Ethylbenzene	3.4	7.0	1.11	7.77	26.89	6.43
o-xylene	29.2	18.70	3.01	6.02	230.97	17.86
m,*p*-xylene	12.8	13.60	2.22	4.44	101.24	14.88

[a]Rate coefficient for compound-OH reaction × 10^{12} cm^3/molecule/s
[b]Ozone formation potential (OFP) = BTEX × MIR
[c]BTEX in ppb × BTEX-OH rate (10^{-12} cm^3/molecule/s) × 10^{12}

Extreme temperatures range from −0.6 °C (30.9 °F) to 46.7 °C (116.1 °F). The annual mean temperature is 25 °C (77 °F); monthly mean temperatures range from 13 °C to 32 °C (56–90 °F). The average annual rainfall is approximately 714 mm (28.1 in.), most of which is during the monsoons in July and August, the average date of the advent of monsoon winds in Delhi is 29 June. The heavy rains of the monsoon act as a ‘scrubber’.

The sampling sites, viz., I and II are located in the north part of Delhi. Site I, around 1.3 km near the Inter State Bus Terminus (ISBT), Kashmiri Gate, is a busy traffic area due to its proximity to a college, a hospital, and a shopping complex and Civil Lines Metro Station (Table 4.1). The area witnesses heavy footfall. It has the latitude of 28°40′39.55″N, longitude of 77°13′30.11″E, and altitude of 719 ft. It, being the only CNG refilling station in approximately 7 km radius, attracts a large number of vehicles for refuelling of CNG and petrol/diesel. It is open for 24 h a day. Approximately, 400–500 vehicles get refuelled every day, consuming around 4000 kg of gas and 3000–4000 L of petrol/diesel. The dominant vegetation of the nearby area are deciduous trees as *Azadirachta indica* (neem), *Ficus religiosa* (peepal), *Moraceae sp.* (mulberry), *Mangifera indica* (mango), *Ficus sp.* (banyan), *Psidium sp.* (guava), bougainvillea, *Plumeria sp.* (champa/frangipani), *Butea monosperma* (palash), etc. Site II is situated in the Northern Ridge area inside the north campus of the University of Delhi, away from traffic intersection with dense vegetation (Table 4.1), with 28°41′19.20″N latitude, 77°12′48.5″E longitude, and altitude of 728 ft. Monitoring was done in the Field Nursery of University of Delhi which is opposite the Zoology Department and close to the main road of university area. The dominant vegetation of the area are deciduous trees as *Acacia arabica* (Babul), *Jujube sp.* (Ber) *Acacia sp.* (VilaytiKikar), *Azadirachta indica* (Neem), *Mangifera indica* (mango), etc.

2.3 Monitoring of BTEX, NO_2, and Ozone

For sampling BTEX, Organic Vapour Sampler (OVS) APM 856 (Envirotech Instruments Pvt. Ltd. India), consisting of fabricated diffusive glass sampling tubes and regulated air suctioning pump, was used. The sampling was done from

November 2010 to February 2011 in every 3 days a week. The ambient air was sucked through known amount of activated charcoal (18–35 mesh size) contained in sealed glass tubes procured from Envirotech Instruments Pvt. Ltd. This method is TO-17 Method given by US EPA (1999). The activated charcoal samples were transferred from the sealed tubes into a glass vial and sealed immediately in order to prevent further adsorption of compounds. These were stored at 4 °C until analysis. To the sample vial, 2 mL of carbon disulphide was added and shaken gently for 40 min (Chan et al. 1991). Carbon disulphide was filtered out with Teflon syringe filter (0.22 μm).

Analysis was done by GC–FID (Shimadzu, GC-2010) equipped with Omega SPTm column (30 m × 0.25 mm id). GC was programmed for 50 °C, held for 2 min, and ramped to 260 °C at a rate of 10 °C/min with 12 min held at 230 °C. Nitrogen was used as carrier gas with flow rate of 1.21 mL/min and split ratio of 1:10. The standard calibration mixture containing benzene, toluene, ethylbenzene, *o*-xylene, *m*-xylene, and *p*-xylene procured from Supelco was used for calibration. Calibration standards were prepared by diluting the stock standard mixture. The quality assurance and quality control (QA/QC) measures included laboratory and field blank and replicates were taken for measurements of samples. For laboratory blank, unexposed charcoal tubes were analysed for VOCs similar to the exposed ones.

For monitoring ozone in ambient air, a chemical method, known as Method 411 developed by the Central Pollution Control Board, was used (CPCB Report 2011). Ozone was determined quantitatively by passing the gas through a neutral solution of potassium iodide and titrating the free iodine with standardized sodium thiosulphate.

3 Results and Discussion

The daily average concentration of BTEX during winter season (Nov–Feb) at both the selected sites, viz., I and II is shown in Fig. 4.1. It has been clearly depicted that *m*,*p*-xylene and toluene were the most abundant BTEX compounds at both the sites. The daily average mean concentrations at Site I for benzene was 0.34 ± 0.11 μg/m^3, 1.23 ± 0.45 μg/m^3 for toluene, 1.11 ± 0.14 μg/m^3 for ethylbenzene, 3.01 ± 0.23 μg/m^3 for *o*-xylene, and 2.22 ± 0.42 μg/m^3 for *m*,*p*-xylene while at Site II, benzene was 0.11 ± 0.21 μg/m^3, 0.66 ± 0.17 μg/m^3 for toluene, 0.22 ± 0.07 μg/m^3 for ethylbenzene, 1.35 ± 0.32 μg/m^3 for *o*-xylene, and 0.87 ± 0.55 μg/m^3 for *m*,*p*-xylene. This is because of the reason that Site I is CNG/petro/diesel refuelling station site which is situated opposite the hospital, adjacent to Civil Lines metro station, nearby traffic intersection zone, i.e. ISBT and surrounded by so many small eateries. All these factors favoured high concentrations of air pollutants whereas Site II is away from traffic intersection area with dense vegetation; therefore, less concentration of pollutants were expected. In addition to that, the daily mean benzene concentration during winter season at Site I (0.34 ± 0.11 μg/m^3) did not exceed the annual threshold concentration (5 μg/m^3) set by the European Union (European Commission

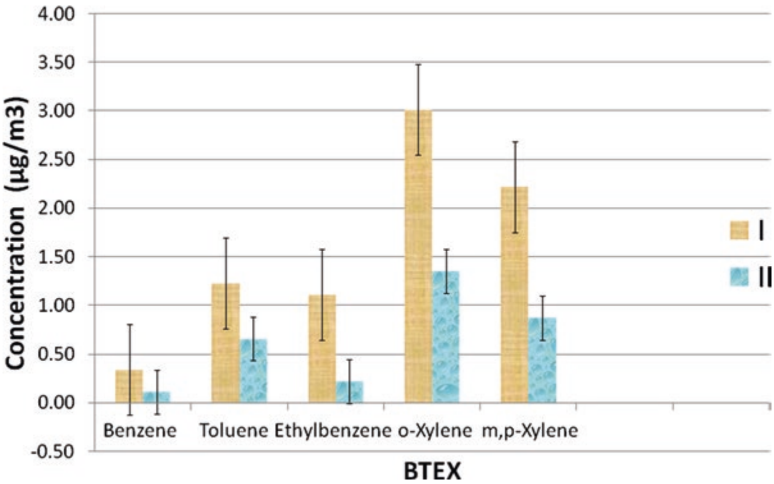

Fig. 4.1 Daily average variation of BTEX during winter season (Nov 10–Feb 11) at two selected sites in Delhi

2013). Benzene is a carcinogenic compound causing leukaemia. The US EPA (2005), through cancer risk analysis, estimates that an individual exposed to benzene levels between 0.13 and 0.45 µg/m^3 for 70 years has a cancer risk probability of 1/1,000,000. Exposure levels between 1.3 and 4.5 µg/m^3 raise the risk to 1/100,000 and between 13 and 45 µg/m^3, the risk of getting cancer, especially leukaemia, rises to 1/1000. Using the unit risk factor from the WHO (2000), in a polluted and populated city like Delhi, average benzene levels of 0.34 µg/m^3, about 22 additional cases of leukaemia would be expected in the city over a 70-year period.

From Fig. 4.2, it has been shown that higher daily mean concentrations of ozone of 45.58 ± 0.11 µg/m^3 were found at Site I as compared to Site II where ozone concentration was found to be lesser, i.e. 22.87 ± 0.01 µg/m^3.

3.1 Ranking of BTEX Compounds with Respect to Ozone Formation Potential and Reactivity with OH

Each element in BTEX compounds plays different roles in photochemical smog formation (Carter 1990), especially in the production of ozone (Carter 1994). Ozone formation potential (OFP) is the most widely used tool for describing the maximum ozone formation capacity in cities where ozone formation is VOC sensitive. It can be evaluated using the maximum incremental reactivity (MIR) developed by Carter (1994). MIR is a popular scale in the assessment of OFP of various VOC compounds (Hung-Lung et al. 2007). Carter's MIR is the amount of ozone formed when 1 g of VOC is added to an initial VOC–NOx mixture under relatively high NOx conditions, indicating how much a compound may contribute to the ozone

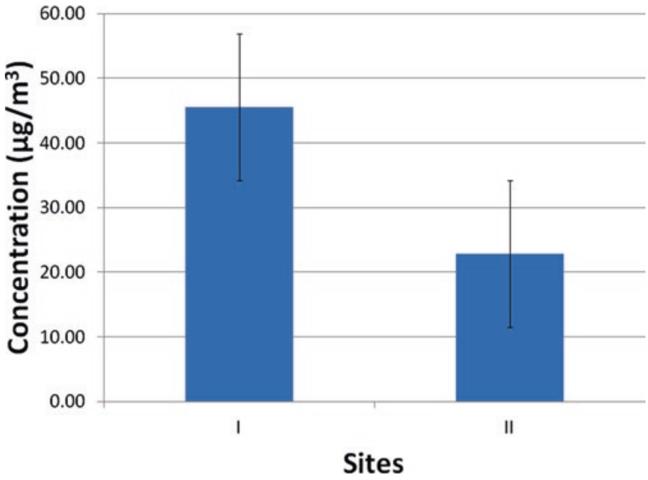

Fig. 4.2 Daily average variation of ozone during winter season (Nov 10–Feb 11) at two selected sites in Delhi

Table 4.2 MIR coefficient, BTEX-OH rate constant and ranking of BTEX compound concentrations, ozone formation potential, and reactivity with OH at Site II during winter season

Hydrocarbon	MIR coefficient	OH[a]	Conc. ($\mu g/m^3$)	Conc. (ppb)	OFP[b]	Reaction with OH[c]
Benzene	0.50	1.23	0.11	0.22	1.60	0.66
Toluene	7.7	5.5	0.66	1.32	24.71	4.53
Ethylbenzene	3.4	7.0	0.22	0.44	10.91	5.21
o-xylene	29.2	18.70	1.35	2.7	93.73	13.45
m,*p*-xylene	12.8	13.60	0.87	1.74	41.08	10.76

[a]Rate coefficient for compound-OH reaction × 10^{12} cm^3/molecule/s
[b]Ozone formation potential (OFP) = BTEX × MIR
[c]BTEX in ppb × BTEX-OH rate (10^{-12} cm^3/molecule/s) × 10^{12}

formation in the air mass (Carter 1994). The reactivity of VOC with OH radical determines the ability of the hydrocarbon to form higher oxidized products such as ketones, acids, aldehydes, and organic peroxy radicals. The MIR coefficients were taken from Atkinson (1997) and Carter (1990, 1994) and rate constants of BTEX-OH reactions from Jenkin et al. (2003). The ranking of the BTEX species according to their concentrations, OFP, and reaction with OH during winter season at different sites is given in Tables 4.1 and 4.2. Based on the MIR scale, *m*,*p*-xylenes were the biggest contributors to ozone formation followed by *o*-xylene and toluene, whereas benzene was the lowest contributor during the different seasons and period of study. This is in accordance with Na et al. (2005) and Grosjean et al. (1998), who found that *m*,*p*-xylene and *o*-xylene were the dominant contributor to ozone formation amongst BTEX at Seoul and Porto Alegre, respectively. In the present study, higher *o*-xylene contribution was found at Site I as compared to Site II. Reaction of BTEX with OH radical, which leads to the formation of oxidized products, followed a similar pattern to that found in the contribution of BTEX to ozone formation at different sites during winter season. The pattern was *o*-xylene > *m*,*p*-xylenes > toluene > ethylbenzene > benzene. In addition, the highest *o*-xylene contribution was found at both the selected sites.

