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Nihal Anwar Siddiqui
S. M. Tauseef
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Advances in Air Pollution Profiling and Control

Select Proceedings of HSFEA 2018

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Editors

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Preface

As per the World Health Organization (WHO), ninety-one per cent of the human population is living in places where the air quality is not as per the prescribed standards. As a result, approximately between 5 and 8 million people die due to inhalation of polluted air outdoors and indoors due to inhalation of smoke from wood or other fuel used in rural areas. The World Bank estimates that air pollution costs the global economy more than USD five trillion annually, with developing world experiencing the worst effects.

The rise in air pollution can be linked directly to rapid industrialization, urbanization and dramatic rise in transportation. Smog, soot, greenhouse gases and other air pollutants are affecting our environment in the worst possible ways, and immediate steps are required to improve air quality. Many cities have taken steps—ranging from curbing the use of cars, odd–even concept for on-road cars, etc.—to curb air pollution.

This volume presents selected papers on *Advances in Air Pollution Profiling and Control* which were presented at the 2nd International Conference on Advances in the Field of Health, Safety, Fire, Environment, Allied Sciences and Engineering (HSFEA 2018), 16–17 November 2018, organized in collaboration with the Centre for Risk, Integrity and Safety Engineering (C-RISE), Memorial University, Canada. The conference was attended by leading academic scientists, engineers, policy makers, budding scholars and graduate students. The contributions from the authors cover topics discussing various air pollution sources—such as from paddy fields, vehicular pollution, industrial and other sources of air pollution—and methods for their monitoring and control. Contributions from authors also present technologies that would help tackle the problem of air pollution and ensure access to clean and healthy air and ensure sustainable development. Through this publication, the reader can update himself/herself with the *Advances in Air Pollution Profiling and Control* and inform on related opportunities and challenges.

Dehradun, India — Nihal Anwar Siddiqui
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Kalapet, India — S. A. Abbasi
St. John's, Canada — Faisal I. Khan

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We thank Dr. S. J. Chopra (Hon'ble Chancellor, UPES) and Prof. Dr. Deependra Kumar Jha (Vice Chancellor, UPES) for their support and encouragement. We are grateful to the Chief Guests of HSFEA 2018—Mr. Howard Pike, (Former) Manager, Operations and Chief Safety Officer, Canada-. Newfoundland Offshore Petroleum Board, Canada and Prof. Faisal I. Khan, Professor and Canada Research Chair (Tier I), Director, Centre for Risk, Integrity and Safety Engineering (C-RISE), Memorial University, Newfoundland, Canada, for gracing the event with their presence. We also thank the distinguished speakers—Senior Prof. S. A. Abbasi (CSIR Emeritus Professor, Pondicherry University), Mr.Satya Prakash Garg (Executive Director, GAIL (India) Limited), Mr. Rajendra Singh (waterman of India, water conservationist and environmentalist), Dr. Tasneem Abbasi (Assistant Professor, Pondicherry University), Dr. Niranjan Bagchi (Former Director, MoEF), Dr. T. K. Joshi (Advisor, Environmental Health, Ministry of Environment, Forest and Climate Change) and Dr. R. K. Sharma (General Manager, India Glycols Ltd.) for their talks.

The organizers of HSFEA 2018 wish to thank all the reviewers for their valuable time and comments on the quality of the papers.

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Contents

Airshed of a Typical Highly Industrialized Suburb of an Indian City: Air Quality Modeling and Forecasting 1
Tasneem Abbasi, Faisal I. Khan, Tabassum-Abbasi and S. A. Abbasi

Responsible Factors of Environmental Degradation in Nandakini River Valley 17
Alok Kumar Pandey

Assessment of Ground Water Quality Along the Coastal Areas of Srikakulam District, Andhra Pradesh, India 25
Sudhakara Rao Ippili, K. Suresh Kumar, N. Srinivas and Akbar Ziauddin

Presence of Microplastic in Water Bodies and Its Impact on Human Health 57
Sreeraj Vijayaraman, Prasenjit Mondal, Abhishek Nandan and Nihal Anwar Siddiqui

Assessment of the Ambient Air Quality of a Highly Industrialized Suburb of a Typical Indian City Part 1: Assessment of Quality 67
Tasneem Abbasi, Faisal I. Khan, Tabassum-Abbasi and S. A. Abbasi

Inherent Safety in Offshore Oil and Gas Activities 103
Mahadevan Shankaren, Surendar Varadharajan, Akshi K. Singh and Abhishek Nandan

Ambient Quality Downwind Major Industrial Estates of Puducherry, India 113
Tabassum-Abbasi, Tasneem Abbasi and S. A. Abbasi

Solid Waste Problem Due to Packaging Material and Its Management Options 133
Amit Kumar Singh, Somya Gandhi, Nihal Anwar Siddiqui, Prasenjit Mondal, Abhishek Nandan and Ehkamul Haq

Atmospheric Aerosols (PM_{10} and $PM_{2.5}$) and their Influence on Air Quality in Visakhapatnam City, Andhra Pradesh, India 143
K. A. Sunil Kumar, K. Suresh Kumar, N. Srinivas and Akbar Ziauddin

Dehradun City: Vehicular Pollution During 2008 to June 2018 167
Sharad Kumar Tripathi and Anupama Tripathi

Effect of Vehicular Pollution in the Fastest Developing Cities of India: A Critical Review 177
Vivek Kumar, Rahul Silori and Raja

Repercussion of Electromagnetic Radiation from Cell Towers/Mobiles and Their Impact on Migratory Birds 193
Nair Shravan Surendran, Nihal Anwar Siddiqui, Prasenjit Mondal and Abhishek Nandan

Sources of Heavy Metal in Indoor Air Quality 203
Kartikay Jha, Abhishek Nandan, Nihal Anwar Siddiqui and Prasenjit Mondal

Impact of Speed Breakers on Air Contamination and Mileage of Vehicles 211
Prathyusha Pentapalli, Nihal Anwar Siddiqui, Prasenjit Mondal and Abhishek Nandan

Improving the Performance of Classification Algorithms with Supervised Filter Discretization Using WEKA on NSL-KDD Dataset 217
Shailesh Singh Panwar and Y. P. Raiwani

Noise Control Mechanisms for Industry Operations—A Review 229
Vaishnavi Tuli, Nihal Anwar Siddiqui, Abhishek Nandan and A. Gautam

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Nihal Anwar Siddiqui is Professor at the University of Petroleum and Energy Studies (UPES) (2005–present). He holds a Master's degree in Environmental Sciences from Lucknow University, India (1996), and a PhD in Environmental Biology from Awadhesh Pratap Singh University (APS) University, Rewa, India. Additionally, he has a number of professional certifications, e.g., a NEBOSH diploma, NEBOSH–IGC, IOSH Managing Safely, Lead Auditor OHSAS 18001, Lead Auditor ISO 14001 and GRAD-IOSH. Prof. Siddiqui's research interests include occupational health, safety and environment. He has co-authored more than 150 papers and eight books and has organized a number of national and international seminars/conferences/MDPs. He has also worked on a number of major R&D projects.

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Prof. S. A. Abbasi is Professor Emeritus (CSIR) and Founder Head of the Centre for Pollution Control & Environmental Engineering, Pondicherry University, India. His main calling has been environmental engineering since 1970—a field to which he has contributed 43 books, 11 patents, and over 500 research papers. In 1992

Prof. Abbasi started the, now globally recognized, process safety research programme at Pondicherry University. In a recent study published from Canada, Prof. Abbasi has been named as the most prolific contributors to this field from Asia and among the top 6 in the world. He also has the best citation-per-paper record in this field. Prof Abbasi's lifetime achievements have been recognized in the form of *National Design Award in Environmental Engineering, National Hydrology Award,* and several other International/national honours and awards awards. He has been elected *Fellow of the Institution of Engineers (1993), Indian Institute of Chemical Engineers (1999),* and *National Academy of Sciences (2003).* From 1984 onwards he has been invited frequently to chair technical sessions or present plenary lectures in international conferences round the globe.

Faisal I. Khan is Professor and Canada Research Chair (Tier I) of Offshore Safety and Risk Engineering. He is founder of Centre for Risk Integrity and Safety and Engineering (C-RISE), which has over research 50 research members. His areas of research interest include offshore safety and risk engineering, inherent safety, risk management, and risk-based integrity assessment and management. He is actively involved with multinational oil and gas industries on the issue of safety and asset integrity. In 2006, he has spent eight months as risk and integrity expert with Lloyd's Register (UK) a risk management organization. He also served as Safety and Risk Advisor to Government of Newfoundland, Canada. He continue to serve subject matter expert to many organizations that include Llyod's Register EMEA, SBM Modco, Intecsea, echnip, and Qatargas. In 2008-10, he visited Qatar University and Qatargas LNG Company as Process Safety and Risk Management Research Chair. In 2012-14 he served as Visiting Professor of Offshore and Marine Engineering at Australian Maritime College (AMC), University of Tasmania, Australia. Where he led development of offshore safety and risk engineering group and an initiative of global engagement with many international institutions. He is recipient of President Outstanding Research Award of 2012-13, CSChE National Award on Process Safety Management of 2014, President Outstanding Research Supervision Award of 2013-14, and recently Society of Petroleum Engineer award for his contribution in Health, Safety and Risk Engineering. He has authored over 400 research articles in peer reviewed journals and conferences on safety, risk and reliability engineering. He has authored five books on the subject area. He is Editor to Journal of Process Safety and Environmental Protection, Process Safety Progress, and ASME Part A (Risk and Uncertainty Analysis).

Airshed of a Typical Highly Industrialized Suburb of an Indian City: Air Quality Modeling and Forecasting

Tasneem Abbasi, Faisal I. Khan, Tabassum-Abbasi and S. A. Abbasi

Abstract In the another chapter of this volume, we have presented the details on the air quality of a highly industrialized suburb of the kind that occurs in all major cities of India—as also of most developing countries. The air quality was monitored by us round the year with a network of 11 sampling stations. We now present studies on the modeling of the air quality of the area, the forecasting carried out thereafter, and its implications.

Keywords Air quality · Air pollution · Modeling · Chennai · Industrial complex

1 Introduction

In the preceding chapter, we have described the findings of a very extensive ambient air quality monitoring programme implemented by us in a suburb of Chennai, India, which houses a large-scale refinery and several downstream petrochemical industries which are all situated shoulder to shoulder. Eleven sampling stations were set in that Manali Industrial Complex (MIC) and the results of year-round ambient air quality monitoring carried out by us for two consecutive years have been summarized in the that chapter.

The present chapter describes the use of those findings in developing air quality model applicable to that region. Such models are necessary to identify the

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relationships between ambient air pollution, the source of the pollution, and the variables such as meteorology and terrain characteristics which influence the pattern of dispersion of the pollutants. Once such relationships are identified and validated, the model becomes usable in forecasting the impacts of decrease or increase in source strength on ambient air quality (AAQ) as a function of other influencing parameters mentioned above.

When setting out to model the air quality in the Manali Industrial Complex (MIC), the following important factors were considered, *inter alia*:

1. The conventional approaches to atmospheric stability classification such as the ones named after Pasquill-Gifford and Turner do not enable precise computations; they are particularly unsuitable under the conditions of coastal meteorology prevailing in the Manali area (Please see the following para). Therefore, we have adopted the most recently modified version of Mohn–Obukhov model for atmospheric stability classification (Abbasi and Khan 2000; Khan and Abbasi 1999a, b; 2000).
2. The industrial complex is close to the East coast. As such the classical stability classifications adequate for inland locations cannot be used because the coastal meteorology is different from the inland one, especially in terms of frequent changes in wind directions and speed (Abbasi et al. 2012).
3. Particular care was needed to handle heavy gas dispersion (i.e., dispersion of gases heavier-than-air) as all the five major air pollutants in Manali are "heavy". Most conventional models are able to handle only lighter-than-air and as-dense-as-air gases (Khan and Abbasi 1999a, b).
4. As most of the gases are released continuously for long durations, it is necessary to incorporate this effect in dispersion calculations (Abbasi and Abbasi 2011). However, most of the classical models for dispersion do not respond to this call (Khan and Abbasi 1998). We have incorporated this effect by modifying the models. In summary, we have used Mohn–Obukhov stability classification with appropriate modifications to handle coastal effects. In this system, the stability is classified using Mohn–Obukhov lengths and Mohn–Obukhov coefficient. For heavy gas dispersion the latest model based on Plume Path Theory (Abbasi and Khan 2000; Khan and Abbasi 2000) has been employed after extensive validation and calibration.

The model results have been validated against the field data generated by an exhaustive network of air quality monitoring stations as detailed in the preceding chapter. Typical results of the validation are presented in Figs. 1, 2, 3 and 4.

2 Air Quality Simulations for Impact Forecasting

Using the model validated as above, the air quality of Manali industrial area was simulated as a function of varying source characteristics, atmospheric characteristics and terrain characteristics. The initial settings of various parameters used in the

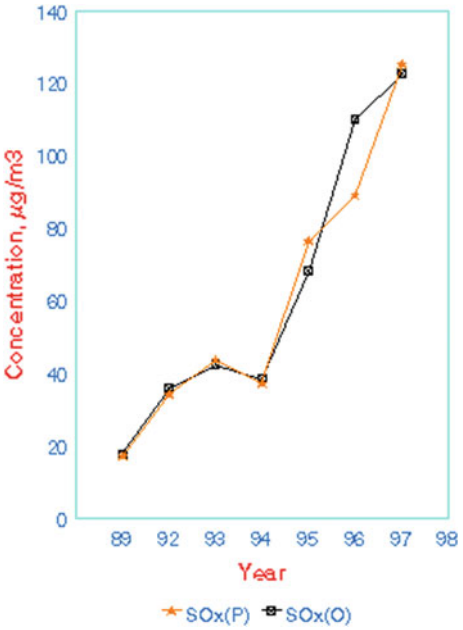

Fig. 1 Comparison of SO_x (predicted and observed) during post-monsoon

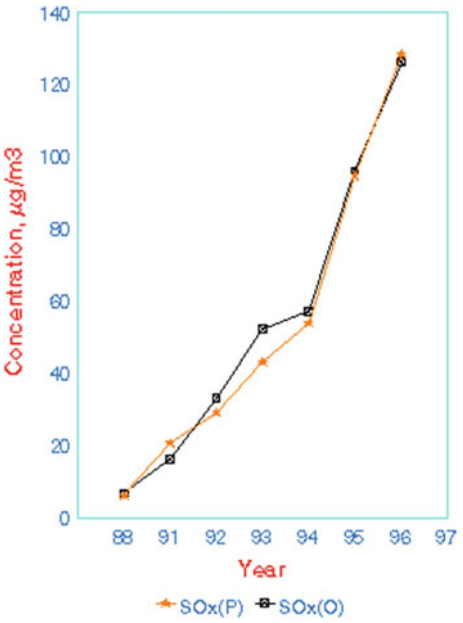

Fig. 2 Comparison of SO_x (predicted and observed) during summer

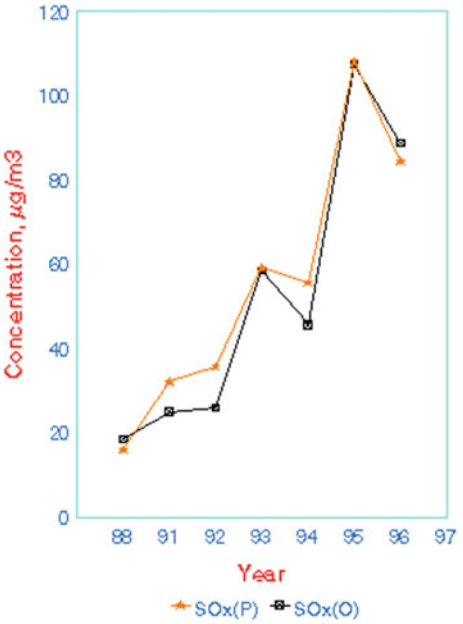

Fig. 3 Comparison of SO_x (predicted and observed) during pre-monsoon

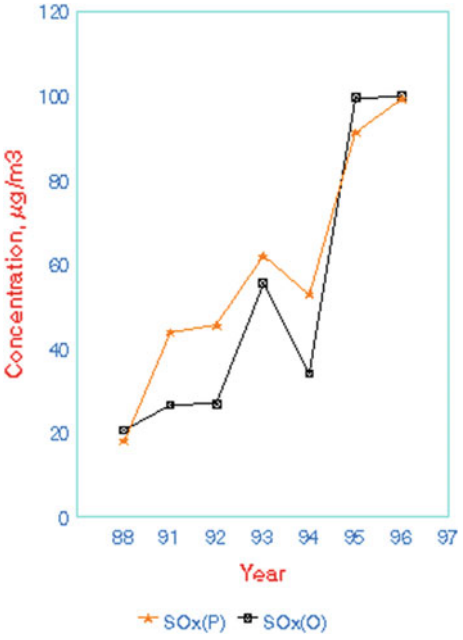

Fig. 4 Comparison of SO_x (predicted and observed) during monsoon

simulations are given in Table 1 percent increase/decrease in various parameters needed to bring down the pollutant levels to acceptable limits during various seasons in Manali residential area are given in Tables 2, 3, 4 and 5 Presented below are illustrative examples of simulations carried out by us.

Table 1 The initial setting of various parameters used in the simulation studies

S. No.	Parameter	Post-monsoon	Summer	Pre-monsoon	Monsoon
1	Location	Manali	Manali	Manali	Manali
2	Flow rate, m^3/d	102,344,232	102,344,232	102,344,232	102,344,232
3	*Source strength*				
	SO_X, mg/m^3	350	320	285	280
	NO_X, mg/m^3	7.0	6.125	9.5	5.0
	SPM, mg/m^3	400	380	250	246.7
4	Friction factor, m	1.5	1.5	1.5	1.5
5	Distance, m	2500	2500	2500	2500
6	Wind velocity, km/h	4.8	6.5	7.4	7.5
7	Stability class	Neutral	Unstable	Unstable	Neutral
8	Ambient temperature, °K	298.3	305.5	303.7	301.5
9	*Stack details*				
	Height, m	31.68	31.68	31.68	31.68
	Diameter, m	1.094	1.094	1.094	1.094
	Exit velocity, m/s	9.02	9.02	9.02	9.02
	Exit-temperature, °K	498.5	498.5	498.5	498.5
10	*Ambient concentration*				
	SO_X, $\mu g/m^3$	115.65	128.52	84.47	99.39
	NO_X, $\mu g/m^3$	38.38	39.80	49.65	34.88
	SPM, $\mu g/m^3$	225.56	257.46	265.16	266.73

Table 2 Percent change* in forcing functions needed to bring down the pollutant level at Manali to acceptable limit during monsoon

S. No.	Parameter	Percent increase/decrease in case of the pollutant		
		SO_X	NO_X	SPM
1	Flow rate, Q	−29.5	Nil	−48.25
2	Source strength, S	−12.0	Nil	−64.5
3	Both Q&S	−9.0	Nil	−33.5
4	Ambient temperature, Ta	63.0	Nil	57.0
5	Exit temperature, Te	10.0	Nil	24.5
6	Wind velocity, Vw	290.0	Nil	175.0
7	Friction factor, Uf	−40.0	Nil	−36.5

* Negative sign indicates the need for reduction

Table 3 Percent change* in forcing functions needed to bring down the pollutant level at Manali to acceptable limit during summer

S. No.	Parameter	Percent increase/decrease in case of the pollutant		
		SO_X	NO_X	SPM
1	Flow rate, *Q*	−43.0	Nil	−75.5
2	Source strength, S	−32.5	Nil	−80.0
3	Both Q&S	−21.0	Nil	−52.75
4	Ambient temperature, Ta	280.0	Nil	117.5
5	Exit temperature, Te	24.0	Nil	75.0
6	Wind velocity, Vw	42.5	Nil	160.0
7	Friction factor, Uf	−74.0	Nil	−54.0

* Negative sign indicates the need for reduction

Table 4 Percent change* in forcing functions needed to bring down the pollutant level at Manali to acceptable limit during pre-monsoon

S. No.	Parameter	Percent increase/decrease in case of the pollutant		
		SO_X	NO_X	SPM
1	Flow rate, Q	−8.25	Nil	−55.75
2	Source strength, S	−2.5	Nil	−64.0
3	Both Q&S	−2.0	Nil	−36.5
4	Ambient temperature, Ta	15.5	Nil	62.0
5	Exit temperature, Te	3.0	Nil	18.25
6	Wind velocity, Vw	6.0	Nil	57.5
7	Friction factor, Uf	−12.5	Nil	−38.0

* Negative sign indicates the need for reduction

Table 5 Percent change* in forcing functions needed to bring down the pollutant level at Manali to acceptable limit during post-monsoon

S. No.	Parameter	Percent increase/decrease in case of the pollutant		
		SO_X	NO_X	SPM
1	Flow rate, Q	−49.75	Nil	−57.25
2	Source strength, S	−20.0	Nil	−64.25
3	Both Q&S	−15.5	Nil	−37.25
4	Ambient temperature, Ta	177.5	Nil	91.75
5	Exit temperature, Te	77.75	Nil	305.0
6	Wind velocity, Vw	77.0	Nil	90.5
7	Friction factor, Uf	−64.0	Nil	−48.5

* Negative sign indicates the need for reduction

3 Impact of Changes in Source Characteristics (Flow Rate and/or Source Strength) on Ambient Air Quality in Manali Residential Area

Simulations to assess the impact of changes in source characteristics on ambient air quality reveal the following.