4 Conclusion

BTEX compounds and ozone were measured during winter season from November 2010 to February 2011 at two different selected sites categorized on the basis of near to traffic intersection area and less vegetation (Site I) and away from traffic intersection area with dense vegetation area (Site II). Site I had reported higher concentrations of BTEX compounds and ozone as compared to Site II. Monthly variation of BTEX concentrations and their potential for ozone formation have been evaluated and discussed. It was found that *o*-xylene was most abundant amongst BTEX compounds, followed by *m*,*p*-xylene, toluene, ethylbenzene, and benzene at both the sites during the study period. Ozone formation potentials for BTEX species were estimated using MIR. Xylenes were the dominant contributor to ozone formation. Benzene had the lowest potential for the formation of ozone. Finally, the annual average benzene level in the study did not exceed the annual limit value set by the European Union but still represents a risk to human health. For a city such as Delhi of 0.34 $\mu g/m^3$, about 22 additional cases of leukaemia would be expected in the city over a 70-year period using the unit risk factor of 6×10^{-6} $(\mu g/m^3)^{-1}$ recommended by the WHO (2000).

References

Arriaga-Colina JL, West JJ, Sosa G et al (2004) Measurements of VOCs in Mexico City (1992–2001) and evaluation of VOCs and CO in the emissions inventory. Atmos Environ 38:2523–2533
Atkinson R (1997) Gas-phase tropospheric chemistry of volatile organic compounds 1. Alkanes and alkenes. J Phys Chem 26:215–290
Barletta B, Meinardi S, Simpson IJ et al (2002) Mixing ratios of volatile organic compounds (VOCs) in the atmosphere of Karachi, Pakistan. Atmos Environ 36:3429–3443
Batterman SA, Peng CY, Braun J (2002) Levels and composition of volatile organic compounds on commuting routes in Detroit, Michigan. Atmos Environ 36:6015–6030
Bravo HA, Camancho RC, Roy-Ocotla GR et al (1991) Analysis of the change in atmospheric urban formaldehyde and photochemical activity as a result of using methyl-t-butyl-ether (MTBE) as an additive in gasoline of the metropolitan area of Mexico City. Atmos Environ 25B:285–288
Carr D, Van EOWS, Wagner C et al (2002) Modeling annual benzene, toluene, NO_2, and soot concentrations on the basis of road traffic characteristics. Environ Res 90:111–118
Carter WPL (1990) A detailed mechanism for the gas-phase atmospheric reaction of organic compounds. Atmos Environ 24A:481–518

Carter WPL (1994) Development of ozone reactivity scales for volatile organic compounds. J Air Waste Manage Assoc 44:881–899
Central Pollution Control Board (CPCB) (1995) Annual report 1993/94. Central Pollution Control Board, Ministry of Environment & Forests, Government of India, New Delhi, 154
Central Pollution Control Board (CPCB) (2011) Status of the vehicular pollution control programme in Delhi, 1–131
Chan CC, Xi CM, Liu JM (1991) Driver exposure to volatile organic compounds, CO, ozone, and NO_2 under different driving conditions. Environ Sci Technol 25:964–972
Chan LY, Lau WL, Wang XM, Tang JH (2003) Preliminary measurements of aromatic VOCs in public transportation modes in Guangzhou, China. Environ Int 29:429–435
Duffy BL, Nelson PF (1997) Exposure to emissions of 1, 3-butadiene and benzene in the cabins of moving motor vehicles and buses in Sidney, Australia. Atmos Environ 31:3877–3885
European Commission, Environment (2013) http://www.ec.Europa.eu/environment /air/quality/standards.htm. Accessed 23 May 2013
Gee IL, Sollars CJ (1998) Ambient air levels of volatile organic compounds in Latin American and Asian cities. Chemosphere 36:2497–2506
Gonzalez-Flesca N, Bates MS, Delmas V, Cocheo V (2000) Benzene exposure assessment at indoor, outdoor, and personal levels. The French contribution to the life MACBETH programme. Environ Monit Assess 65:59–67
Grosjean E, Rasmussen RA, Grosjean D (1998) Ambient levels of gas phase pollution in Porto Alegre, Brazil. Atmos Environ 32:3371–3379
Hoque RR, Khillare PS, Agarwal T et al (2008) Spatial and temporal variation of BTEX in the urban atmosphere of Delhi, India. Sci Tot Environ 392:30–40
Hsieh CC, Tsai JH (2003) VOC concentration characteristics in southern Taiwan. Chemosphere 50:545–556
Hsieh LT, Wang YF, Yang HH, Mi HH (2011) Measurements and correlations of MTBE and BETX in traffic tunnels. Aerosol Air Qual Res 11:763–775
Hung-Lung C, Jiun-Horng T, Shih-Yu C, Kuo-Hsiung L, Sen-Yi M (2007) VOC concentration profiles in an ozone non-attainment area: a case study in an urban and industrial complex metroplex in southern Taiwan. Atmos Environ 41:1848–1860
Jenkin ME, Saunders SM, Wagner V, Pilling MJ (2003) Protocol for the development of the master chemical mechanism, MCMv3 (part B): tropospheric degradation of aromatic volatile organic compounds. Atmos Chem Phys 3:191–193
Kandlikar M (2007) Air pollution at a hotspot location in Delhi: detecting trends, seasonal cycles and oscillations. Atmos Environ 41:5934–5947
Khare M, Kansal A (2004) Sectoral analysis of air pollution control in Delhi. In: Elsom DM, Longhurst JWS (eds) Regional and local aspects of air quality management. WIT Press, Southampton, pp 193–222
Khoder MI (2007) Ambient levels of volatile organic compounds in the atmosphere of Greater Cairo. Atmos Environ 41:554–566
Kourtidis KA, Ziomas I, Zerefos C et al (2002) Benzene, toluene, ozone, NO_2 and SO_2 measurements in an urban street canyon in Thessaloniki, Greece. Atmos Environ 36:5355–5364
Lau WL, Chan LY (2003) Commuter exposure to aromatic VOCs in public transportation modes in Hong Kong. Sci Tot Environ 308:143–155
Monod A, Sive BC, Avino P et al (2001) Monoaromatic compounds in ambient air of various cities: a focus on correlations between the xylenes and ethylbenzene. Atmos Environ 35:135–149
Mukherjee AK, Bhattacharya SK, Ahmed S et al (2003) Exposure of drivers and conductors to noise, heat, dust and volatile organic compounds in the state transport special buses of Kolkata city. Trans Res Part D Trans Environ 8:11–19
Na K, Moon KC, Kim YP (2005) Source contribution to aromatic VOC concentration and ozone formation potential in the atmosphere of Seoul. Atmos Environ 39:5517–5524
Nelson PF, Quigley SM (1984) The hydrocarbon composition of exhaust emitted from gasoline fueled vehicles. Atmos Environ 18:79–87

Padhy PK, Varshney CK (2000) Total non-methane volatile organic compounds (TNMVOC) in the atmosphere of Delhi. Atmos Environ 34(4):577–584
Pankow JF, Luo W, Bender DA et al (2003) Concentrations and co-occurrence correlations of 88 volatile organic compounds (VOCs) in the ambient air of 13 semi-rural to urban locations in the United States. Atmos Environ 37:5023–5046
Riediker M, Williams R, Devlin R, Griggs T, Bromberg P (2003) Exposure to particulate matter, volatile organic compounds, and other air pollutants inside patrol cars. Environ Sci Technol 37:2084–2093
Romieu I, Ramirez M, Maneses F et al (1999) Environmental exposure to volatile organic compounds among workers in Mexico City as assessed by personal monitors and blood concentrations. Environ Health Pers 107:511–555
Srivastava A (2005) Variability in VOC concentrations in an urban area of Delhi. Environ Monit Assess 107:363–373
Srivastava A, Joseph AE, Patil S et al (2005) Air toxics in ambient air of Delhi. Atmos Environ 39:59–71
Tonooka Y, Kannari A, Higashino H, Murano K (2001) NMVOCs and CO emission inventory in East Asia. Water Air Soil Pollut 130:1–4
Tsujino Y, Kuwata K (1993) Sensitive flame ionization detector for the determination of trace of atmospheric hydrocarbons by capillary gas chromatography. J Chromatogr 642:383–388
Upmanis H, Eliasson I, Andersson-Sköld Y (2001) Case studies of the spatial variation of benzene and toluene concentrations in parks and adjacent built-up areas. Water Air Soil Pollut 129:61–81
US EPA (1999) Compendium method TO-17, EPA/625/R-96/010b
US EPA (2005) Guidelines for carcinogenic risk assessment. Risk Assessment Forum, EPA/630/P--03/001F, March 2005
Wang XM, Sheng GY, Fu JM et al (2002) Urban roadside aromatic hydrocarbons in three cities of the Pearl River Delta, People's Republic of China. Atmos Environ 36:5141–5148
WHO (2000) Air quality guidelines for Europe, 2nd edn. World Health Organisation, Copenhagen
Xianglu H, Naeher LP (2006) A review of traffic-related air pollution exposure assessment studies in the developing world. Environ Int 32(1):106–120

Chapter 5
Global Dimming and Global Warming: Dangerous Alliance

Monika Thakur

Abstract Global dimming is a phenomenon which produces forces that act opposite to global warming in nature. Global dimming reduces the amount of sun's rays reaching the earth's atmosphere causing a drop of temperatures around the globe. In addition, global dimming interferes with the hydrological cycles in the biosphere and reduces evaporation rate. The study on global warming wouldn't be complete without mentioning global dimming. Global dimming is caused by an increase in particulates such as sulfate aerosols in the atmosphere. The pollutants that lead to global dimming also lead to various environmental problems, such as phytochemical smog, respiratory problems, and acid rain. The present review discusses the combined effect of global dimming and global warming. Global Dimming and Global Alliance have been opposite phenomenon with contrasting effects and are destructive to plants. The effect can be reduced by every individual playing his role by reducing fuel consumption, creating awareness for the consumption of nonessential commodities, walking, and planting trees.

Keywords Pollutants • Greenhouse gases • Global dimming • Global warming • Suspended pollutants • Surface solar radiations

1 Introduction

The changing climate impacts our health and well-being. The major health organizations of the world visualize climate change as a critical public health problem. Climate change expresses an increase in the temperature of the planet, ocean expansions, rise in the sea level, floods, and droughts.

Weather and climate are very often confused. There is a lot of difference between climate and weather. *Weather* is short-term variations in atmospheric phenomenon that interact and affect environment and life; whereas, *Climate* is a long-term

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7_5

average of variation in weather for a particular area. Global climate (temperature) is changing and humans are influencing the change in climate. Global climate has changed in the geological past; various factors influence global climate change. Climate will probably change in the future too.

The amount of solar radiation incident at the earth's surface is not stable over the years but undergoes significant decadal variations (Pathirana 2008). Wild (2009) reviewed the evidence for the changes, magnitude, possible causes, representation in climate models, and their potential implications for climate change. Solar radiation incident at the earth's surface is the ultimate energy source for the life on this planet, and majorly determines the climatic conditions of the planet. The amount of solar energy reaching the earth's surface is a major component of the surface energy and governs a large number of diverse surface processes: evaporation, snow, glacier melting, photosynthesis, terrestrial carbon uptake, diurnal and seasonal course of surface temperatures, etc. Changes in the amount of solar energy reaching the earth's surface can therefore have profound environmental, societal, and economic implications. On the other hand, there is growing evidence that human interference with and in climate leads to various alterations of solar radiation in polluted atmospheres. Solar energy reaches the earth's surface either as direct beam from the sun or in diffuse form after scattering in the atmosphere. The sum of the direct and diffuse radiation incident on the surface is known as Global Radiation or Surface Solar Radiation (SSR).

Nowadays, the main focus of climatologists is on global dimming (GD) and global warming (GW). GD reduces the amount of sun's rays reaching the earth's atmosphere and causes a drop of temperature around the globe. In addition, global dimming interferes with the hydrological cycles of the biosphere and reduces the rate of evaporation. The study on global warming wouldn't be complete without mentioning global dimming. Global dimming is a phenomenon which produces forces that have to act opposite to global warming in nature. The combined effects of GD and GW are deadly; climatologists nowadays emphasize dealing with both global dimming causing pollutants and global warming causing greenhouse gases together at global level. GW is accelerating day by day because of the increased amount of particulate pollution in the atmosphere. We can combat the combined effect of global dimming and global warming only by reducing carbon emissions in all forms and by taking steps which reduce the use of fossil fuels. Therefore, each individual must play his role by reducing fuel consumption, creating awareness for the consumption of nonessential commodities, walking, planting trees, or just by being a citizen aware of this globalized world. This chapter summarizes the introduction, impact, and effects of global warming and dimming. The main focus was on their joint alliance so that both the deadly problems can be dealt simultaneously.

2 Global Dimming

Global dimming is the gradual reduction in the amount of direct irradiance at the earth's surface. It has been caused by an increase in particulates such as sulfate and aerosols in the atmosphere due to various human activities. The pollutants that lead to global dimming also lead to different human and environmental problems, such as smog, respiratory problems, and acid rain. Global dimming is basically from air pollutants and fossil fuels which make clouds reflect more of the sun rays back to the space. This leads to global dimming, whereby less heat and energy reaches the earth (Sarkar 2009). Global dimming is the increase of reflection and absorption of solar radiation by the troposhere (Pathirana 2008).