3.1 Post-monsoon

When the flow rate is increased four times, the SO_x, and SPM, and NO_x concentrations increase by 80.5%, 37%, and 25.5%, respectively. When the flow rate is reduced by 30%, the concentration of SO_x is reduced by 17.5%, SPM by 9.8% and NO_x by 8%. A 57.25% reduction is needed to bring down the SPM level to acceptable limit (Table 2). The simulation results are summarized in Table 6.

Changes in the source strength effects ambient SO_x concentration to a much greater degree than it does other pollutants; when the concentration of SO_x in the source is increased by 200%, it leads to an increase of ambient SO_x concentration by 515%. When the source strength is doubled, the SO_x, NO_x, and SPM concentrations increase by 214.5%, 13.8%, and 18%, respectively. To bring down SO_x and SPM to acceptable limits the source strength must be reduced by 20% and 64.25%, respectively (Table 7).

3.2 Summer

The impacts in summer differ markedly in degrees compared to the previous season; an increase in flow rate by 200% leads to increase in ambient SO_X by 154.5%, NO_X by 139%, and SPM by 17.4%. On the other hand, a 30% reduction of SO_X and NO_X at source reduces their ambient concentrations by 35% and 21.5%, respectively (Table 7). A minimum of 75.5% reduction in flow rate is needed to bring the ambient pollutant concentrations down to acceptable limits.

The ambient SO_x increases to 278% when the source concentration of SO_x is increased by 200% (Table 7). There is a less significant change in the ambient SPM concentration with the increase in source SPM levels: the former increases by only 9.5% when source concentration is increased by 100%. But a similar NO_X at source increases the ambient NO_X concentration by 60.5%; a 30% reduction at source decreases the ambient concentration by 21.5%. During this season, a reduction of at least 80% at source is needed to bring down the ambient SPM level to the permissible limit.

Table 6 Gist of simulations—I: Impact of flow rate on ambient air quality of Manali; the rows containing enclosed figures indicate the situation where air quality is brought under permissible levels

S. No.	Season	Percent increase/ decrease in flow rate, %	Ambient concentration			
			SO_X μg/m^3	NO_X μg/ m^3	SPM μg/m^3	Overall quality polluted (P) or unpolluted (U)
1	Monsoon	200	198.85	46.77	431.43	P
		100	153.94	41.97	361.27	P
		50	128.38	38.87	318.53	P
		25	114.42	37.02	294.10	P
		0	99.39	34.88	266.73	P
		−29.50	79.71	31.77	228.89	P
		−48.25	**65.67**	**29.26**	**199.92**	**U**
2	Summer	200	327.02	95.14	302.34	P
		100	231.67	68.97	285.78	P
		50	181.41	54.90	274.02	P
		25	155.36	47.50	266.57	P
		0	128.52	39.80	257.46	P
		−43.0	79.69	25.48	234.49	P
		−75.5	**38.88**	**13.04**	**199.99**	**U**
3	Pre-monsoon	200	170.12	77.95	388.71	P
		100	131.39	66.00	337.53	P
		50	109.38	58.64	305.36	P
		25	97.38	54.41	286.58	P
		0	84.47	49.65	265.16	P
		−8.25	79.96	47.92	257.33	P
		−55.75	**50.24**	**35.52**	**199.63**	**U**
4	Post-monsoon	200	208.80	48.16	350.98	P
		100	167.89	44.55	312.20	P
		50	143.83	41.99	287.31	P
		25	130.40	40.37	272.57	P
		0	115.65	38.38	255.56	P
		−49.75	79.88	32.25	209.50	P
		−57.25	**73.23**	**30.81**	**199.95**	**U**

3.3 Pre-monsoon

When the flow rate is doubled, the ambient concentrations of SO_x, NO_x, and SPM increase by 55.5%, 33%, and 27%, respectively (Table 6).

When the source concentration of SO_x, NO_x, and SPM are doubled, their ambient concentrations increase by 419%, 20%, and 21%, respectively (Table 7).

Table 7 Gist of simulations—II: Impact of source strength on ambient air quality of Manali; the rows containing enclosed figures indicate the situation where air quality is brought under permissible levels

S. No.	Season	Percent increase/ decrease in source strength, %	Ambient concentration			
			SO_X μg/m^3	NO_X μg/ m^3	SPM μg/m^3	Overall quality polluted (P) or unpolluted (U)
1	Monsoon	200	692.04	44.83	362.72	P
		100	338.13	40.86	323.82	P
		50	203.42	38.26	298.77	P
		25	147.41	36.7	283.92	P
		0	99.39	34.88	266.73	P
		−12.0	79.30	33.88	257.36	P
		−64.5	**15.95**	**27.54**	**199.63**	**U**
2	Summer	200	485.96	84.4	296.94	P
		100	297.45	63.95	282.37	P
		50	209.97	52.52	272.03	P
		25	168.38	46.36	265.48	P
		0	128.52	39.80	257.46	P
		−32.5	79.86	30.41	243.33	P
		−80.0	**18.31**	**13.23**	**199.62**	**U**
3	Pre-monsoon	200	1149.6	66.06	360.15	P
		100	438.63	59.45	321.67	P
		50	221.41	55.17	296.88	P
		25	143.56	52.61	282.18	P
		0	84.47	49.65	265.16	P
		−2.5	79.54	49.32	263.30	P
		−64.5	**7.45**	**38.07**	**−199.46**	**U**
4	Post-monsoon	200	711.03	46.76	332.09	P
		100	363.74	43.66	301.49	P
		50	226.07	41.47	281.50	P
		25	167.25	40.08	269.53	P
		0	115.65	38.38	255.56	P
		−20.0	79.97	36.68	242.32	P
		−64.25	**21.12**	**30.54**	**199.98**	**U**

3.4 Monsoon

An increase in the flow rate by 200%, would lead to 100%, 34%, and 62% increase in the ambient of SO_x, NO_x, and SPM levels, respectively (Table 6).

An increase in source strength by 100% would lead to an increase in ambient SO_x by 240%, NO_x by 17%, and SPM by 21% (Table 7).

The impacts of flow rate and source strength on ambient air quality of the locations where the pollutant levels are the highest are presented in Tables 8 and 9. The extent of decrease in flow rate, source strength and both needed to bring down the pollutant concentrations to acceptable levels in these worst-case situations is presented in Table 10.

Table 8 Gist of simulations—III: Impact of flow rate on ambient air quality in the worst situations; the rows containing enclosed figures indicate the situation where air quality is brought under permissible levels

S. No.	Season	Location	Percent increase/ decrease inflow rate, %	Ambient concentration			
				SO_x μg/m^3	NO_x μg/m^3	SPM μg/m^3	Overall quality polluted (P) or unpolluted (U)
1	Monsoon	TNHB	200	202.62	47.71	442.88	P
			100	156.86	42.82	370.86	P
			50	130.81	39.65	326.99	P
			25	116.59	37.77	301.91	P
			0	101.27	35.58	273.82	P
			−31.25	79.94	32.19	232.40	P
			−51.25	**64.35**	**29.37**	**199.93**	**U**
2	Summer	Chinnamathur	200	347.98	100.75	315.37	P
			100	246.52	73.03	298.80	P
			50	193.04	58.13	287.05	P
			25	165.32	50.30	279.60	P
			0	136.75	42.14	270.48	P
			−47.0	79.72	25.46	244.54	P
			−82.85	**31.45**	**10.69**	**199.85**	**U**
3	Pre-monsoon	Chinnamathur	200	183.44	83.31	430.93	P
			100	141.67	70.53	374.19	P
			50	117.94	62.67	338.53	P
			25	105.00	58.15	317.71	P
			0	91.09	53.06	293.96	P
			−18.5	79.95	48.78	273.75	P
			−67.0	**44.94**	**33.65**	**199.83**	**U**
4	Post-monsoon	Chinnasekkadu	200	226.33	48.93	381.78	P
			100	181.99	45.32	339.59	P
			50	155.91	42.76	312.52	P
			25	141.35	41.13	296.49	P
			0	125.37	39.15	277.98	P
			−56.75	79.88	31.68	218.22	P
			−68.25	**67.65**	**28.93**	**199.85**	**U**

Table 9 Gist of simulations—IV: Impact of source strength on ambient air quality in the worst situations; the rows containing enclosed figures indicate the situation where air quality is brought under permissible levels

S. No	Season	Location	Percent increase/ decrease in source strength, %	Ambient concentration			
				SO_x μg/ m^3	NO_x μg/ m^3	SPM μg/m^3	Overall quality polluted (P) or unpolluted (U)
1	Monsoon	TNHB	200	705.17	45.73	372.35	P
			100	344.54	41.68	332.42	P
			50	207.27	39.03	306.71	P
			25	150.2	37.44	291.46	P
			0	101.27	35.58	273.82	P
			−12.5	79.99	34.51	263.77	P
			−67.5	**13.91**	**27.53**	**199.93**	**U**
2	Summer	Chinnamathur	200	517.11	89.37	309.96	P
			100	316.51	67.71	295.39	P
			50	223.42	55.61	285.05	P
			25	179.17	49.09	278.50	P
			0	136.75	42.14	270.48	P
			−36.0	79.67	31.05	254.44	P
			−86.0	**12.65**	**10.97**	**199.83**	**U**
3	Pre-monsoon	Chinnamathur	200	1239.60	70.60	399.27	P
			100	472.96	63.53	356.60	P
			50	238.74	58.96	329.13	P
			25	154.79	56.23	312.82	P
			0	91.09	53.06	293.96	P
			−5.5	79.63	52.28	289.36	P
			−75.0	**3.38**	**37.00**	**199.75**	**U**
4	Post-monsoon	Chinnasekkadu	200	770.75	47.52	361.23	P
			100	394.29	44.43	327.94	P
			50	245.06	42.24	306.20	P
			25	181.29	40.85	293.17	P
			0	125.37	39.15	277.98	P
			−24.0	79.64	37.05	260.38	P
			−75.0	**12.67**	**28.58**	**199.74**	**U**

Table 10 Percent decrease in the flow rate, source strength and both needed to bring down the pollutants level to acceptable limits in worst situations occurring in the four seasons

S. No.	Season	Parameter	Location recording maximum air pollution (i.e., worst situation)	Percent decrease in the parameters needed to bring down the pollutants level to acceptable limits, %	
				for SO_X	for SPM
1	Monsoon	Flow rate	TNHB	−31.25	−51.25
		Source strength		−12.5	−67.50
		Both		−9.5	−35.50
2	Summer	Flow rate	Chinnamathur	−47.0	−82.25
		Source strength		−36.0	−86.00
		Both		−23.0	−60.25
3	Pre-monsoon	Flow rate	Chinnamathur	−18.5	−67.00
		Source strength		−5.5	−75.00
		Both		−4.25	−46.00
4	Post-monsoon	Flow rate	Chinnasekkadu	−56.75	−68.25
		Source strength		−24.0	−75.00
		Both		−18.75	−46.50

4 Impact of Changes in Terrain Characteristics on Ambient Air Quality in Manali Residential Area

The terrain characteristics and the friction factor of the area are simulated to find out the impact of their changes on ambient air quality.

4.1 Post-monsoon

As the friction factor increases by 100%, the ambient SO_x, NO_x and SPM concentrations increase by 28.5%, 6%, and 30%, respectively. When the friction factor is reduced by 30%, it leads to a decrease in ground-level concentration of SO_x by 12%, NO_x by 3%, and SPM by 12.5%. A 48% reduction in friction factor brings down the SPM concentration to 199.74 $\mu g/m^3$.

4.2 Summer

When the friction factor is increased by 100%, the ground-level concentrations of SO_x increases by 28%, NO_x by 25.5%, and SPM by 20%. The reduction in pollutants concentration is found to be 12% in SO_X, 11% in NO_x, and 10% in SPM with a reduction of friction factor by 30%.

4.3 Pre-monsoon

There is an increase of 35% in SO_x, 30% in NO_x, and 50.5% in SPM with 100% increase in the friction factor. When the friction factor is reduced by 30%, the pollutant concentrations of SO_x, NO_x, and SPM reduce by 14%, 13%, and 19% respectively.

4.4 Monsoon

The most significant increase in the pollutant concentration is seen to occur during monsoon as the increase in SO_x is 37.5%, NO_x is 40%, and SPM is 56% for an increase of 100% in friction factor. A 30% reduction in the friction factor causes the ambient concentrations to drop by 15% (SO_x), 16% (NO_x), and 20.5% (SPM), again indicating the sensitivity of pollutant attenuation to the friction factor. Reduction of 40% and 36.5% in friction factor is needed to bring down the SO_x and SPM concentrations to acceptable limits.

5 Impact of Changes in Atmospheric Conditions on the Ambient Air Quality in Manali Residential Area

The pollutant dispersion under different conditions of wind velocity and atmospheric stability was simulated to forecast the impacts.

5.1 Post-monsoon

There is a reduction of 36% in SO_x, 15% in NO_x, and 23% in SPM concentrations with a two-fold increase in the wind velocity. A 77% increase in wind velocity would bring the SO_X concentration down to permissible level and a 90.5% increase would bring down the SPM to permissible level.

During post-monsoon, the atmosphere was generally neutral. The simulations reveal that all other factors remaining the same, a shift in atmospheric condition to unstable would cause a decrease in the ambient SO_x by 24%, NO_x by 7%, and SPM by 25%. A similar shift to stable conditions would cause increase in SO_x by 65%, NO_x by 12%, and SPM by 68.5%.

5.2 Summer

When the wind velocity increases by 100% there is a reduction of SO_x by 61%, NO_x by 54%, and SPM by 16%. Only a 160% increase in wind velocity would bring down SPM concentration to permissible levels.

Instability conditions had prevailed during summer in both the years during which the air quality was sampled. An increase of SO_x by 31%, NO_x by 28.5%, and SPM by 22% would occur in neutral atmospheric condition and an increase of 115%, 102.5%, and 62% in these parameters would occur if stable conditions prevail.

5.3 Pre-monsoon

If the wind velocity is increased by 6%, there is a decrease of SO_x concentration to acceptable level but as much as 57.5% increase in wind velocity is needed to bring the ambient SPM level down to acceptable limit.

These observations pertain to unstable atmospheric condition. For neutral condition there would be an increase of SO_x by 39%, NO_x by 34%, and SPM by 57% and in stable atmospheric condition there would be increase in these concentrations to the extent of 153% for SO_x, 127% for NO_x, and 257% for SPM.

5.4 Monsoon

In this season an increase in wind velocity by 100% would depress the ambient concentration of SO_x, NO_x, and SPM by 11%, 3%, and 18%, respectively. A 290% increase in wind velocity is needed to bring down the SO_x level to acceptable limit and 175% increase to achieve the same result with SPM.

When atmospheric conditions are highly unstable, there is a reduction of SO_x by 30%, NO_x by 31%, and SPM by 39%. But when atmosphere is stable, the ambient concentrations would rise sharply to 89%, 96%, and 143.5% for SO_x, $NO_{X,}$ and SPM, respectively.

6 Summary and Conclusion

The chapter describes the first-ever study on the modeling of air quality of the Manali Industrial Complex, Chennai, in which aspects such as coastal meteorology and long-term dispersion of dense gases have been taken into account.

Simulation and forecasting reveal that whereas the effect of favorable conditions like unstable weather and higher friction factor would be marginally beneficial, adverse impacts of unfavorable conditions would be proportionately a lot more severe.

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Responsible Factors of Environmental Degradation in Nandakini River Valley

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Abstract The high peak of Himalayan range is the origin of ganges river system. Ancient Indian scriptures contain several references of worship natural forces, e.g., rivers, mountains, and forests. The world-famous three-week-long **Nanda Devi Raj Jat** Yatra starting in Nandakini River Valley. Famous **Tal Roop Kund** is situated in this valley. The Ramayana, Mahabharata, the Vedas, the Upanishads, the Gita, the Puranas, and the Smritis have underlined the significance of environmental and ecological balance vis-à-vis survival of mankind on this planet. Indians have been in prayers saying for centuries, "So long as the earth has mountain, forests, trees, etc., the human race will survive". Himalayan mountain chain came into existence as a result of collision of northward moving Indian plate with Tibetan plate. Due to resultant tectonic forces of regional dimension, the Himalaya is still rising, though at a very slow pace. The entire Himalayan belt continued convergence was due to long going compression. Nandakini valley ranges from Nanga Parbat at 8125 m in the west and the Namcha Barwa 7828 m in the east, the 30 to 450 km broad Himalayan Range extends for a length of about 2400 km. So the title is based on Nandakini Valley and related pollution problems. Over the millions of years of geological time, the rocks of the crust of the earth have been subjected to an assortment of natural resources that tend to break them up and carry fragments away. Presently Himalayan region is under severe environmental threat of soil erosion, deforestation, landslides, decline soil fertility, overpopulation, and over-grazing. Thus, in the study of environmental changes, the systematic knowledge of landform plays a dominant role. The study finds the basis for the causes and responsible factors for degraded environment of Nandakini Valley.

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1 Introduction

The Nandakini Valley of Garhwal Himalayas is comprised of natural resources (forest, soil, water) with varied landscape morpho units. Valley landscape due to varied micro—climatic causes dissimilar view. Nandakini river valley huge land reserve resources properly not utilized in full way. So it requires part of control methods to prevail depletion of resources and to locate the area of depletion for ecological treatments. The Nandakini river valley sustainable development and environment management done through study of geo catastrophic structure (includes forest, land, soil, and water depletion) and consider environmental factors of landslides regions make eco plan involving forest, rock, soil and water resources preventable and conservation method (Fig. 1).

Nandakini valley of Garhwal Himalaya degradation due to landslides, deforestation illegal quarrying, mining, severe infiltrate dam construction, tunnel, and road construction causes ecological imbalance and environmental problems.

The highly increase activities on land by making difference in soil formation, soil conservation, and soil erosion. It is the function of soil and water conservation measures to restore and maintain this balance (Anantharaman 1980). The Nandakini valley is frequently now a large-scale soil erosion due to deforestation, quarrying, flood, water logging, land sliding, runoff leaching, and soil creeping and these lead to depletion of soil, water, forest, mineral, and climatic resources.

The region affected by soil erosion is enormous. The main cause of soil erosion (Khan 1960) is both biotic and abiotic.

2 Increased Anthropogenic Activities

Human activities cause disturbance in large scale on earth materials by ongoing activity of construction of buildings, transportation dam routes, reservoirs, canals communication system and its up-gradation leading slope failures and property

Fig. 1 Nandakini river valley

damages. Due to increased anthropogenic activities such as deforestation, road construction, the ecology of the valley has become very fragile. This tampers the natural slopes and environment of the mountain regions, thereby increasing susceptibility to landslides occurrence. Slope failure processes are the major causes of concern, in the region. Deforestation noticed around Nand Prayag town area initiated major sliding movements.

These hazards obstruct the roads, break communication, block flowing water in stream and also bring down a lot of soil cover and thus ad enormous silt and gravel to the streams. Large landslides create loss of both human life and property. It is, therefore, required that slopes vulnerable to failure may be identified, so that proper measures may be converted into vulnerable zones.

Besides deforestation, human movements for construction and tourism activities caused slope instability without proper execution of map planning in construction work and water outlet increase water seepage leading to landslides. It has been confirmed after field visit. Construction of roads and engineering cuts of slopes, produce a sizeable volume of debris (Valdiya 1987).

Landslides have adversely affected socio-economy of the area, its people; their homes and possession, lifeline such as canals, pipeline, highways, and communication system. Due to development and increase population major causes of socio-economic losses and property destruction (Fig. 2).

Forest render great Service to Man. They provide products for human use and indirectly they safeguard man's environment. They are subjected to destruction by few Agencies like fire and biotic phenomena. The role of forest among the natural resources is highly beneficial. They themselves are one of the Conservators of other resources and needs preservation and care. They, if not managed properly, face serious injuries. The natural factors include fire, frost, and climbers. The valley having heavy rains has less chance for the occurrence of fire except in dry summer. The biotic factors include overgrazing, soil erosion, overlapping, damage by insects and wild animals. Overgrazing by animals is heavy all over the valley but heaviest in the outskirts of the forest.

Fig. 2 Anthropogenic disturbances of Nandakini river

Grazing leads to loosing of soil which is washed off by rains. Ruthless overlapping, another very important source of injury and serious damage to forest, is practiced by the villagers regularly.