Due to this phenomenon, there is a decrease in the amounts of solar radiations reaching the surface of the earth. Use of fossil fuel produces various greenhouse gases and releases other by-products such as sulfur dioxide, soot, and ash (Hansen and Lacis 1990) which are also pollutants. These pollutants change the properties of clouds and make them more reflective. More of the sun's heat and energy is therefore reflected back into space. Eccleston (2007) called global dimming as a darkening problem all over the globe.

Human activities could cause cooling effect in the nature. Reflection from atmospheric particles could reduce incoming solar radiation by 10% in the process of global dimming.

2.1 Causes of Global Dimming

Earlier it was thought that changes in the sun's luminosity cause global dimming but, later, it was realized that this was a very small aspect of the same. The burning of fossil fuels used by industry emits various by-products, and aerosols have been found to be major cause of global dimming. Ramanathan et al. (2001) stated that these aerosols together form particulate pollution. They act as precursor to global dimming in the following two ways:

- The particle matters enter the atmosphere and directly absorb solar energy, and they then reflect radiation back into the space, before it reaches the planet's surface.
- Water droplets containing these air-borne particles form polluted clouds. These polluted clouds have heavier and larger number of droplets. Because of the changed properties of the clouds, they are called as "brown clouds" and are more reflective (Ramanathan et al. 2005). Figure 5.1 explains the formation of polluted clouds.

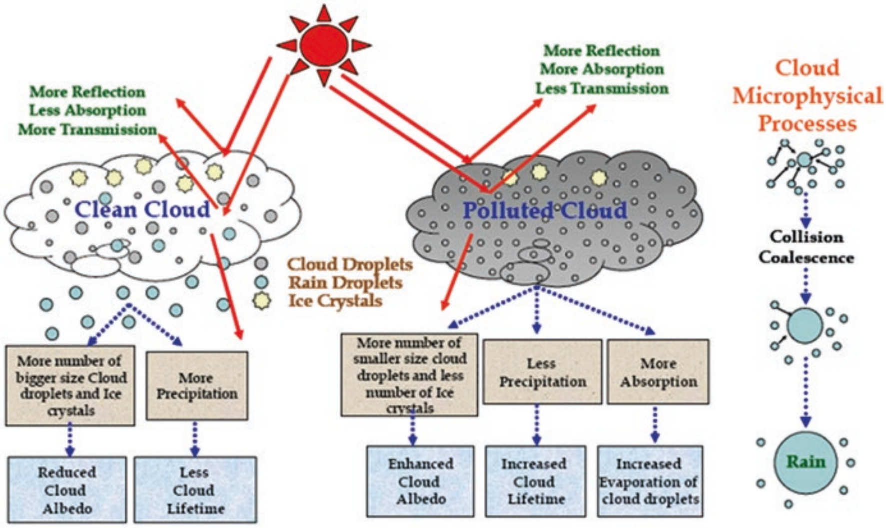

Fig. 5.1 Polluted clouds

2.2 *Impact of Global Dimming on Climate System*

Global dimming has devastating effects on the earth's environment and living beings. Global dimming and global warming have caused severe changes in the rainfall patterns (Max and Seattle 2010). The clear-cut effect of global dimming is "famine" and "drought." The famines of 1970s and 1980s were a direct effect of rainfall shortage which resulted from this phenomenon. Many people from all over the world including America, Europe, Asia, and Africa experienced famines. The anthropogenic pollutants added in the developed countries are affected by acid rain, which is caused by the aerosols in the clouds. The process of photosynthesis in the plants gets reduced due to the shortage of solar radiations. The sulfur aerosols when inhaled can cause various respiratory diseases in human beings.

Global dimming is also believed to cause heat waves and runaway fires. GD is thought to be counteracting the actual effect of carbon emissions on global warming. So, if efforts are made to reduce particulate emission causing global dimming, it will enhance global warming and double the global temperatures. This will make planet Earth, almost uninhabitable. To prevent such a situation, it is important that emission of both greenhouse gases and particulate matters are to be reduced simultaneously to balance out both the phenomena.

It is well known that the fossil fuel productions generate greenhouse gases that cause global warming and release by-products which are pollutants that cause global dimming (Wild et al. 2007). These pollutants also lead to difference. The impacts of global dimming itself, however, can be devastating. Various studies have been conducted on the impacts of global dimming and climate change. Some of the major effects have been discussed below:

- Less solar energy will limit the rate of photosynthesis.
- Masking effects of global warming.
- Chemical nature of clouds will be changed.
- Causes famine and drought.
- Acid rain formation.
- The pollutants can cause congenital (birth) defects, coughing, sneezing, itchy throat, lung damage, and other respiratory diseases.
- Because of GD process, the water in some areas has cooled and has resulted in less rainfall. This has led to bad crops or droughts for a longer period in many parts of the world.
- Global dimming also leads to acid rain, smog, and respiratory diseases in humans.

2.3 Evidences of Global Dimming

Sukumar (2011) discussed the change in the United States after 9/11 attacks. Three days after the attack scientists found that the sky was abnormally very clear. The contrails (artificial vapor cloud) were the causes for such a climatic change. It was later revealed that the temperature during the 3 days after 9/11 was reduced to 1 °C from the average range before 9/11 and few days after the incident. The 1 °C reduction in temperature is nothing much for a common man, but scientific records reveal that this kind of abrupt reduction in temperature can have adverse effects in the near future.

2.4 Global Warming

There are three different factors of temperatures on earth's surface: (i) the amount of sunlight received; (ii) the amount of solar energy reflected and absorbed; (iii) the amount of retention by atmosphere. Earth is absorbing the short wavelength solar energy, and then radiating long wavelength IR radiation. In global warming, the greenhouse gases are actually needed to keep the earth warm. Without the greenhouse effect, the water on the earth's surface would be frozen. Earth would be a very cold place. However, the excessive greenhouse gases could potentially warm the earth too much. Several atmospheric gases: CO_2, CH_4, CFCs, nitrogen oxides trapping more heat and warming up the lower atmosphere, similar to the effect of a greenhouse. The concentration of green house gases have been increased in the environment due to anthropogenic souces (especially burning fossil fuels). Figure 5.2 illustrates the energy balance on the earth's surface as how the 100% incoming solar radiations on the earth's surface will be distributed and reflected back.

It is a phenomenon caused by an increase in the atmospheric temperature of the earth's surface, due to the increase in concentration of greenhouse gases such as CO_2, CH_4, and CFCs. These greenhouse gases trap the solar rays and cause temperature rise in the earth's atmosphere (Fig. 5.3). This process of trapping solar energy

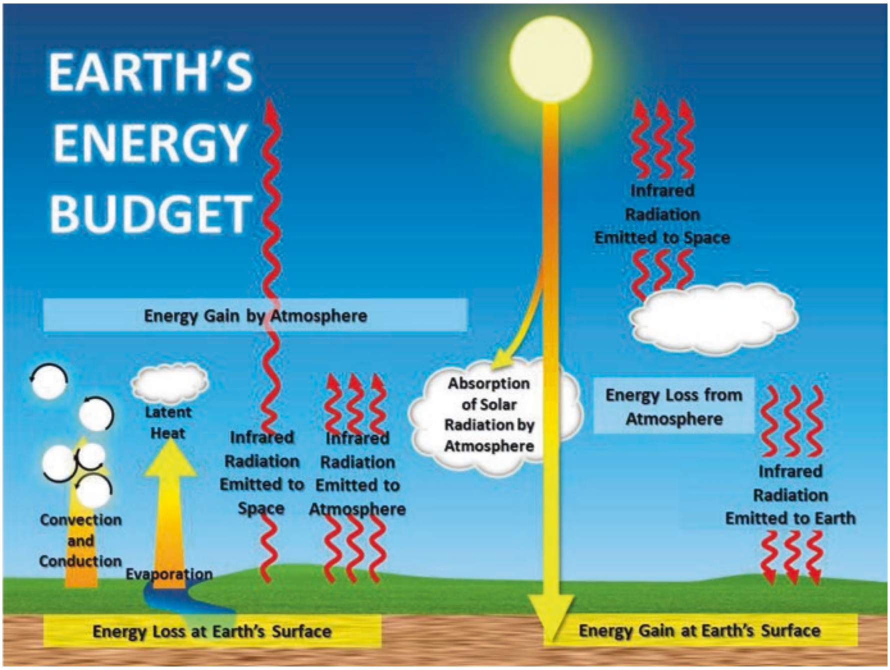

Fig. 5.2 Energy balance of earth's surface

is called greenhouse effect. Increase in population causes demand in energy sources by burning fossil fuels and cutting down trees (deforestation) which is major cause for global warming. It is clear now that the burning of fossil fuels directly contributes to global warming by releasing greenhouse gases (GHG). Trees and plants take in CO_2 and give out O_2. If these plants and trees are cut down, the CO_2 will remain unused in the atmosphere and increase the temperature of the earth's surface, which is called global warming (Sukumar 2011).

2.5 Impacts of Global Warming and Climate System

In recent years, we have heard a lot about various natural disasters like floods, hurricanes, tornadoes, droughts, extinction of certain species, earthquakes, etc. Basically, humans are interfering too much with the nature and act against it in many ways. The natural balance in the earth is being shaken by various human activities and the direct result is global warming. Glaciers in the Polar Regions and mountains melt down and the sea level rises which is all due to the increase in temperature, and it causes floods and damage the food crops. Large areas of lands are damaged permanently due to extraction of fossil fuels from deep underground. This leads to frequent earthquakes on earth. Ozone layer is a blanket that

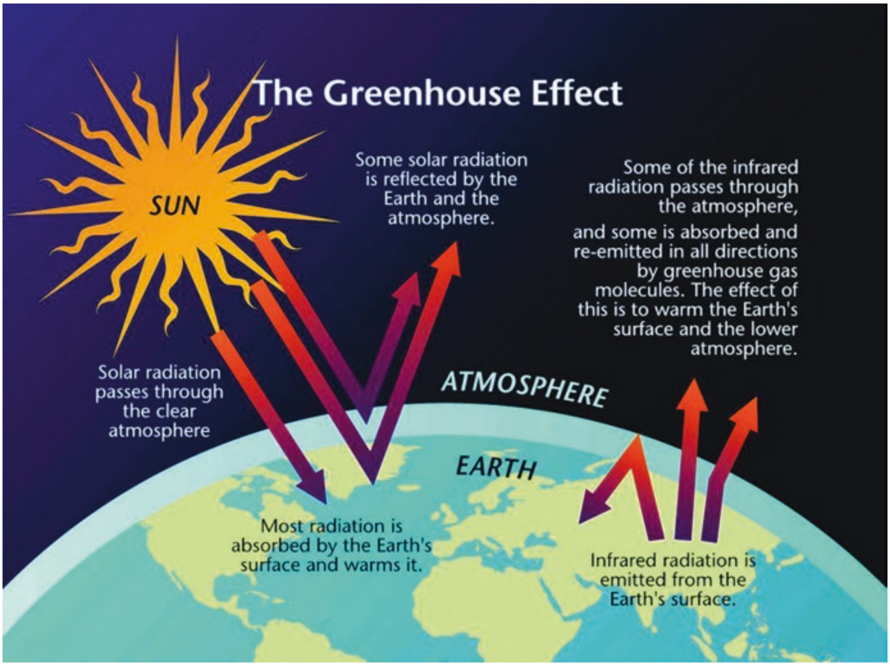

Fig. 5.3 Greenhouse effect (incoming infrared radiation has short wavelengths but the outgoing infrared radiation has longer wavelengths)

entirely covers the earth's surface and protects it from harmful UV (ultraviolet) radiations. The CFC that is emitted from refrigerators, insecticides, and other resources depletes the ozone layer and makes our earth vulnerable to harmful UV rays (Sukumar 2011).

Various effects of global warming have been listed below:

- As there is doubling in the amount of the greenhouse gases, then 1.5–6 °C (2.6–10.2 °F) increase in average global temperature.
- Significant rise of sea level and melting of glacierice due to the increase in planet temperature have been affecting more seriously the island nations and also increased coastal erosion worldwide.
- The number of retreating glaciers accelerating in many areas of the world.
- Global warming leads to significant changes of rainfall and soil moisture.
- Agricultural activities and world food supplies affected greatly by climatic factors.
- Global warming affects the frequency, intensity, and distribution of various natural hazards.
- Desert areas have been expanding gradually.

2.6 Comparison Between Global Dimming and Global Warming

The two deadly phenomena that have great effect on our earth are global warming and global dimming, and they have attracted much attention in the recent years. Due to industrial revolution, increase in population, and growing demands of the people, these issues are booming out at a greater pace. They pose great danger to our earth, and the sole responsibility is in the hands of human beings.