The mineral and rock wealth of the valley include phosphorite, gypsum, dolomite, marble, calcite, and limestone. The Sulphur Springs can also be included in this head. Their quarrying and mining in the most unscientific manner leads to loosing of soils, land sliding, closure of the mouths of springs and increase the erosive power of the speedy rivers and torrents. The quarrying is done by blasting which leads to acceleration of erosion causing Rock and mineral haphazard and depletion of both phosphorite and lime are recorded by the fast-flowing runoff through perennial and erosional torrents and heavy downfall of rains on steeply sloping lesser Himalayan hills. Severe limestone erosion is due to action under heavy rains.

In the Nandakini river valley the rainfall is very heavy but most of it is wasted by the way of excess of surface runoff. The hill tracts especially the Alluvial terraces are deficient in agriculture water. The available water is wasted by high gradient, heavy surface runoff, and infiltration through structurally weak planes which are numerous in the valley.

3 Role of Hydro Electric Projects in Environmental Degradation

The state government of Uttarakhand proposes to construct several hydroelectric projects across the river Ganges and its tributaries. Many of the hydroelectric project constructed/proposed to be constructed across Nandakini river and its tributaries. The proposed reservoirs have led to submergence of forest areas. Most part of the area to be submerged in under scrub and meadows. The environmental impacts of Hydro Electric project in light of the activities that have taken place during the construction of cofferdam, barrage, drilling and blasting during tunneling for headrace tunnel, road, construction of temporary and permanent rehabilitation colony quarrying for construction material and dumping of muck generated from various project work and other working areas are presented in the direct and indirect environmental damages due to various construction activities related to the proposed and under construction hydro projects.

Environmental degradation due to construction of hydelpower project is visible right from the exploration stage and gradually increases due to tunneling, road construction, drilling blasting and foundation excavation of dam and its appurtenant structures. Unscientific dumping of muck creates siltation problem in rivers and streamlets. Similarly, construction of network of project roads leads to deforestation (environmental problem) and slope instability related geological problem.

Due to haphazard dumping of the excavated muck, the water quality of the streams is badly affected on account of enhanced turbidity and suspended load (Sediments).

4 Natural Hazards and Disasters

The Nandakini Basin is located in the centre of Himalayan Mountains system. Nandakini Valley is narrow with deep gorges of high gradient in high hills. The topography is highly precipitous. It consists of a series of peaks. The slope of this peaks covered snow forming hanging valley glaciers, snowed peaks and cirques in Nandakini Valley landforms in form of moraines hanging valleys, indicating Pleistocene period glacial activities in the valley.

Some common of geomorphic features of valley are glacier and fluvial origin material covering the valley area are morainic inactive like lateral moraines with prevalently landforms denudational structure mountain, river terraces, V-Shaped fluvial valleys, and U-Shaped glaciers. Hills posses little level land. The Valley area is structurally disturbed and lies in seismic zone 4 and receives very high precipitation. The natural hazards example earthquake, landslides, cloud burst, and flash burst are frequent and common phenomenon noticed all around the Himalayan region.

In most cases, these natural disasters are triggered by extreme weather conditions (high or extreme rainfall events) during monsoon period. The impact of extreme events on the highly vulnerable Himalayan Mountain ecosystem is increased by many folds due to inherent geological characters, geomorphology (topography) seismicity, land use pattern and other anthropogenic activities.

5 Glacial Hazard and Glacial Lake Outburst Flood (GLOF)

In Nandakini valley glaciers and glacial lakes in high areas a mountain associated with glacial hazards and their impacts down streams. Recent decades considerable changes occur in climate made serious impact on glacier life cycle in the Himalayas resulting melting of glaciers. This lead formation of large number glacial lakes and increasing the rate of ice and snow melting causing increasing water accumulation in these lakes. Glaciers snow lake are mainly dammed by lateral or end moraine have heightened of breaching. Such lakes could be dangerous as they may hold a large quantity of water. Outburst from glaciers lakes has repeatedly caused the loss of human lives as well as severe damage to local infrastructure.

Of late, global warming and greenhouse effect are the main cause of glacial melting and enhanced discharge in snowfed rivers. Due to the increase of water

quantity in a glacial lake, possibility of lake burst is always there which has the potential to wreak havoc in the downstream. (e.g., Kedarnath Desaster June 2013).

6 Geological Hazards

The Himalayan mountain system is structurally and tectonically a complex terrain consisting of folds, thrust, faults, and lineaments of regional dimension exhibiting large horizontal and vertical dislocation of varied lithological stacks. Geological upheavals also bring a change in the setup of natural environment.

There has been intense metamorphosis in the whole region and rocks contain weak cohesion. Nandakini Valley climatic conditions vary from perpetual snow cloud mountains peak to subtropical. Monsoon rain is quite heavy and the intense; it leads to mass movement, slop failure, flash floods, and debris—flow landslides. Every year during the monsoon, heavy loss to lives and damage to property is recorded through heavy rainfall and heavy flood.

During the present and past decades, Nandakini Valley is the example of flashflood a resulting of cloudburst on past many years and face very large impact on related people in this area.

Cloudburst and its relation with dense vegetation in high altitude areas and watershed are well established. Toe-erosion by the swollen rivers renders the river banks and slopes unstable and makes them susceptible to massive land sliding and debris flows. Such violent incidents lead to siltation of reservoirs and destruction of natural habitat of animals, some time leading to extinction of species.

High-intensity rainfall in a short time span is defined, generally, as cloudburst which leads to flash floods in the low lying downstream areas which may be completely washed away. Due to heavy hydrological discharge, the bank erosion and landslide incidences increase many fold leading to destruction of agricultural fields and infrastructure facilities in the region and loss of human and animal lives.

High discharge of the streams causes toe-erosion of the slopes rendering them unstable. The rainy session in Uttarakhand area continues for about three months (July–September) and it receives 300–400 cm of average annual rainfall. Due to steep slopes, the trunk stream and its first order and second-order tributaries flow through highly dissected and deep valleys/gorges. The Nandakini River itself becomes violent during the rainy seasons and floors above the danger marks. Many times there are flash floods in the river due to high rainfall. In Nandakini valley, flash floods were observed first during 1772 and later on in 1992, 1995 frequencies of such extreme rainfall events are found to be increasing in last two decades. 2002 and 2013 floods have devastating impact on the region.

7 Conclusion

The present study "Responsible Factors of Environmental Degradation in Nandakini River Valley" has clearly revealed that the Nandakini Valley is facing severe environmental degradation due to the frequent landslides and hydelpower projects which has led to land degradation and depletion of natural resources. These problems are seriously assuming acute dimensions with increasing pressure of biotic and abiotic factors as the study region happens to be one of the most frequented Himalayan track by the ever-increasing population—Rishikesh–Nandprayag–Ghat–Trishul route. It is not feasible to avoid the utilization of such risk area, as it is also not possible to eliminate the frequent occurrence of landslides because of the natural causes, even though it is possible to partially check it by the human interferences.

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Assessment of Ground Water Quality Along the Coastal Areas of Srikakulam District, Andhra Pradesh, India

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Abstract In India, there has been three-fold increase in the production and consumption of mineral water for the last decade. Earlier only the Bisleri bottles were available as a brand name and today there are mushrooming of companies who are manufacturing so-called mineral water (Now marked as packaged drinking water). This is just because of deterioration in quality of possible drinking water. Earlier this type of water was used only while traveling to higher society, but now a days even a common man prefers to use mineral water as compared to available water on the railway station, bus stands, etc., even in the marriage parties people prefer mineral water to get rid of all risk related to water. Water has become the foremost requirement of all human being. In most of the developing countries the problem of drinking water is increasing day by day. This can be solved only implementing modern treatment plants at the industries and proper sewage treatment facilities at urban areas. Water harvesting and watershed management are other options available to mankind to get rid of this type of water crises. The present paper has been attempted to highlight the ground water quality of a coastal area. The water quality analysis has been carried out in 10 monitoring stations for 17 parameters and final WQI are calculated for both the periods of summer and winter season.

1 Introduction

From ancient days to till today man is dependent on water either surface or ground water and sometimes both. The civilization of humans has happened over the millions of years near the rivers and lakes. Water is used and has been using even

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now for several purposes like irrigation, drinking and for industries, etc. Living species get water because of its circulation through the ecosphere with continuous hydrological cycle that is evaporation, precipitation, percolation and runoff into the oceans. In the ecosphere consist a total of 1408.7×10^6 km^3 out of which, 1370×10^6 km^3 (97.25%) of water is in the form of oceans and only 2.8% is non-oceanic component out of which only 9.5×10^6 km^3 (0.68%) is in the form of ground water (Mackenzie 1999).

The drastic increase in population demand for the supply of water has increased hence dependency on ground water has been increasing tremendously. Nowadays because of the anthropogenic activities ground water being polluted. In olden days, there used to be one open well for each house or at least one for four to five houses. Now, in a small area from the same aquifer, several hundreds to thousands of people are depending on it, which results in the decrease in the level of ground water, or they even dried up fast. Because of this when they are recharge or as the level go down the salinity increases. Over the years, quality of ground water has degraded such that people are even scared to use the water as it has become extremely harmful particularly in India. The availability and quality of ground water may change due to overexploitation, waste disposal especially in urban and rural areas (Ramesh and BhuvanaJagadeeswari 2012).

Generally, the contamination of ground water is very difficult if contaminated purification becomes a daunting task (UNEP 2006). Hence, ground water quality maintenance is very important. The physico-chemical characteristics in the ground water a pivotal role in the quality of the ground water supply for commercial, irrigational, industries and especially for drinking purposes.

2 India's Water Budget and Evapotranspiration

India receives a total rainfall of 3838 cu kms, out of which 1869 cu kms average surface flow as rivers, while 432 cu kms percolates as recharge of ground water and 700 cu kms evaporates into the atmosphere directly and the remaining is available for human use. Rainy season in India is primarily for about three or four months which ranges 100 mm in Rajasthan to 10,000 mm at Mawsynram in Meghalaya. Ground water level increases during monsoon season and will be very scarce during summer. According to water resources systems, division of National Institute of Hydrology stated that the availability of exploitable water, is about 3000 cu m in 1951, and it's reduced to 1100 cu m in 1998 and is speculated to be 687 cu m by the year 2050, as the population is going to increase.

3 Demand of Water and Its Importance

The statistics of water requirement for the year 2025 will be a huge quantity. Around 1025 cu kms required towards irrigational and industrial purposes. For irrigational purposes approximately 770 cu kms of water will be utilized whereas for industrial and other purposes around 228 cu km of water will be required. This statistical data estimated by Indian Water Resources in "Water Management-Need for Public Awareness" report. India's total water resource not evenly distributed throughout the country.