Global warming and global dimming are opposite phenomena. Global warming is defined as the increase in the atmospheric temperature. This is largely caused by greenhouse gases. Greenhouse gases produced from the burning of fossil fuels traps the infrared radiations. This heats up the earth's atmosphere. Global dimming is a less well known but real phenomenon resulting from atmospheric pollution. It has devastating effects on the earth's environment and living beings. The burning of fossil fuels in the industries, in addition to releasing the carbon dioxide, traps the sun's heat within our atmosphere, causing the emission of the so-called particulate pollution—composed primarily of sulfur dioxide, soot, ash, etc. When these particulates enter the atmosphere, they absorb solar energy and reflect sunlight otherwise bound for the earth's surface back into space. Particulate pollution also changes the properties of clouds—the so-called brown clouds are more reflective and produce less rainfall than their more pristine counterparts (Ramanathan et al. 2005). The reduction in heat reaching the earth's surface as a result of these processes is global dimming.

"**The twin effects of Global Warming and Global Dimming due to human pollution can be extremely disastrous. While global warming increases temperature due to the greenhouse gases, global dimming reduces sun's intensity due to suspended solid pollutants. They can cause massive climatic change and catastrophic natural disasters like cyclones, droughts, floods, hurricanes, etc.**" Though both the phenomena are opposite with contrasting effects, they are destructive to the planet. It is due to both global warming and global dimming that the earth's temperature has increased less than what it should have been. Without global dimming, this planet would have turned to be too hot for all of us to survive. Both of them are dangerous and can prove fatal for our environment and need to be solved together. If the focus is really not made on such conditions, it may be harmful and may prove fatal for all of us.

- The global warming causes heating effect in the earth's atmosphere, whereas global dimming causes cooling effect.
- Global warming is caused by greenhouse gases, and global dimming is caused by aerosols and other pollutants.
- GW traps sunlight and GD blocks sunlight.
- GW will damage the environment whereas GD will cause health problems to living organisms.

2.7 Common Factors of GD and GM

The commonality between these two phenomena is that both are destructive alliances to our earth, which will causes environmental and ecological problems. Scientists in developed and developing countries should be more cautious and take the necessary steps to mitigate the effects of global warming and global dimming. The developing countries are always the most affected and fall prey to these phenomena, due to industrialization and other acts of the people in the developed countries. It is important that we all should join hands and protect our earth from the adverse effects of global warming and global dimming (Sukumar 2011).

3 Future Challenges

Since both the phenomena are dangerous alliances and are to be dealt with greater importance, various steps are to be taken to protect the earth from their adverse effects. Various solutions have been suggested below:

1. Simultaneous tackling of global dimming and global warming
2. Reductions of particulates matter in the atmosphere
3. Simultaneous effect at global level

We as humans need to create a balance, so that both global warming and global dimming can be kept in control. Some anthropogenic measures can wisely be taken as mentioned below:

- We need to reduce our dependence on fossil fuels and turn towards new green technologies.
- We need to create strict regulations for industries, so that gas emitting from factories can be reduced to the acceptable levels.
- Awareness programmes on Global Dimming and Global warning
- We need to protect or natural resources such as forests, oceans, and snow-capped mountains.

This chapter discusses in detail and emphasizes the need to keep focused on all solar and thermal components of the earth's atmosphere. Both GD and GM are deadly, therefore, creating awareness and tackling them together is necessary. We should fully quantify and understand the anthropogenic and natural perturbations of the radiation balance, which are on at the sole basis of global climate change. In conclusion, joint efforts and association is required so that the problems being directly / indirectly screened and their hazardous impacts may be minimized on human population and the climate.

References

Eccleston CH (2007) Global Dimming: A Darkening Problem. Environ Pract 3:152–153

Hansen JE, Lacis AA (1990) Sun and dust versus greenhouse gases: an assessment of their relative roles in global climate change. Nature 346:713–718

Max S, Seattle WA (2010) Dear Earth Talk: I've heard of global warming, of course, but what on Earth is "global dimming"? Retrieved from business-ethics.com. Earth Talk—Consumer Info. Accessed 2 Feb 2016

Pathirana A (2008) Global dimming—a cure for climate change or an agent for making its impacts worse. In: Proceedings of the 11th international conference on urban drainage, 31 August 2008

Ramanathan V et al (2001) ATMOSPHERE: aerosols, climate, and the hydrological cycle. Science 5549:2119–2126

Ramanathan V et al (2005) Inaugural article: atmospheric brown clouds: impacts on South Asian climate and hydrological cycle. Proc Natl Acad Sci U S A 102:5326–5333

Sarkar AN (2009) Global climate change and sustainable energy development. Pentagon Press, New Delhi, India

Sukumar S (2011) http://www.buzzle.com/articles/what-is-the-difference-between-global-dimming-and-global-warming.html. Accessed Feb 2015

Wild M (2009) Global dimming and brightening: a review. J Geophys Res Atmos. doi:10.1029/2008JD011470

Wild M, Ohmura A, Makowskim K (2007) Impact of global dimming and brightening on global warming. Geophys Res Lett 34(4):L04702. doi:10.1029/2006GL028031

Chapter 6
Biological Control Agents for Sustainable Agriculture, Safe Water and Soil Health

Abhishek Chauhan, Anuj Ranjan, and Tanu Jindal

Abstract Use of bio-agents must be encouraged in agriculture as the use of chemicals inversely impact population and natural resources. This chapter gives a wide variety of biological agents being used in India for various pests in different crops. Studies can further be stretched to use these bio-agents in turf and for ornamental pest control. Neem-based bio-insecticide is used at a concentration of 5% against Diamondback moth, *Plutella xylostella* in cabbage management. Farm yard manure (FYM) enriched with *Trichoderma harzianum* (4 g/kg) is used to control thrips, mites, and soil-borne diseases and *Pseudomonas fluorescens* is used (5 g/L) for inducing systemic resistance in hot peppers. *Beauveria bassiana* alone or in combination with BT have been used to control soil insects including potato beetles. The isolates of *Trichoderma* spp. have been characterized for biopriming, plant growth promotion characteristics, reduction of disease incidence, and corresponding yield increase in cabbage, cauliflower, mustard, and field pea at 5–10 g/kg seed. *T. harzianum* in the concentration of 2×10^8 cfu/g of soil and *P. fluorescens* 1×10^{12} cfu/g of soil was said to be the best towards management of root knot nematode (Meloidogyne incognita). Application of *T. harzianum* (250 g) + *P. fluorescens* (250 mL), and FYM (25 kg) + *T. harzianum* (250 g) + *P. fluorescens* (250 mL) against fusarium wilt, mites, and root knot nematode has been found promising in cucumber. The above bio-agents can also be successfully used for the control of turf and ornamental plants by conducting field trials.

Keywords Bio-agents • Natural resources • Public health • Safe water • Soil health

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7_6

1 Introduction

The rigorous use of synthetic pesticides and their environmental and toxicological risks have generated augmented global interest to develop alternative sources of chemicals to be used in safe management of agricultural pests. The issue becomes important in the areas where large population is exposed agrochemicals. Recently, in different parts of the world, attention has been drawn towards exploitation of higher plant products as novel chemotherapeutics for plant protection because they are mostly non-phytotoxic and easily biodegradable. Different botanicals and microbes have been formulated for large-scale application as biopesticides in eco-friendly management of plant pests and are being used as alternatives to synthetic pesticides in crop protection. Annual Report (2010-11).

Environmental scientists throughout the world are searching for the alternatives of chemical pesticides for a healthy and fruitful tomorrow. Plants and their secondary metabolites are an important source for natural pesticides and the development of new pesticides. A number of plants are known to have insecticidal activity. Essential oils and other bioactive compounds have also been searched for potential insecticides Casida and Quistad (1998). The identification of the important role of these compounds has increased, particularly in terms of resistance to pests and diseases. Moreover, the purity of natural product is highly variable and is dependent upon the plant part, plant age, extraction method selected, geographical origin and location, climate, and overall growth and health of the plant from which the chemical is extracted. The rigorous use of synthetic pesticides and their environmental and toxicological risks have generated augmented global interest to develop alternative sources of chemicals to be used in safe management of agricultural pests. The excessive use of these chemicals has led to pesticides contaminating almost every part of the environment and poses a significant risk to non-target organisms (insects, plants, fish, and birds) (Aktar et al. 2009; Azmathullah et al. 2013).

Recently, in different parts of the world, attention has been paid towards exploitation of higher plant products as novel chemotherapeutics for plant protection because they are mostly non-phytotoxic and easily biodegradable. Currently, different botanicals have been formulated for large-scale application as biopesticides in eco-friendly management of plant pests and are being used as alternatives to synthetic pesticides in crop protection. Despite these difficulties, research and development in plant-derived pesticides has increased considerably (Arthur 1996; Rahman and Talukder 2006; Rahman and Islam (2007); Murti et al. 2010; Panagiotakopulu et al. 1995).

Currently, the market is full with a variety of chemical, organic, and even some herbal pesticides, but the most commonly used are the chemical and organic pesticides which pose a threat to our environment when used on a large scale. Because of this reason, many plants and herbs are currently being researched for their insecticidal properties (Chauhan et al. 2016). One such plant is *Lantana camara*, also commonly known as wild sage or big sage; it is a species of flowering plant within the verbena family, Verbenaceae that is native to the American tropics. Over time, it has spread to southern Asia, Europe, and Australia, making it an invasive species of weed. In the last decade, this plant has been extensively studied for its medicinal potential by using advanced scientific techniques (Ranjan et al. 2016; Jain et al. 1996; Giday et al. 2003).

Exposure of the general population to pesticides occurs primarily through eating food and drinking water contaminated with pesticide residues, whereas substantial exposure can also occur in or around the home (Damalas and Eleftherohorinos 2011). There are several factors that determine the toxicity of pesticides in the environment, including the measures taken during its application, the dosage applied, the adsorption on soil colloids, the weather conditions prevailing after application, and how long the pesticide persists in the environment. Thus, the need arises to look towards biological control of insects on plants.

Biopesticides include a wide range of microbial pesticides, biochemicals derived from microorganisms and other natural sources (including plants) and processes involving the genetic incorporation of DNA into agricultural commodities that confer protection against pest damage (Gupta and Dikshit 2010). Recently, the potential of products derived from higher plant products is being studied (Dubey et al. 2008) because of their phytotoxicity, easy biodegradability and stimulatory nature of host metabolism (Mishra and Dubey 1994), and low mammalian toxicity.

Botanical insecticides pose significantly less threat to the environment and non-target organisms. The increasing acceptance of their use is proven by the commercial production Pyrethrum and neem essential oils for use as insecticides (Isman 2006; Nauen and Bretschneider 2002). A major barrier to their limited commercial usage has been their relative cost and safety as compared to their chemical counterparts. Biopesticides tend to overcome many difficulties that are possessed by chemical or synthetic insecticides. They are inherently less harmful, have less environmental load, and are designed to affect only one specific pest or, in some cases, a few target organisms. The pesticides are often effective in very small quantities and are biodegradable, thereby resulting in lower exposures. Furthermore, the approach of Integrated Pest Management (IPM) can enable effective utilization of botanical insecticides (Gupta and Dikshit 2010).

Since ancient times, there have been efforts to protect harvest production against pests. The Egyptian and Indian farmers used to mix the stored grains with fire ashes (Bhargava 2009). The ancient Romans used false hellebore (*Veratrum album*) as a rodenticide, the Chinese are credited with discovering the insecticidal properties of *Derris* species, whereas *Pyrethrum* was used as an insecticide in Persia and China. In many parts of the world, locally available plants are currently in wide use to protect stored products against damage caused by insect infestation. Indian farmers use neem leaves and seed for the control of stored grain pests (Arthur 1996; Sharon et al. 2014).

2 Brief History of Biopesticides

Historically, nicotine was used to control plum beetles as early as the seventeenth century. A number of experiments were carried out in the nineteenth century by using plants and fungus as biological controls for insect pests in agriculture**.** The extensively used biopesticide included spores of the bacteria *Bacillus thuringiensis*. In 1938 (France), Sporeine, a first commercially available Bt product came in to picture. In 1977, *Bacillus thuringiensis* var. *israelensis* (toxic to flies) was discovered, and in 1983 the strain tenebrion is (toxic to beetles) was found. In 1979, the U.S. EPA registered the first insect pheromone for use in mass trapping of Japanese beetles. In the 1990s, researchers began testing kaolin clay as an insect repellent in organic fruit orchards. It was made commercially available, particularly for use in organic systems, in 1999. Throughout the early twentieth century, soil microbiology and ecology experiments had led to the identification and isolation of many soil-borne microorganisms that act as antagonists or hyper parasites of pathogens and insect pests. During 1980s and 1990s, several studies were done on the root cause of resistant pathogenic bacteria for the prevention of fire blight in orchards. Approximately 100 biopesticide active ingredients have been registered with the U.S. EPA Biopesticides Division since 1995 (Sources: University of Arkansas, the Ohio State University, U.S. EPA).