The demand for clean water increased in the present decade drastically through the growth of world population. People in many countries in the world lack of fresh and potable water that is necessary to their sustainability to develop and prosper, more secured and lowest cost of water supplies needed. Maintained fresh and secured water supplies for drinking, domestic, agriculture and industries are impossible to sustain without groundwater. Unlike the other resources of natural or raw materials and ground water is available throughout the world. The possibilities for abstraction vary greatly from place to place, due to the conditions of rainfall and aquifers distribution.

Ground water, even though second to rivers as a fresh water distributor, is much the largest regulator of fresh water resource. The main components of the ground water resources are subsurface part of natural water cycle, in which evaporation, precipitation, seepage, and discharge. Ground water resources divided into shallow water resources that is <800 m and deep-water resources that is >800 m. The shallow waters are easy to get using conservative water well technologies whereas, deep ground water difficult to exploit and expensive, Because the need for water resources increased advanced technologies developed in petroleum industry have been used to reach the deeper groundwater.

Ground water has to be managed to maintain its cleanliness within standard limits because 80% of diseases in human beings caused by water (WHO). This is necessary for sustainable use in agriculture and potability by quality assessment and management. Once the ground water is contaminated, its quality cannot be restored by stopping the pollutants from the source, if therefore becomes imperative to regularly monitor the quality of groundwater and means to protect it. Water Quality Index (WQI) is one of the most effective tools to communicate information on the quality of water and play an important index in assessment and management studies related to water quality. It defined as "a rating reflecting the composite influence of different water quality parameters and calculated from the point of view of the suitability of ground water for human consumption" (Ramakrishnaiah 2009).

4 Coastal Aquifers and Its Importance

Aquifers is an underground layer of water life form a porous rock and unconsolidated materials are like gravel, sand or silt from which it can be extracted using water well. In some cases, human activities are responsible to deplete aquifers rapidly.

Fresh water aquifers particularly those with limited recharge by rainfall, it can be overexploited and depending on the local hydrology and can be drawn in non-portable water or salt water intrusion or surface water bodies. In coastal areas, where the aquifer pumping is excessive the ground water can be contaminated by mineral poisons.

Aquifers are essential for agriculture and human habitat; deep aquifers in dry regions have been water resources for irrigation. Many villages and large cities represent their water supply from aquifer wells. Aquifers supply sustainable ground water to urban areas and agricultural irrigation are naturally close to the ground surface and have some fresh water recharge. This recharge is typically from rivers or precipitation that percolates into the aquifers through overlay the unsaturated mineral deposits.

In the coastal areas, water resources are under pressure contrivance because of overexploitation, population growth, activities related to development as well as environmental degradation (Choudri et al. 2015). Developmental activities have created serious challenges for policy makers and planners towards ensuring long-term sustainability and demand, especially vulnerable to salt water intrusion through overexploitation (World Bank 1996).

In many coastal aquifers, salt water intrusion has become one of the major constraints imposed on groundwater utilization. As salt water intrusion progresses, existing pumping wells, especially those close to the coast, become saline and have to be abandon. In addition, the area above the intruding seawater wedge is lost as a source of natural replacement to the aquifer. India has a vast stretch of coastline nearly 7500 km, including its island territories. More than 30% of the population in the country lives along the coastal region. Groundwater for lot of important uses including town water supply, domestic water supply, irrigation of crops and pastures and industrial processes by strategic resources of coastal aquifers. Coastal aquifers also provide base flow to creeks and rivers during dry periods, thus supporting diverse ecosystems. However, fresh water resources in these coastal aquifers are possible to understanding disastrous and irreversible impact in the coming times owing to over-exploitation of ground water resources and sea-level rise.

The pressures of expanding coastal populations and emerging industrial activities are exerting on the coast and coastal waters, thereby negatively affecting groundwater, coastal water quality, and marine life as means of coastal pollution which is increasingly becoming a major issue in the coastal areas (Van Lavieren et al. 2011). The land-based activities such as agriculture, industry, and mineral exploitation have widely contributed to the degradation of coastal water quality (Salim).

5 Sources of Ground Water Pollution

In current years, increasing risk to ground water quality due to human activities has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, inadvertently by agriculture, domestic and industrial effluents, unexpectedly by subsurface or surface disposal of sewage and industrial wastes. Ground waters contaminated due to leachate of refuse dumps, wastewater seepages and spillages.

Suitability of ground water is important to water supply to public, irrigation, industrial applications and power generation etc. The resultant of quality of ground water for the entire processes and reactions that have acted on the water from the moment it condensed in the atmosphere to the time it discharged by a well. Therefore, the quality of ground water varies from place to place, the depth of water table, from season to season and is primarily governed by the extent and composition of dissolved solids present in it. Most ground water quality problems are difficult to detect and hard to resolve is slowly but surely declining everywhere.

The quality of polluted water may be characterized according to their physico-chemical and microbiological characteristics. For complete specifications of polluted water, the required number of water quality parameters is so large that it makes the task of regular monitoring of water quality quite difficult. Due to shortage of trained manpower and inadequate laboratory facilities, it becomes difficult to determine all these parameters. So, among these numerous water quality parameters, if one can find some correlation, the important task of periodic monitoring water quality parameters may be facilitated largely. The analyzed data has been found to be a highly useful tool for correlating different parameters. Correlation analysis measures the closeness of the association between chosen independent and dependent variables. If the correlation coefficient is nearer to +1 or –1, it shows the possibility of linear relationship between the variables x and y. This way analysis attempts to establish the nature of the relationship between the variables and thereby provides a mechanism for prediction or forecasting.

6 Salinity in Aquifers

Sea water generally has integrated chemistry with the occurrence of chloride and sodium possessing a molar ratio of 0.86 (mass ratio = 0.55). Sea water solutes are specifically characterized by the excess of chloride over alkali ions (Na^+ and K^+) and magnesium greatly in excess of calcium. In different continental fresh ground waters are characterized by variable chemical composition, the predominant anions are HCO^{3-}, SO_4^{2-} and Cl^-, and the primary main cations are calcium (Ca^{+2}) and magnesium (Mg^{+2}) and to lesser extent the sodium (Na^+) and potassium (K^+). In most cases over Mg^{+2} are majorly by Ca^{2+}.

Numerous criteria suggested using as indicators for seawater intrusion into coastal aquifer. Revelle (1941) pointed that the increase in total dissolved solids is not sufficient proof of occurrence intrusion by sea water. Sea water intrusion involves mixing between fresh water and saline. The most obvious indication of sea water intrusion is increase in chloride (Cl^{-}) in sea water is the ratio of chloride to carbonate and bicarbonate ions which is known as Simpson ratio (Moujabber et al. 2006), carbonate and bicarbonate ions are present only in very small amount in sea water. Sea water intrusion is assessed by the ratio of certain chemical parameters such as Ca^{+2}/Mg^{+2}, $Cl/(CO_3 + HCO_3)$ and T_A/T_H (Rengaraj et al. 1996). The following scale is used for assessing the contaminated groundwater by salt water intrusion (Simpson 1946).

7 Objectives of the Study

Srikakulam district bounded among three sides by the Bay of Bengal on the east, northeast, and southwest with a coastline of 192 kms of Andhra Pradesh and classified as a backward district. The Srikakulam district served by the irrigation sources of surface and ground waters. Major and medium irrigation projects exist in the district, the total net area is 191,662 ha by all means sources of irrigation available in the district.

As there is an increasing demand for the ground water supply the quality of water being deteriorated and the present study was undertaken with the following objectives.

1. To analyze physico-chemical parameters of groundwater in coastal villages of Srikakulam District.
2. To assess the quality of water by calculating using Water Quality Index for ground water samples based on its physico-chemical characteristics.

8 Methodology

Srikakulam district is the north-eastern district of Andhra Pradesh. The district has a coastline of 192 kms, and sandwiched between the Eastern Ghats and Bay of Bengal. It is one of the less populated and literacy districts of the state. The district is endowed by good rainfall, surface water, forest wealth and mineral resources.

Srikakulam district lies between North Latitude of 18° 20′/19° 10′ and East Longitude of 83° 05′/84° 50′ with an aerial extent of 5837 km^2. The district was bounded by the Bay of Bengal on the east, northeast, and southwest with a coastline of 192 kms, Vizianagaram district of Andhra Pradesh on west and south, Orissa state on north and northwest, it almost parallel to the coastline.

The district headquarters is also located at Srikakulam town and it is parted into three revenue divisions viz., Srikakulam, Palakonda, and Tekkali. These divisions are separated into 38 mandals, 6 towns, and 1763 villages in this district. As per Census 2011, the district population was 2,537,593 (Urban-436,347, Rural-2,101,246). The population density is 462 persons per sq.

The main rivers of the district are the Vamsadhara and the Nagavali and the other important rivers are following Suvarnamukhi, Vegavati, Mahendra Tanya and Bahuda. Among the rivers Vamsadhara, Nagavali and Suvarnamukhi are perennial. The common drainage pattern is dendritic to sub-dendritic and occasionally parallel at places. The drainage in western part of the district resembles dendritic type, whereas in the central part it is parallel to sub-dendritic. The overall drainage is of medium to coarse textured towards west and north of the district, whereas in central and southern parts it is very coarse. The drainage density varied from less than 0.2–1 km/km^2. In Palakonda area, the density is of 0.6 to 1 km/km^2. While areas with a density of more than 0.2 km/km^2 are observed in Itchapuram, Sompeta, Narasannapeta, and Srikakulam. The density is less than 0.2 km/km^2 in plain area of Tekkali and in parts of Pathapatnam.

The district, having surface and ground water irrigation sources, and some major and minor irrigation projects exists in the district. The total irrigated net area is 191,662 ha by means of all irrigation sources available in the district.

Predominant soils in Srikakulam district are red soils, red loams, sandy loams, sandy soils, black soils, and alluvial soils. Red soils which are derived from the weathering of khondalites and gneissic rocks occur mostly along hill slopes. The narrow valleys and low lying areas between the hills are also covered with red loamy soils. Sandy soils are seen occurring in the southern and the eastern parts of the district. The deltaic alluvial soil is seen distributed along the banks of the rivers Vamsadhara, Nagavalli, and their tributaries. The coastal alluvial soils are seen in the coastal tracts of the district in parts of Ichapuram, Sompeta and Tekkali area. The red sand and lateritic soils are mostly distributed throughout the district.

In the present study, the ground water samples from open wells, bore wells, and hand pumps were collected from ten sites along the coast line of Srikakulam (From Sompeta to Srikakulam). The sampling sites are 5–8 km from the coastal line and the samples are collected during 2011–2013. The samples were collected with two liters polythene bottles (soaked overnight within 2% nitric acid and washed well in distilled water) as of each location. The samples were analyzed for various physico-chemical parameters like pH, conductance, total dissolved solids, alkalinity, total hardness (calcium and magnesium), sodium, potassium, iron, chloride, nitrate, phosphate and sulfate, according to standard techniques (APHA-1985, CPCB-2009) (Table 1; Fig. 1).