3 Biopesticides in India

In India, so far only 12 types of pesticides have been registered under the Insecticides Act, 1968 (Table 6.1). The pattern of pesticide usage in India is different from that for the world in general. The foremost use of pesticides in India is for cotton crops (45%), followed by paddy and wheat.

Table 6.1 Biopesticides registered as insecticides Act, 1968

S. No.	Name of the biopesticide
1.	*Bacillus thuringiensis* var. israelensis
2.	*Bacillus thuringiensis var. kurstaki*
3.	*Bacillus thuringiensis var. galleriae*
4.	*Bacillus sphaericus*
5.	*Trichoderma viride*
6.	*Trichoderma harzianum*
7.	*Pseudomonas fluorescens*
8.	*Beauveria bassiana*
9.	NPV of *Helicoverpa armigera*
10.	NPV of *Spodoptera litura*
11.	Neem-based pesticides
12.	Cymbopogan

A rough estimate shows that about one third of the world's agricultural production is lost every year due to pests despite the pesticide consumption which totalled more than 2 million tons. In India, pests cause crop loss of more than Rs. 6000 crores annually, of which 33% is due to weeds, 26% by diseases, 20% by insects, 10% by birds and rodents, and the remaining (11%) is due to other factors (Bunch et al. 2003).

The advent of the green revolution in India in the 1960s to boost agricultural productivity using High Yielding Variety (HYV) crops led to an increased use of fertilizers (as nutrients) and pesticides (as insecticides) (Sebby 2010). The use of insecticides increased considerably as Government of India statistics reveal (Bunch et al. 2003). The research studies to assess the environmental impact of heavy use of pesticides in India have revealed that it is detrimental for us to look at alternates to chemically synthesized pesticides. The adverse environmental impact ranges from soil infertility, pollution of water bodies, and health impact on farmers, labourers as well as consumers (Bunch et al. 2003; Kandpal 2014).

4 Botanical Insecticides

Approximately 2400 plant species have bioactive compounds that possess pest control properties (Table 6.2). The activities of the extracts of such plants possess pest control properties, including killing activity, non-killing repellency activity, feeding deference, and growth inhibition (Bunch et al. 2003). In 1990, studies done by the World Health Organization reported that no segment of the population is protected against the hazardous exposure to pesticides and its adverse effects. The survey also noted that the risk of exposure detrimental to health is higher in developing countries (Aktar et al. 2009). The risk varies from direct impact on humans (Nigam et al. 1993), impact through food commodities (Kashyap et al. 1994), and impact on

Table 6.2 Plant products registered as biopesticides (Kandpal 2014)

Plant product used as biopesticide	Target pests
Limonene and Linalool	Fleas, aphids, and mites, also kill fire ants, several types of flies, paper wasps, and house crickets
Neem	A variety of sucking and chewing insect
Pyrethrum/Pyrethrins	Ants, aphids, roaches, fleas, flies, and ticks
Rotenone	Leaf-feeding insects, such as aphids, certain beetles (asparagus beetle, bean leaf beetle, Colorado potato beetle, cucumber beetle, flea beetle, strawberry leaf beetle, and others), and caterpillars, as well as fleas and lice on animals
Ryania	Caterpillars (European corn borer, corn earworm, and others) and thrips
Sabadilla	Squash bugs, harlequin bugs, thrips, caterpillars, leaf hoppers, and stink bugs

environment, surface water contamination (Kubiak et al. 1989) ground water contamination, soil contamination, and effect on soil fertility (beneficial soil microorganisms), contamination of air, soil and non-target vegetation and non-target organisms (Reijnders 1986).

In northern Cameroon, cowpeas are traditionally mixed with sieved ash after threshing and the mixture put into mud granaries or clay jars. In eastern Africa, leaves of the wild shrub Ocimum suave and the cloves of Eugenia aromatic are traditionally used as stored grain protectants. In Rwanda, farmers store edible beans in a traditional closed structure (imboho) and whole leaves of *Ocimum canum* are usually added to the stored foodstuff to prevent insect damage within these structures. Owusu suggested some natural and cheaper methods for the control of stored products from pests, with traditionally useful Ghanaian plant materials. In some south Asian countries, food grains such as rice or wheat are traditionally stored by mixing with 2% turmeric powder. The use of oils in stored products for pest control is also an ancient practice. Botanical insecticides such as *Pyrethrum*, derris, nicotine, oil of citronella, and other plant extracts have been used for centuries. More than 150 species of forest and roadside trees in India produce oilseeds, which have been mainly used for lighting, medicinal purposes, and also as insecticides from ancient times to early twentieth century. Turmeric, garlic, *Vitex negundo*, gliricidia, castor, *Aristolochia*, ginger, *Agave americana*, custard apple, Datura, *Calotropis*, *Ipomoea*, and coriander are some of the other widely used botanicals to control and repel crop pests (Rajashekar et al. 2012; Verma et al. 2010).

4.1 Plant Pesticides/Bio-agents

Plant pesticides are pesticidal substances that plants produce from genetic material that have been added to the plant (Table 6.3). For example, scientists can take the gene for the Bt pesticidal protein and introduce the gene into the plants own genetic

Table 6.3 Potential biopesticides (from plant extract) (Kandpal 2014)

Plant extracts	Effective against
Adathoda kashayam and Pudhina kashayam	Leaf folder, bacterial leaf blight, Helminthosporium leaf spot
Thriphala kashayam	Bacterial leaf blight and Helminthosporium leaf spot
Andrographis kashayam and Sida kashayam	Aphids and borers in brinjal, ladies finger
Barley Sesamum Horsegram kashayam	Acts as fruit yield enhancer
Cow's urine arkam and Sweet flag arkam	Bacterial leaf blight, Helminthosporium leaf spot, vein clearing disease, fusarium wilt
Garlic arkam	Leaf folder, bacterial leaf blight, Helminthosporium leaf spot
Neem seed extract (for all crops)	Leaf folder, aphids, Jassids, fruit borer, and stem borer

material. Then the plant, instead of the Bt bacterium, manufactures the substance that destroys the pest. Both the protein and its genetic material are regulated by EPA; the plant itself is not regulated.

4.2 Neem as Pesticides

Derived from the neem tree, it contains several chemicals, including ‘azadirachtin’, which affects the reproductive and digestive process of a number of important pests. Recent research carried out in India and abroad has led to the development of effective formulations of neem, which are being commercially produced (Asogwa et al. 2010). As neem is non-toxic to birds and mammals and is non-carcinogenic, its demand is likely to increase. However, the present demand is very small. Neem-based pesticides are marketed in India in different trade names containing 300, 1500, 3000, 5000, 10,000, and 50,000 ppm of azadirachtin in it. Some of them are Ozoneem Trishul, Margocide OK, Godrej Achook, Nimbicidine, Bioneem, Neemark, Neem gold, Neemax, Rakshak, Econeem, Limnool, and Repelin containing 300 ppm of azadirachtin (Mishra 2014).

Almost all parts of neem tree, viz., leaves, drupes, barks, and seeds contain a pool of biologically active constituents, including the triterpenoids azadirachtin, salanin, and meliantriol. These compounds give protection against more than 100 species of insects, mites, and nematodes including economically important pests like desert and migratory locusts, rice and maize borers, plant hoppers of rice, pulse beetle and rice weevil, rootknot and reniform nematodes, and citrus red mite. Modes of pest control by neem include antifeedant, growth regulatory, repellent, hormonal or pesticidal action in larva, and/or adult stages of these pests. It is probably because of the pest control quality, idol of ‘Lord Jagannath’ is made up of neem tree trunk which will not be attacked by wood boring beetles, termites, and last long. That also proves the use of neem as a pest control agent in ancient India. Mishra in 2014 has described, *Pyrethrum*, Niotine Sulphate, *Parthenium hysterophorus*, *Vitex negundo* (Begunia), *Acorus calamus* L. (Bacha), Adhatoda zeylanica (Basanga), *Anacardium occidentale* (Cashew nut), *Ageratum conyzoides* (goat weed Pokasungha), *Chireita*, *Catharanthus roseus* (Sadabihari), *Clerodendron* inermi (Genguti), *Plumbago zeylanica* (Dhalachita): *Ipomeacarnea* (Amari) in details in his potential and comprehensive review.

5 Microbial Pesticides

Microorganisms such as bacteria, fungi, viruses, algae, and protozoan have been reported single or in combination as biopesticides. Microbial pesticides can control a variety of pests (Table 6.4). The most extensively known microbial pesticides are varieties of the bacterium *Bacillus thuringiensis*, or Bt, which can control certain

Table 6.4 Microbial agents, crops, and target diseases

Microbial agent	Crop	Target disease
Bacillus subtilis DB1501	Turf grass	Brown leaf blight
Paenibacillus polymyxa AC-1	Pepper, cucumber	Phtophythora bright powdery mildew
Streptomyces goshikiensis WYE 325	Rice, turf grass	Sheath blight large patch
Streptomyces eolombiensis WYE 20	Turf grass, strawberry, cucumber	Grey mold, brown leaf bright powdery mildew
Bacillus subtilis KBC 1010	cucumber	Grey mold
Bacillus subtilis GB-365	Tomato	Bright grey mold
Bacillus subtilis GB-365	Turf grass	Phytophthora bright powdery mildew

insects in cabbage, potato, and other crops. Bt produces a protein that is harmful to specific insect pests. Certain other microbial pesticides act by out-competing pest organisms.

5.1 Bacteria

Several bacterial strains have been reported as entomopathogens but biopesticides that have been most successful commercially are based on spore forming bacterium *Bacillus thuringiensis* (Bt). Over 30 Bt subspecies have been discovered, but only half a dozen of them have been closely evaluated as pest control agents. Bt is known to infect at least four orders (Lepidoptera, Diptera, Coleoptera, Acarina) but lepidopteran larvae with gut pH of 9.0–10.5 are most susceptible. Bt is a crystalliferous spore former and in addition to endospores produces a parasporal crystal which contains delta endotoxin. Upon ingestion by susceptible individuals, the delta endotoxin crystal is digested into active toxins which kills the insects or weakens the host so that the bacteria can readily invade the haemocoel from the gut and produce lethal septicaemia (Mishra 2014).

5.2 Fungi

Approximately 750 fungal species belonging to 100 genera are entomopathogenic. Several strains of fungal pathogens have been used for the control of crop pests in India. The important genera are *Coelomomyces, Entomophthora, Massospora* belonging to *Mastigomycotina*; *Cordyceps*, *Podonectria*, *Torrubiella* belonging to *Ascomytina*; and *Aspergillus*, *Beauveria*, *Fusarium*, *Hirsutella*, *Metarhizium*, *Nomuraea*, *Paecilomyces*, etc. belonging to *Deuteromycotina*. The development of fungal infections in terrestrial insects is largely influenced by terrestrial conditions.

High humidity is vital for germination of fungal spores and transmission of the pathogen from one insect to another. Entomopathogenic fungi have several strains. They are known to produce toxins and nearly 33 toxins are known till date (Mishra 2014). Examples are *Metarhizium* anisopliae on Oryctes rhinoceros L., *Fusarium oxysporum* on BPH, *Verticillium lecanii* on *Coccus viridis* (Green), *Beauvaria bassiana* on Spodoptera litura, and *Helicoverpa armigera*. Some of the trade products of *Beauveria bassiana* available in Indian market are Boverin, Biopower, Ankush, Daman, and Multiplex Beauveria.

5.3 Viruses

Approximately 60% of the 1200 known insect viruses belong to baculoviridae that can be used against 30% of all major pests of food and fibre crops. Majority of the baculoviridae, those have been developed as biopesticide are bacilliform or rod shaped and include nuclear polyhedrosis viruses (NPVs) and to a lesser extent granulosis viruses (GVs). Upon ingestion by the larvae, the protein coat dissolves in the mid gut and the virions enter the epithelial cells of mid gut. Later, they infect the fat bodies, epidermis, tracheal matrix, muscle, gonads, haemocytes, nervous and endocrine system. After an incubation period of 5–7 days (sometimes 20 days), the larvae become sluggish, yellowish, or pinkish in colour, swell slightly, and then become limp and flaccid. Shortly before death, the integument becomes very fragile. The dead larvae found hanging by their pro-legs from the top of the host plant. Finally, they dry up and look like a dark brown or black cadaver. Presently, NPVs for *Helicoverpa* (*Helicide*, *Heliocel*, Biovirus H) and Spodoptera (*Spodocide*, *Litucide*, *Biovirus* S) are available in India and used for control of these two polyphagous pests infesting tomato, tobacco, arhar, cotton, vegetables, oilseeds, etc. The need for propagating these organisms and costs involved in producing them have limited viruses as products of significant commercial importance. GV of Chilo infuscatellus, codling moth, potato tuber moth, and cabbage butterfly are widely used for control of vegetable and field pests in advanced countries and some parts of India. These are produced by the farmer's co-operatives or cottage industries (Mishra 2014).

5.4 Nematodes

Nematodes are known to parasitize insects. Notable among them are *Neoaplectana carpocapsae*, which infects ten different orders of insects. One of its strains DD-136 is used extensively for control of insect pests of orchards, vegetables, field crops, forests, and turf crops. Another nematode *Tetradonema plicans* is used against sciarid flies and pests of cultivable mushrooms. Similarly, *Romanomermis* *culicivorax* is marketed under the trade name 'Skeeter' and *Steinernema feltiae* as 'Doom', 'Seek', and 'Spear' is used for control of soil pests and termites. In India, *Rhabditis* sp. has been reported to be useful against *Holotrichia serrata* (white grub). (Mishra 2014).

5.5 Protozoa

Approximately 1000 species of protozoans pathogenic to insects have been described. Most of them are chronic debilitating agents, affecting host vigour, longevity, and fecundity. Most of the protozoa considered for use are microsporidia, and their spores enter the host by ingestion. Once in the gut, they exude a long tube that injects the pathogens into the host tissue where it multiplies vegetatively in the cytoplasm of cell, gradually spreading throughout the body and causing a chronic disease that may or may not kill the host. In India, *Farinocystis tribolii* has been found to be promising against *Tribolium castaneum*. 'Noloc' is the formulation based on *Nosema locustae* infecting grasshoppers and is regarded as safe to use. *Nosema* has been evaluated for control of grasshoppers, European corn borer, and spruce bud worm (Mishra 2014).

Advantages

1. Microbials are naturally occurring.
2. These have a high degree of specificity to target pests.
3. No or little adverse effect on beneficial insects.
4. Potential development of pest resistance to microbials is less common or may develop more slowly due to unique mode of action.
5. No known environmental hazards.
6. Less residual activity. (Adopted from Mishra 2014)

Limitations

1. Microbials have narrow spectrum of activity. They control only the target pest which is not economical when mixed populations are required to be controlled.
2. These are effective only when applied at specific development stage of target species.
3. Often slow acting.
4. Microbials have short residual toxicity, require frequent applications.
5. In order to be effective microbials require high application rate and thorough spray coverage.
6. Some of them require specific weather conditions to be effective (Adopted from Mishra 2014) (Table 6.5)

Table 6.5 Benefits of biopesticides (Gupta and Dikshit 2010)

Factors	Benefits of biopesticides
Cost-effectiveness	Costlier but reduced number of applications
Persistence and residual effect	Low, mostly biodegradable and self-perpetuating
Knockdown effect	Delayed
Handling and bulkiness	Bulky: Carrier based Easy: Liquid formulation
Pest resurgence	Less
Resistance	Less prone
Effect on beneficial flora	Less harmful on beneficial pests
Target specificity	Mostly host specific
Waiting time	Almost nil
Nature of control	Preventive
Shelf life	Less

6 Conclusion

Rich source of Indian biodiversity is a potential source of all types of natural biopesticides which can be used at a large scale in agriculture. Biopesticides and natural enemies of pests are likely to play an important role in IPM in modern agriculture for controlling pests of vegetables and fruit crops in the near future besides grain crops, forest pests, and pests of domestic and public health. Because of their slow active nature, we need to develop effective strategies for using them in agriculture. Research and development of pest control methods must be given importance. Extension workers and farmers need to be educated on their use. The price of the commercial biopesticides has to be competitive with synthetic chemical pesticides or alternately the government has to provide subsidies for encouraging their use in agriculture. Related regulations do not go nearly far enough in evaluating the broader impacts of biopesticides. This will lead to an overall increased awareness and action about the benefits of biopesticides.

Acknowledgement Authors of this chapter are thankful to Dr. Ashok K. Chauhan, Founder President, Amity University and Dr. Atul Chauhan, Chancellor, Amity University, Noida Campus for providing all necessary support and encouragement.

References

Aktar MW, Sengupta D, Chowdhury A (2009) Impact of pesticides use in agriculture: their benefits and hazards. Interdiscip Toxicol 2:1–12

Annual Report (2010–2011) National Centre for Integrated Pest Management, LBS Building, Pusa Campus, New Delhi, India

Arthur FH (1996) Grain protectants: current status and prospects for the future. J Stored Prod Res 32:293–302

Asogwa EU, Ndubuaku TCN, Ugwu JA, Awe OO (2010) Prospects of botanical pesticides from neem, *Azadirachta indica* for routine protection of cocoa farms against the brown cocoa mirid—Sahlbergella singularis in Nigeria. J Med Plant Res 4(1):1–6

Azmathullah NM, Sheriff MA, Mohideen AS (2013) Phytochemical screening and Larvicidal efficacy of *Calotropis procera* flower extract against Culex Sp. and *Anopheles* Sp. Mosquito larvae. J Environ Sci 2:938–943

Bhargava MC (2009) Pests of stored grains and their management. New India Publishing Agency, New Delhi

Bunch MJ, Suresh VM, Kumaran TV (2003) Environment and health aspects of pesticides ue in Indian agriculture. *Callosobruchus chinensis* (Chinese bruchid) [WWW Document], n.d. http://www.cabi.org/isc/datasheet/10986. Accessed 27 Mar 15

Casida JE, Quistad GB (1998) Golden age of insecticide research: past, present, or future? Annu Rev Entomol 43:1–16

Chauhan A, Ranjan A, Jindal T (2016) Insecticidal activity of Methanolic extract of *Calotropis procera* against *Callosobruchus maculatus* using Moong seeds (*Vigna radiata*). J Biomed Pharm Res 5(6):75–82

Damalas CA, Eleftherohorinos IG (2011) Pesticide exposure, safety issues, and risk assessment indicators. Int J Environ Res Public Health 8:1402–1419

Dubey NK, Srivastava B, Kumar A (2008) Current status of plant products as botanical pesticides in storage pest management. J Biopest 1:182–186

Giday M, Asfaw Z, Elmqvist T, Woldu Z (2003) An ethnobotanical study of medicinal plants used by the Zay people in Ethiopia. J Ethnopharmacol 85:43–52

Gupta S, Dikshit AK (2010) Biopesticides: an eco-friendly approach for pest control. J Biopest 3(1):186–188

Isman MB (2006) Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu Rev Entomol 51:45–66

Jain SC, Sharma R, Jain R, Sharma RA (1996) Antimicrobial activity of *Calotropis procera*. Fitoterapia 67:275–277

Kandpal V (2014) Biopesticides. Int J Environ Res Dev 4(2):191–196

Kashyap R, Iyer LR, Singh MM (1994) Evaluation of daily dietary intake of dichloro-diphenyl-trichloroethane (DDT) and benzene hexachloride (BHC) in India. Arch Environ Health 49:63–66

Kubiak TJ, Harris HJ, Smith LM, Schwartz TR, Stalling DL, Trick JA, Sileo L, Docherty DE, Erdman TC (1989) Microcontaminants and reproductive impairment of the Forster's tern on Green Bay, Lake Michigan—1983. Arch Environ Contam Toxicol 18:706–727

Mishra AK, Dubey NK (1994) Evaluation of some essential oils for their toxicity against fungi causing deterioration of stored food commodities. Appl Environ Microbiol 60:1101–1105

Mishra HP (2014) Role of botanicals, bio pesticides and bio agents in integrated pest management. Odisha Review, India

Murti Y, Yogi B, Pathak D (2010) Pharmacognostic standardization of leaves of *Calotropis procera* (Ait.) R. Br. (Asclepiadaceae). Int J Ayurveda Res 1:14–17

Nauen R, Bretschneider T (2002) New modes of action of insecticides. Pestic Outlook 13:241–245

Nigam SK, Karnik AB, Chattopadhyay P, Lakkad BC, Venkaiah K, Kashyap SK (1993) Clinical and biochemical investigations to evolve early diagnosis in workers involved in the manufacture of hexachlorocyclohexane. Int Arch Occup Environ Health 65:S193–S196

Panagiotakopulu E, Buckland PC, Day PM, Doumas C (1995) Natural insecticides and insect repellents in antiquity: a review of the evidence. J Archaeol Sci 22:705–710

Verma R, Satsangi GP, Shrivastava JN (2010) Ethno-medicinal profile of different plant parts of *Calotropis procera*. Ethnobot Leafl 14:721–742

Rahman A, Talukder FA (2006) Bioefficacy of some plant derivatives that protect grain against the pulse beetle, *Callosobruchus maculatus*. J Insect Sci 6:3

Rahman MM, Islam W (2007) Effect of Acetonic extracts of *Calotropis procera* R Br. In (Ait.) on reproductive potential of flat grain beetle *Cryptolestes pusillus* (Schon.) (Coleoptera: Cucujidae). Bangladesh J Sci Ind Res 42:157–162

Rajashekar Y, Bakthavatsalam N, Shivanandappa T (2012) Botanicals as grain protectants. Psyche J Entomol. doi:10.1155/2012/646740

Ranjan A, Kumar A, Thakur S, Gulati K, Shrivastav C, Jindal T (2016) *Lantana camara* as an alternative for biological control of pulse beetle *Callosobruchus maculatus*, Asian. J Microbiol Biotechnol Environ Sci 18(2):535–539

Reijnders PJ (1986) Reproductive failure in common seals feeding on fish from polluted coastal waters. Nature 324:456–457

Sebby K (2010) The Green Revolution of the 1960's and Its Impact on Small Farmers in India

Sharon M, Abirami CV, Alagusundaram K (2014) Grain storage management in India. J Post-Harvest Technol 2:12–24

Chapter 7
Environmental Toxicological Studies with Reference to Increasing Asthma Cases in Rural and Urban India

Khushbu Gulati, Shalini Thakur, and Tanu Jindal

Abstract Asthma is a chronic condition characterized by swelling of walls and contraction of smooth muscles in the airway with the secretion of thick, tenacious mucus resulting in narrowing/obstruction of the airways. It affects people regardless of age, and in some cases can prove to be fatal. Growing incidence of asthma in both developed and developing countries has been a major public health challenge for more than two decades. In this review, we will discuss different instances indicating the detrimental effect of environmental pollution. One of the major issues of interest will be whether the daunting levels of environmental pollution in India has a great impact on lung diseases particularly asthma and allergic diseases.

Keywords Asthma • Toxicological studies • Rural • Urban • Environmental pollution

1 Introduction

Vehicle traffic is one of the most significant emission sources of air pollutants in urban areas. Vehicle-related emissions can cause severe air pollution problems in many sectors, and air pollution associated with traffic is a widespread environmental concern (Colvile et al. 2001). Exposure to traffic-generated pollutants, which include oxides of nitrogen (NOx), carbon monoxide (CO), volatile organic carbon (VOC), and particulate matter (PM), can cause adverse health effects such as impaired lung function and asthma (Anderson et al. 2011; Clark et al. 2010), deficits in lung function growth (Gauderman et al. 2007), and cancer (Buffler et al. 2005;

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7_7

Langholz et al. 2002). Vulnerable groups include individuals with existing respiratory and cardiovascular disease, e.g., children with asthma (Gasana et al. 2012; Lindgren et al. 2010).

1.1 Global Scenario

Approximately 300 million people are asthma patients worldwide. The global prevalence of asthma is anticipated to be about 4.5%. There are about 334 million patients with asthma affecting all age groups, across the world. The prevalence of asthma has increased over time, and an additional 100 million people worldwide are expected to develop asthma by the year 2025 (Behera and Sehgal 2015).

1.2 Indian Scenario

According to the Indian Council of Medical Research (ICMR), the number of asthmatics in India is approximately 30 million. Asthma affects 3–38% of children and 2–12% of adults. There is an increasing evidence of the negative health impact resulting from environmental air pollution, in particular, that associated with respiratory diseases and allergy. The growing prevalence of respiratory diseases and allergy such as asthma has drawn attention to the potential role of air pollution in causing this (Behera and Sehgal 2015).

In the Indian Study on Epidemiology of Asthma, Respiratory Symptoms and Chronic Bronchitis in adults (INSEARCH), a survey conducted in two phases across 16 centers in India, the prevalence of asthma in adults was 2.05%, with an estimated burden of 17.23 million (Aggarwal et al. 2006). A recent analysis using three different assessment models, i.e., INSEARCH, Global Initiative for Asthma (GINA), and World Health Organization (WHO) survey suggests that the prevalence of asthma in India varies between 2.05 and 3.5% which roughly amounts to 17–30 million patients (Agarwal et al. 2014). The estimated cost of asthma treatment per year for the year 2015 has been calculated to be approximately Rs. 139.45 billion (Murthy and Sastry 2015). An estimated 15 million Disability-Adjusted Life Years (DALYs) are lost due to asthma (To et al. 2012).