Table 1 Details of sampling

Code	Sample site	Latitude	Longitude	Source	Use of water
S1	Sompeta	18′965114	84′593556 °	Hand pump	Drinking, domestic
S2	Baruva	18′918726	84′562459	Open well	Domestic, laundry
S3	Ratti	18′837278	84′539551	Bore well	Drinking, domestic
S4	Chinnavanka (V)	18′774346	84′478051	Bore well	Drinking, domestic
S5	Dokulapaadu	18′746237	84′466508	Bore well	Drinking, domestic
S6	Nuvvularevu	18′722497	84′451052	Hand pump	Drinking, domestic
S7	Naupada	18′599417	84′275143	Hand pump	Domestic, laundry
S8	Kotabommali	18′505031°	84′204998°	Hand pump	Drinking, domestic
S9	Kalingapatnam	18′495769°	84′203166°	Hand pump	Drinking, public use
S10	Srikakulam	18′291018°	84′896963°	Hand pump	Drinking, domestic

9 Results and Discussions

9.1 Introduction

Based on the physico-chemical analysis of the ground water quality and its suitability for drinking is the major objective of the present study. Samples collected, during summer and winter seasons, have been analyzed for sixteen water quality parameters and are presented in Tables 2 and 3.

The performance of key ions (Ca, Mg, Na, K, CO_3, HCO_3, SO_4, Cl) and important physico-chemical parameters (pH, electrical conductivity (EC), Total Dissolved Solids (TDS), and Total Hardness (TH) and its seasonal variations were discussed to assess the suitability of ground water.

9.2 pH

pH is to assess the balance between the concentration of hydrogen ions and hydroxyl ions in water. The pH of water provides vital information in many types of solubility calculations (Hem 1985). The limit of pH value for drinking water is specified as 6.5–8.5 (WHO 2004; ISI 1993). The pH value of most the ground water samples in the study area varies from 7.0 to 8.2 in summer and 6.8–7.8 in winter. This clearly specifies that the ground water in the study area is slightly acidic in nature except for Chinnavanka village and the values are within the permissible limit. pH values of the study area showed a wide range from slightly acidic to

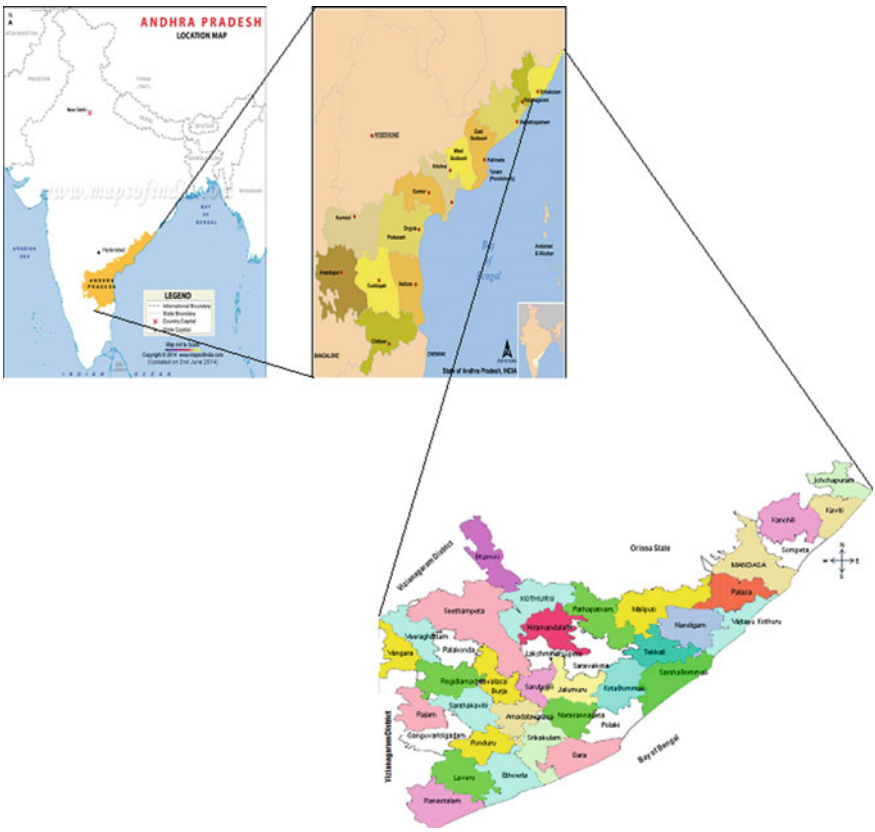

Fig. 1 Ground water sample location in Srikakulam district

Table 2 Classification of groundwater based on TDS (Davis and De Wiest)

TDS (mg/l)	Water type	No. of sites	
		Summer	Winter
<500	Desirable for drinking	01	02
500–1000	Permissible for drinking	03	04
<3000	Useful for irrigation	10	10
>3000	Unfit for drinking and irrigation	–	–

neutral and slightly alkaline. This indicates that continues increase in human activities like sewage disposal and excessive use of fertilizers in the extremely populated coastal segments of the study area may influence the pH (Fig. 2).

Table 3 Physico—Chemical characteristics of ground water samples collected from different areas of Srikakulam District in Summer

SL	pH	EC (mmhos/cm)	TDS (mg/l)	Alkalinity (mg/l)	TH (mg/l)	CaH (mg/l)	MgH (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	CO_3	HCO_3	Cl (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	SO_4 (mg/l)
SI	7.4	2.9	1490	443	112	60.6	41	5.2	9.7	0.25	143	300	13.8	11.9	1.1	32
S2	7.3	1.2	559	210	128	84.8	52	7.1	4.3	0.05	68	142	16	13	1.3	3
S3	7.4	1.6	830	297	160	96.6	69	49	8.4	0.16	96	201	55	12.3	1.3	12
S4	7	1.9	1077	257	133	76.8	58	50.5	7.6	0.01	83	174	63	16.4	0.9	16.5
S5	7.9	1.8	875	269	162	91	70	7.1	9.7	0.01	87	182	19	12.5	1.5	11
S6	7.5	2	1058	325	266	162.52	105	10.9	8.1	0.064	105	220	16.4	11.7	1.12	33.6
S7	8.1	0.88	450	269	109	74.01	38	44.6	11.5	0.15	87	182	125	11.8	0.7	10.4
S8	8.2	3	1222	372	154	84.07	70	16.9	12.5	0.081	120	252	21.9	12.4	1.56	17.9
S9	8	2.2	1152	238	172	91.01	81	116.49	7.9	0.091	77	161	200	13.4	1.4	21
S10	7.9	3	1605	542	177	83.01	92	105	9.4	0.195	175	367	128	12.18	0.8	34
Min	**7**	**0.88**	**450**	**210**	**109**	**60.6**	**38**	**5.2**	**4.3**	**0.01**	**68**	**142**	**13.8**	**11.7**	**0.7**	**3**
Max	**8.2**	**3**	**1605**	**542**	**266**	**162.52**	**105**	**116.49**	**12.5**	**0.25**	**175**	**367**	**200**	**16.4**	**1.56**	**34**
Mean	**7.67**	**2.048**	**1031.8**	**322.2**	**157.31**	**90.442**	**67.6**	**41.279**	**8.91**	**0.1061**	**104.1**	**218.1**	**65.81**	**12.758**	**1.168**	**19.14**
SD	**0.40**	**0.74**	**368.05**	**103.07**	**45.085**	**27.30**	**21.36**	**40.863**	**2.261**	**0.09**	**33.21**	**69.86**	**64.34**	**1.39**	**0.30**	**10.86**

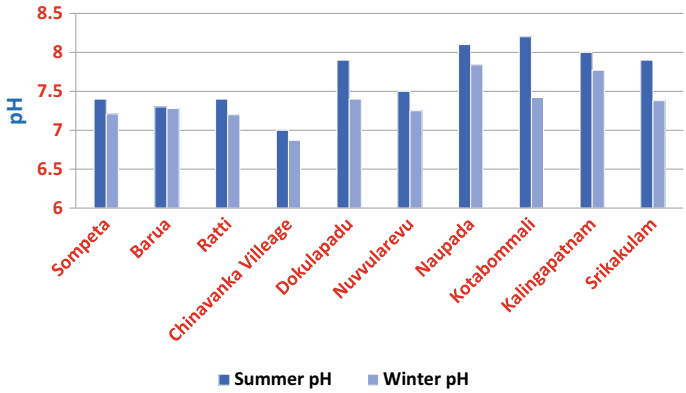

Fig. 2 pH of ground water samples in different areas at Srikakulam district

9.3 Conductivity

Conductivity is a measure of capacity of substance or solution to conduct the electric current. It is a reciprocal of resistance. The conductivity recorded with a maximum of 3 mmhos/cm in summer at Kotabommali and winter at Kalingapatnam), the minimum of 0.8 mmhos/cm recorded in summer at Naupada and winter at Nuvvularevu. The normal range of ground water samples is 0.3 mmhos/cm. This is because of high concentration of ionic constituents present in the water bodies under study reflected the contributions geological, coastal as well as pollution by domestic wastes. The electric conductivity is influenced mainly the dissolved ions such as bicarbonates, chlorides, sodium, potassium, and sulfate. Many dissolved substance may produce esthetically displeasing color and taste and odor. In the present study, in all samples, the conductivity exceeds the level of 0.3 mmhos/cm (Fig. 3).

9.4 Total Dissolved Solids (TDS)

As per the World Health Organization (WHO) specification TDS up to 500 mg/l is the uppermost desirable and up to 1500 mg/l is maximal acceptable. In the present study areas the TDS value varies between a minimum of 450 mg/l and a maximum of 1605 mg/l in summer, the minimum value of 453 mg/l and 1650 mg/l in summer, indicating that all water samples exceeded the required limit except at Naupada in both summer and winter seasons within the maximum permissible limit. As per the Davis and De Wiest (1966) classification of groundwater based on TDS, 30% of the total groundwater samples are desirable for drinking (TDS\500 mg/l), 40% samples

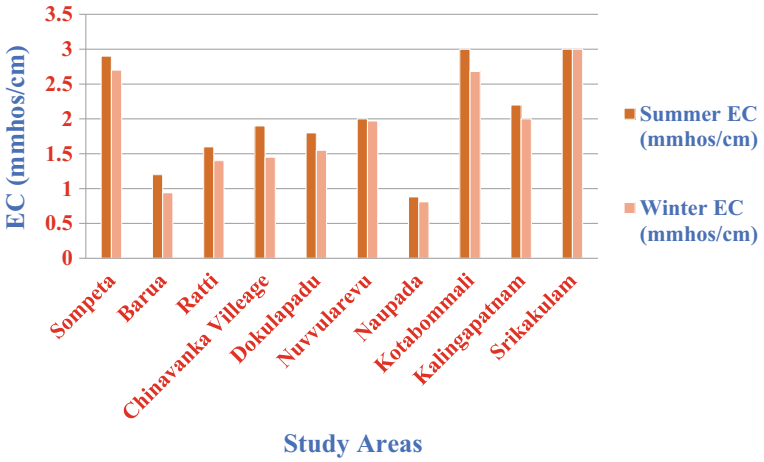

Fig. 3 Conductivity of ground water samples in different areas at Srikakulam district

are permissible for drinking (500–1000 mg/l) and 30% samples are appropriate for irrigation purposes. High concentration of TDS in the ground water sample is because of draining of salts from soil furthermore household sewage may seep into the ground water, which may show the way to increase in TDS values (Table 2). This shows that most of the stations fall above standard level, this shows that anthropogenic impact which can be due to agricultural activity leading to local spatial and temporal variability of runoff (Fig. 4).