Data published by the Health Effects Institute indicates that a 10 μg m^{-3} increase in PM_{10}, the coarse particulate fraction of air pollution, is associated with an increase in mortality of 0.6% in daily all natural cause mortality in the main cities such as India and China (HEI, International Scientific Committee 2010).

Recently, a nationwide survey called "*Breath Blue 15*" concluded that the lung health of children in metropolitan cities of India is poor. In all, 2000 children in the age group of 8–14 years were screened for lung health status. Out of children population in Delhi, 40% were found to have ratings of "*bad*" to "*poor*" lung health, while Bengaluru followed closely with 36%, Kolkata with 35%, and Mumbai with 27%.

It is no coincidence that these cities are some of the most polluted cities in the world. Air pollution levels in these cities are at an all-time high, owing to multiple factors such as overcrowding, mass immigration, the rise in vehicular population and consequent smoke emission, and industrial activity.

1.3 Prevalence of Asthma: Urban vs. Rural Areas

It has been suggested that, compared to urban dwellers, people living in the countryside generally have better health, along with fewer disabilities and long-term limiting illnesses (Iversen et al. 2005). Coherent evidence shows that differences in the prevalence of asthma morbidity between urban and rural areas exist (Yemaneberhan et al. 1997; Ellison-Loschmann et al. 2004; Smith et al. 2009). Such difference in the prevalence of asthma morbidity may result from increasing urbanization, or from socioeconomic and cultural factors, as well as individual societal factors.

Vehicular pollution, particularly in metropolitan cities experience thick smog and haze resulting in asthmatic attacks. When combined with smog and other atmospheric pollutants, illness from allergic respiratory diseases, particularly asthma, could increase.

The quality of air is likely to decrease as surface ozone concentrations begin to rise with increasing temperatures. This will lead to an increasing incidence of asthma and other cardiovascular and respiratory diseases (Liggins 2008). This issue is being addressed by the Govt. of India by introducing compressed natural gas (CNG) for transport and replacement of wood fire for cooking by the liquid petroleum gas (LPG) in villages (USAID/ASIA Report 2007). It is an excellent example of co-benefits of other sectors to human health.

Indian cities today are among the most polluted areas in the world, and it is estimated that outdoor air pollution leads to approximately 670,000 deaths annually (Lim et al. 2013). Current standards, for particulate matter set by the Central Pollution Control Board (CPCB2009), are much higher than those recommended by the WHO (Krzyzanowski and Cohen 2008). Also, unlike other countries (Bell et al. 2003; Dominici et al. 2007), the CPCB does not take into account findings from health literature when deciding on air quality standards (Balakrishnan et al. 2011).

A periodic review of epidemiological evidence informs policy makers about current health risks associated with air pollution and sets the agenda towards finding a balance between reducing health impacts and the costs of implementing further air pollution controls (Dominici et al. 2004). An interesting finding of the analysis is that cities such as Ahmedabad and Mumbai that have higher levels of pollution experience a relatively lower increase in mortality for every 10 mg m^{-3} increase in PM_{10}. In contrast, the percentage increase in mortality is highest for Shimla which is among the cleanest cities. The percentage increase in mortality associated with a 10 mg m^{-3} increase in PM_{10} is highest for Shimla (1.36%) and the least for Ahmedabad (0.16%). Bangalore and Mumbai showed similar results with a 0.22%

and 0.20% mortality increase, respectively, at a 95% confidence interval. Findings suggested that small reductions in pollution in cleaner cities will yield tremendous health benefits, whereas, in less clean cities, even significant reduction in pollution may yield only modest health advantages in a relative sense.

Indian metropolitan cities remain exposed to high levels of air pollutants mainly due to high vehicular movements and poor roads. Although the concentration of these pollutants varies according to the traffic density, type of vehicles, and time of day, some people by their occupation are more exposed to high levels of traffic-related air pollutants. These people include filling station workers, traffic police officers, professional drivers, and toll booth workers because of the proximity and high emissions from vehicle idling, deceleration, and acceleration (Sehgal et al. 2014).

In a recently conducted study on air quality monitoring ($PM_{2.5}$, CO, NO_X, SO_2, and EC/OC) at highway toll plazas, municipality toll plazas, and control sites which were 23 in number, it was found that there was a high level of air pollution at almost all locations with $PM_{2.5}$ values exceeding the national permissible limit (60 μg m^{-3}) except at a few control sites. The study found that pollutant concentrations were highest at municipality toll plazas with minimum protective work areas. The observed reduction in lung function indices was significant over years of occupational exposure even after making adjustments for age, among non-smoking outdoor workers (TERI 2015).

Some studies have suggested that ambient air pollution can trigger asthma attacks (Bjorksten 1999; Koren and Utell 1997). Exposure to several specific air pollutants, such as respirable particulate matter (RSPM) [≤10 μm in aerodynamic diameter (PM_{10})], carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), has been associated with increased asthma symptoms (Baldi et al. 1999; Bates 1995; Castellsague et al. 1995; de Diego Damia et al. 1999; Greer et al. 1993; Hajat et al. 1999; Koren 1995; Zhang et al. 1999).

2 Case Studies

India has about 10% of the global asthma burden of between 100 and 150 million people—roughly the equivalent of the population of Russia. This number is increasing, and global deaths due to asthma have reached over 1,80,000 annually (Times of India Report 2015).

The primary source of suspended particulate in Delhi is burning of fossil fuels, power stations, vehicular transport, industries, domestic coal, and open biomass burning. Vehicle exhausts have been implicated for an increased prevalence of wheeze, rhinitis, asthma, and other respiratory symptoms in children (Ciccone et al. 1998). Few studies (Shima et al. 2002; Edward et al. 1994) have reported air pollution as a causative factor for asthma. In a 6-year follow-up study (Shima et al. 2002) among Japanese children, a significant association was found between the annual average concentration of NO_2 and the incidence of asthma.

Many northern cities including Agra, Patna, and Lucknow continue to show an alarmingly high pollution level. The pollution levels in few Indian cities have earned the embarrassing distinction of having exceeded the toxic levels of Beijing and other Chinese cities, demonstrating levels at least ten times higher than the WHO standards, making air pollution indeed a national emergency.

Greenpeace India analyzed the data provided by the National Air Quality Index (NAQI) portal and concluded that control strategies need to move beyond just Delhi because air pollution seems to be a regional problem rather than just local one. The organization said that steps are needed at national level to reduce the levels of particulate matter $PM_{2.5}$ and PM_{10} (Myllyvirta and Dahiya 2015).

While Delhi was found to have pollution levels 12 times higher than WHO guidelines, another six cities—Lucknow, Faridabad, Ahmedabad, Kanpur, Agra, and Varanasi—had pollution levels at least ten times as higher than permissible under these standards.

Greenpeace also compared the levels of pollution in Indian cities to Beijing's red-alert standard and estimated how many days the cities would be shut if they were following China's rules of issuing alerts in times of severe air pollution. It turned out that in a 91-day period between September and November, Delhi met the Chinese criteria for 33 days while Lucknow met it for 40 days.

In 2014, the WHO released a list of world's 20 most polluted cities, 13 of which were in India (WHO Report 2014). Earlier, the Global Burden of Disease (GBD) report had estimated air pollution to be the fifth deadliest killer in the country (GBD Report 2013).

Even as Indian cities remain exposed to critically high levels of toxic substances in their air, the absence of comprehensive data collection makes things worse. Delhi is now the 11th most polluted city in the world, based on average annual $PM_{2.5}$ readings of 3000 cities in 100 countries while Gwalior (2), Allahabad (3), Patna (6), and Raipur (7) figured in the top seven (WHO 2016).

Cases of severe breathlessness, asthma and allergy have sharply risen in Delhi as the city was recently blanketed in a thick layer of toxic air due to the worst smog in 17 years. A thick shroud of menacing gray haze enveloped the national capital even as pollution level breached the safe limit by over 17 times at many places (The Indian Express Report 2016).

Air pollution is one of the top 10 killers in the world and the fifth leading cause of death in India said the study titled *Body Burden 2015: State of India's Health* (Narain et al. 2015). In 2015, the highly polluted conditions in the capital saw a spurt in asthma cases by up to 20% when compared to the previous year. After Diwali, the number of asthmatic patients has increased substantially. The Delhi High Court has observed that living in Delhi is like living "*in an open gas chamber*."

To curb this menace, the Delhi Government initiated an odd-even plan which restricted the movement of vehicles to a great extent thus resulting in a decline in air pollution levels to a certain degree. Also, given managing pollution concentrations in the city, the Supreme Court has decided to double the "*green tax*" on commercial vehicles entering the city in a bid to curb air pollution in the national capital by discouraging such vehicles from using city roads to avoid tolls on other routes. For taxi services like Ola and Uber, the court is likely to direct a complete shift to CNG from diesel. It is also liable to order the civic bodies in Delhi and the central government to ensure that no waste shall be burned in the city. Further, the court may stop vehicles older than 2005 from entering the city limits. According to a study released by environment research organization Centre for Science and Environment, air pollution claims at least 10,000 to 30,000 lives a year in Delhi (Livemint 2015).

The odd-even pilot reduced hourly particulate air pollution concentrations by 10–13%. This car ban may help cut emissions of the smallest particles because combustion of fuel in vehicles produces these directly. But for the longer run, a congestion-pricing program may be better.

Air pollution is shortening lives in Delhi and too many other places in India and elsewhere. The odd-even scheme has delivered over these 2 weeks, but may not over the long term. Furthermore, vehicles are only one source of pollution.

There is no shortage of creative ideas and potential pilots, but what is all too often lacking is evidence on which ones work as intended. In one effort to improve matters, the University of Chicago has launched a competition with the Delhi Dialogue Commission to crowdsource ideas for reducing air and water pollution (the Delhi Urban Labs Innovation Challenge). More generally speaking, governments need to accept that we don't have all the answers to policy problems and adopt a culture of trying out new ideas, testing them carefully, and then deciding which ones to choose at scale.

The Delhi government's odd-even road rationing policy resumed with the government evaluating the effects of the implementation between January 1 and January 15, 2016. The second phase of the odd-even plan was also implemented from April 15 to 30, 2016. Delhi Pollution Control Committee (DPCC) data shows peak levels of O_3 dropped this year at some stations in Central Delhi. According to scientists, the real impact of the scheme could be accessed scientifically only after comparing the 15 days with the whole summer season as was done for the January data. The data of the odd-even fortnight needs to be compared with the entire winter season to understand its impact on air quality.

The agenda behind the policy is necessary to comprehend. The aim of the implementation was to arrest the peaks of pollution as was done in winter. Even if the ambient air quality does not indicate that it needs to be understood that the actual human exposure has come down significantly. The study shows broadly consistent impact on traffic congestion over two rounds of odd-even in Delhi suggesting that it can be a short-term or emergency measure in the future too. Odd-even led to a consistent reduction in traffic congestion, which was remarkably stable across the two rounds (The Indian Express Report 2016).

Beyond odd-even, an IIT Kanpur report titled "*Source Apportionment Study of $PM_{2.5}$ and PM_{10}*" on air pollution in Delhi has made a slew of recommendations required till 2023 after identifying the top sources of emission.

Along with vehicles, construction, and industries, the study has identified road dust, coal-based tandoors, and concrete batching as primary sources of air pollution in Delhi. The study has estimated the total PM_{10} emission load in the city at 143 tons day^{-1} and listed the top contributor as road dust (56%) and the $PM_{2.5}$ load at 59 tons day^{-1}, the top contributors being road dust (38%) and vehicles (20%), followed by domestic fuel burning and industrial point sources.

2.1 Vehicles

These are the second largest source of particulate matter, particularly $PM_{2.5}$. According to the report, vehicular pollution grew from 64 to 72% between 1990 and 2000. In winter, on average vehicles can contribute 25% to $PM_{2.5}$ and at certain locations this could be above 35%. There is a significant contribution of diesel vehicles to PM_{10} and $PM_{2.5}$.

2.2 Road Dust

The silt load on some of Delhi's roads is very high, and silt can become airborne with the movement of vehicles. The estimated PM_{10} emission from road dust is over 65 tons day^{-1}. Soil from open fields too gets airborne in summer. In some parts of the city, roads are broken, poorly maintained and partially paved surfaces and the study found that movement of vehicles may cause non-exhaust road dust emission in significant amounts. PM_{10} and $PM_{2.5}$ emission from road dust is 79,626 and 22,165 kg day^{-1}, respectively.

2.3 Concrete Batching

During the study period, massive construction activities were found that required concrete batching, including at 60 Delhi Metro Rail Corporation (DMRC) locations where construction was under progress. It was assumed that there would be 40 concrete batching plants of 120 cu.m h^{-1} capacities operating for 16 h. Several medium and small construction activities were also observed in the city. PM_{10} and $PM_{2.5}$ emissions from concrete mix plants are estimated at 14.37 and 3.5 tons day^{-1}, respectively. A few hundred plants in National Capital Region (NCR) may contribute to this.

2.4 Hotels and Restaurants

Details of hotels and restaurants were obtained from DPCC and related websites. The field survey found that hotels, restaurants, etc. use coal as fuel in tandoors. The average consumption of fuel in tandoors based on the study was 30 kg day^{-1}. The number of hotels and restaurants was 36,099 (Delhi Statistical Handbook 2014). The study assumes 25% of these enterprises use tandoors for food preparation.

2.5 Municipal Solid Waste Burning

The contribution of burning MSW is surprising. A study in Delhi has estimated 190–246 tons day^{-1} of MSW burning (Nagpure et al. 2015). This emission, it says, is expected to be large in the regions of economically lower strata of the society, which do not have the infrastructure for collection and disposal of MSW.

2.6 Diesel Generator Sets

Diesel generator sets are used as the source of power in shopping complexes and industries during the power-cut hours. The IIT Kanpur survey concluded that there is a minimum of 2 h day^{-1} power cuts in the city, especially in summer.

The study highlights the importance of involving the NCR cities in controlling air pollution. According to the report, sources outside Delhi (excluding secondary particles) contribute about 100 μg cu.m^{-1} of PM_{10} and 59 μg cu.m^{-1} of $PM_{2.5}$ in Delhi.

The problem of air pollution is not only restricted to the plains, but the hilly states have also been affected by it during the recent years. Similar steps have also been taken by National Green Tribunal (NGT) to combat air pollution levels in Himachal Pradesh capital Shimla. The NGT has directed the state Government to impose Rs. 500/− as "*green tax*" on each vehicle emitting pollution on Shimla's restricted roads, including the Mall Road.

Also in a bid to curb pollution levels across Himachal Pradesh, electric buses would now be used as the public mode of transport across all the routes. The distance between Manali and Rohtang Pass would be covered by CNG buses. Efforts to introduce an alternate mode of transportation are on after NGT took cognizance of diesel and petrol vehicles that are being used more and more nowadays with the increasing tourist influx. The decision would discourage the usage of diesel vehicles and would encourage the use of eco-friendly vehicles.

3 Discussion

There is now adequate affirmation to reveal that the practical damaging effect of contaminated environment on asthma and allergic diseases primarily observed in the developed countries is now occurring in developing countries like India. The evidence also supports the finding that outdoor air pollution poses significant adverse effects on allergic diseases and respiratory health, while its risk level may be modified by the temporospatial and meteorological changes. Children and the elderly are particularly vulnerable to the effects of air pollution (Zhang et al. 2015).

While further extensive and more comprehensive studies are needed, the currently available data would serve as an important evidence-based foundation in establishing the link between the outdoor air pollution and allergic diseases. The health implications and the importance of regional and intra-city differences and the combination of pollutant constituents should continue to be investigated. While the epidemiological evidence alone still carries some degrees of uncertainty in defining the environmental etiology, accumulated experimental evidence has provided evidence supporting their causative role. The solution to this problem is of course to reduce emissions of these pollutants. On the other hand, effective preventive measures and treatments need to be found.

A lot has to be done to reduce the burden of asthma in India. Cities have to be decongested, and rapid urbanization has to be checked. Vehicular emissions have to be measured, and erring vehicles should be kept off the roads. Deforestation and cutting of trees in urban areas have to be reduced; every area in a city should have a green space. Smoking has to be reduced through legislation and public health messages.

More than law and policy making, people should be disciplined enough to make sure that they are not contributing to air pollution themselves. Switching off engines of vehicles at traffic junctions, using public transport, and car-pooling may be simple, but effective ways of contributing to the environmental cause. It is important to remember that by causing air pollution, we are affecting the health and future of our children.

References

Agarwal R, Denning DW, Chakrabarti A (2014) Estimation of the burden of chronic and allergic pulmonary aspergillosis in India. PLoS One 9(12):e114745

Aggarwal AN, Chaudhry K, Chhabra SK, D'Souza GA, Gupta D, Jindal SK (2006) Prevalence and risk factors for bronchial asthma in Indian adults: a multicentre study. Indian J Chest Dis Allied Sci 48:13–22

Anderson HR, Favarato G, Atkinson RW (2011) Long-term exposure to air pollution and the incidence of asthma: meta-analysis of cohort studies. Air Qual Atmos Health 6(1):47–56

Balakrishnan K, Ganguli B, Ghosh S, Sankar S, Thanasekaran V, Rayadu VN, Caussy H (2011) Short-term effects of air pollution on mortality: results of a time series analysis in Chennai, India (Research report no. 157). Health Effects Institute

Baldi I, Tessier JF, Kauffmann F, Gadda JH, Nejjari C, Salamon R (1999) Prevalence of asthma and mean levels of air pollution: results from the French PAARC survey. Eur Respir J 14:132–138

Bates DV (1995) Observations on asthma. Environ Health Perspect 103(6):243–247

Behera D, Sehgal IS (2015) Bronchial asthma-issues for the developing world. Indian J Med Res 141:380–382

Bell ML, Samet J, Dominici F (2003) Time series studies of particulate matter. Johns Hopkins University, Department of Biostatistics working paper 10, Johns Hopkins, Bloomberg School of Public Health

Bjorksten B (1999) The environmental influence on childhood asthma. Allergy 54:17–23

Buffler PA, Kwan ML, Reynolds P, Urayama KY (2005) Environmental and genetic risk factors for childhood leukemia: appraising the evidence. Cancer Investig 23:60–75

Castellsague J, Sunyer J, Saez M, Anto JM (1995) Short-term association between air pollution and emergency room visits for asthma in Barcelona. Thorax 50:1051–1056
Ciccone G, Forastiere F, Agabiti N (1998) Road traffic and adverse respiratory effects in children. Occup Environ Med 55:771–778
Clark NA, Demers PA, Karr CJ, Koehoorn M, Lencar C, Tamburic L, Brauer M (2010) Effect of early life exposure to air pollution on development of childhood asthma. Environ Health Perspect 118:284–290
Colvile RN, Hutchinson EJ, Mindell JS, Warren RF (2001) The transport sector as a source of air pollution. Atmos Environ 35:1537–1565
CPCB (2009) National ambient air quality standards. The Gazette of India, New Delhi
Damia DA, Fabregas LM, Tordera PM, Torrero CL (1999) Effects of air pollution and weather conditions on asthma exacerbation. Respiration 66:52–58
Dominici F, McDermott A, Hastie TJ (2004) Improved semiparametric time series models of air pollution and mortality. J Am Stat Assoc 99(468):938–948
Dominici F, Peng RD, Zeger SL, White RH, Samet JM (2007) Particulate air pollution and mortality in the United States: did the risks change from 1987 to 2000? Am J Epidemiol 166(8):880–888
Edward J, Walters S, Griffiths RK (1994) Hospital admissions for asthma in preschool children: relationship to major roads in Birmingham, United Kingdom. Arch Environ Health 49:223–227
Ellison-Loschmann EL, King R, Pearce N (2004) Regional variations in asthma hospitalisations among Maori and non-Maori. N Z Med J 117:U745
Gasana J, Dillikar D, Mendy A, Forno E, Vieira RE (2012) Motor vehicle air pollution and asthma in children: a meta-analysis. Environ Res 117:36–45
Gauderman WJ, Vora H, McConnell R, Berhane K, Gilliland F, Thomas D, Lurmann F, Avol E, Kunzli N, Jerrett M, Peters J (2007) Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study. Lancet 369:571–577
Global Initiative for Asthma (GINA) (2014) Global strategy for asthma management and prevention
Greer JR, Abbey DE, Burchette RJ (1993) Asthma related to occupational and ambient air pollutants in nonsmokers. J Occup Med 35(9):909–915
Hajat S, Haines A, Goubet SA, Atkinson RW, Anderson HR (1999) Association of air pollution with daily GP consultations for asthma and other lower respiratory conditions in London. Thorax 54:597–605
HEI International Scientific Oversight Committee (2010) Outdoor air pollution and health in the developing countries of Asia: a comprehensive review. Special report 18. Health Effects Institute, Boston
Iversen L, Hannaford PC, Price DB, Godden DJ (2005) Is living in a rural area good for your respiratory health? Results from a cross-sectional study in Scotland. Chest 128:2059–2067
Koren HS (1995) Associations between criteria air pollutants and asthma. Environ Health Perspect 103(6):235–242
Koren HS, Utell MJ (1997) Asthma and the environment. Environ Health Perspect 105:534–537
Krzyzanowski M, Cohen A (2008) Update of the WHO air quality guidelines. Air Qual Atmos Health 1:7–13
Langholz B, Ebi KL, Thomas DC, Peters JM, London SJ (2002) Traffic density and the risk of childhood leukemia in a Los Angeles case-control study. Ann Epidemiol 12:482–487
Liggins F (2008) Impacts of climate change in India. Met Office Report
Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Rohani H, Aryee M (2013) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the global burden of disease study 2010. Lancet 380(9859):2224–2260
Lindgren A, Bjork J, Stroh E, Jakobsson K (2010) Adult asthma and traffic exposure at residential address, workplace address, and self-reported daily time outdoor in traffic: a two-stage case-control study. BMC Public Health 10:716
Murthy KJR, Sastry JG (2015) Economic burden of asthma. In: Burden of disease in India

Myllyvirta L, Dahiya S (2015) A status assessment of National Air Quality Index (NAQI) and pollution level assessment for Indian cities. Greenpeace India
Nagpure AS, Ramaswami A, Russell A (2015) Characterizing the spatial and temporal patterns of open burning of municipal solid waste (MSW) in Indian cities. Environ Sci Technol 49:12904–12912
Narain S, Varshney V, Mahapatra R (2015) Body burden 2015: state of India's health: a down to earth annual.
Sehgal M, Suresh R, Sharma VP, Gautam G (2014) Assessment of outdoor workers' exposure to air pollution in Delhi (India). Int J Environ Stud 72(1):99–116
Shima M, Nitta Y, Ando M, Adachi M (2002) Effects of air pollution on the prevalence and incidence of asthma in children. Arch Environ Health 57:529–535
Smith K, Warholak T, Armstrong E, Leib M, Rehfeld R, Malone D (2009) Evaluation of risk factors and health outcomes among persons with asthma. J Asthma 46:234–237
TERI (2015) Air pollution and health. Discussion paper by the Energy and Resources Institute, New Delhi
To T, Stanojevic S, Moores G, Gershon AS, Bateman ED, Cruz AA (2012) Global asthma prevalence in adults: findings from the cross-sectional world health survey. BMC Public Health 12:204
USAID/ASIA (2007) India country report from ideas to action: clean energy solutions for Asia to address climate change. Bangkok (Thailand), pp 1–143
WHO (2014) Ambient air pollution database update
WHO (2016) Global urban ambient air pollution database (update)
WHO-Global Burden of Disease (GBD) Report (2013). US based Health Effect Institute. Joint workshop by CSE, ICMR and Health Effects Institute
Yemaneberhan H, Bekele Z, Venn A, Lewis S, Parry E, Britton J (1997) Prevalence of wheeze and asthma and relation to atopy in urban and rural Ethiopia. Lancet 350:85–90
Zhang J, Qian Z, Kong L, Zhou L, Yan L, Chapman RS (1999) Effects of air pollution on respiratory health of adults in three Chinese cities. Arch Environ Health 54:373–381
Zhang Q, Qiu M, Chung KF, Huang SK (2015) Link between environmental air pollution and allergic asthma: east meets west. J Thorac Dis 7(1):14–22

Web References

http://www.newindianexpress.com/magazine/Asthma-The-Pollution-Contagion/2015/01/31/article2642766.ece
http://indianexpress.com/article/cities/delhi/hardlook-air-pollution-odd-even-ii-scheme-death-by-breath-how-delhis-air-fared-2779759/
http://indianexpress.com/article/india/india-news-india/delhi-pollution-cases-of-breathlessness-asthma-allergy-rise-in-the-city-3739775/
http://www.livemint.com/Politics/HwmDRVfTUMgrbX55qegmtM/SC-may-double-antipollution-cess-on-commercial-vehicles-ent.html
http://www.delhi.gov.in/wps/wcm/connect/2c42618046940f96994afd7d994b04ce/Final+-Statistical+Hand+Book+2014.pdf?MOD=AJPERES&lmod=1349404260&CACHEID=2c42618046940f96994afd7d994b04ce
http://timesofindia.indiatimes.com/life-style/health-fitness/health-news/Air-pollution-triggers-asthma-in-urban-India-Experts/articleshow/47158512.cms

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T. Jindal (ed.), *Paradigms in Pollution Prevention*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-58415-7