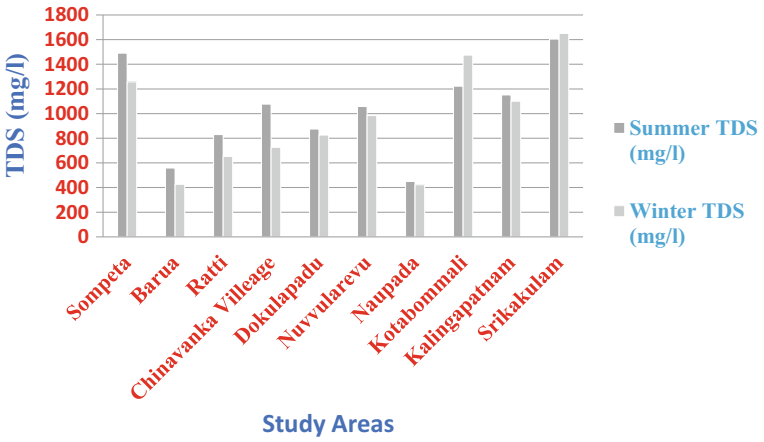

Fig. 4 TDS of ground water samples in different areas at Srikakulam district

9.5 Total Hardness (TH)

Hardness is measure of the capacity of water which brings about precipitation of insoluble calcium and magnesium salts of high unsaturated fats and soap solutions. The foremost hardness bringing about cations of calcium, magnesium, bicarbonates, chlorides, and sulphates.

The total hardness is reported in the range of 82–233 mg/l in all the sampling locations during winter and 109–266 mg/l in summer season. In all the examining locations total hardness within the acceptable limit as per ISI standard of 200 mg/l except Nuvvularevu (S_6) sampling location in summer and Srikakulam (S_{10}) samples location in winter. Generally, the total hardness below 75 mg/l is considered as the best for drinking purposes. Above 75 mg/l is considered moderately hard. Total hardness in water may cause cardiovascular diseases on prolonged consumption (Fig. 5).

9.6 Alkalinity

Alkalinity is limit of water to kill the solid corrosive, contingent on the limit of hydroxyl ions to consolidate with hydrogen ion. The constituents of alkalinity in normal framework essentially contain carbonate, bicarbonate, and hydroxide. These constituents result from dissolution of mineral substances in the soil and atmosphere (Mittal and Verma 1997). Carbonate and Bicarbonate may start from microbial decline of organic matter too. Alkalinity esteem with less than 100 mg/l is enviable for domestic use. However, in large quantities imparts sour taste to water.

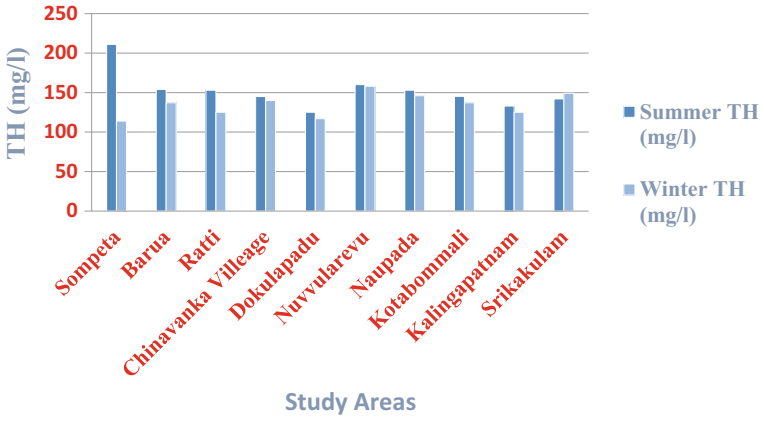

Fig. 5 Total hardness of ground water samples in different areas at Srikakulam district

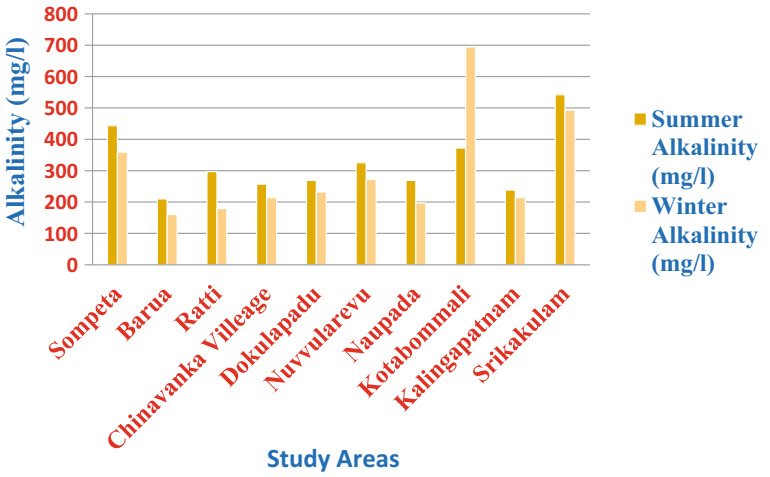

Fig. 6 Alkalinity of ground water samples in different areas at Srikakulam district

Alkalinity reported high in all the sampling locations in both summer and winter seasons except in Baruva (S_2), Ratti (S_3), and Naupada (S_3) sampling stations in winter season. The values of alkalinity are very high in summer compared to winter and it ranged from 160 to 694 mg/l. Moderate concentrations of alkalinity are desirable to drinking water to balance the corrosive effect of acidity. When it is present in, excess amount arises health problem such as excessive drying of the skin. This is due to the fact that tends to remove the natural skin secretions. This might be because of the percolation of household sewage (Naik 2005) (Fig. 6).

9.7 Calcium Hardness

Calcium is the most copious element in the surface and ground water. Ca^{2+} concentrations are differentiating from 60.6 to 162.52 mg/l in summer at Sompeta and Nuvvularevu and 17.6 to 155.8 mg/l in winter at Naupada and Srikakulam. Relatively, the higher concentration of Ca^{2+} is observed at 162.52 mg/l from the ground water location at Nuvvularevu. The most extreme desirable limit of Calcium in drinking water is 75 mg/l and maximum permissible limit is 200 mg/l. Calcium ions in most of the samples of study exceeded the desirable limit, however, they are within permissible limits. Calcium is a crucial constituent of human being, the higher Ca^{2+} substance can cause stomach diseases and is objectionable for household utilizes as it causes encrustation and scaling. The lower content of calcium may cause rickets and defective teeth by drinking water. The amount of calcium in natural water is depending upon the type of rocks. Small concentration of calcium is advantageous in reducing the corrosion in pipes (Fig. 7).

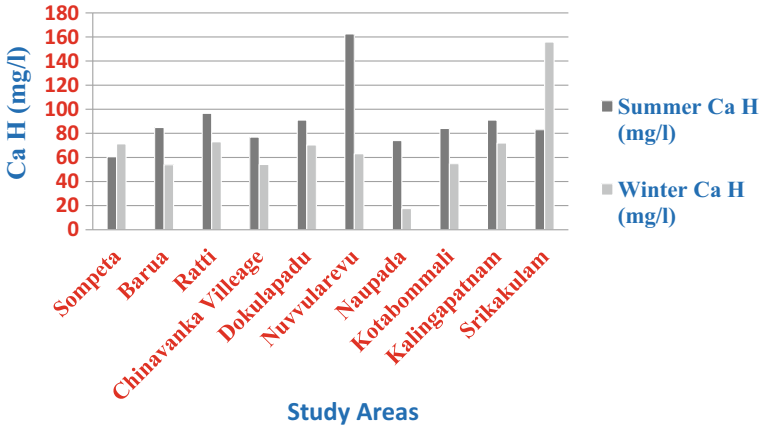

Fig. 7 Calcium hardness of ground water samples in different areas at Srikakulam district

9.8 Magnisium Hardness

In the present study area, the concentration of magnesium ranged from 38 to 105 mg/l in summer at Naupada and Nuvvularevu and 40–90 mg/l in winter at Sompeta and Dokulapadu. The maximal limit of Magnesium in drinking water is 30 mg/l and maximum permissible limit is 100 and 150 mg/l (ISI I1993; WHO 2004). The absorption of Mg^{2+} in water is comparatively less than the Calcium probably due to lesser occurrence of Mg^{2+} minerals. Magnesium hardness is particularly associated through sulfate particle has diuretic on persons unaccustomed to it (Khursid and Basher 1998) (Fig. 8).

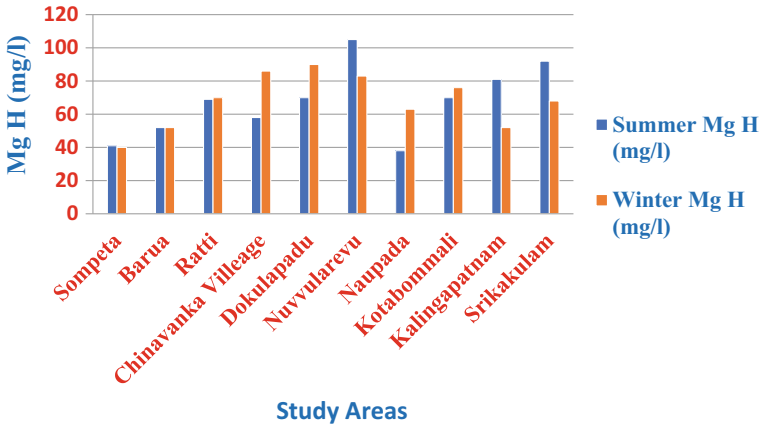

Fig. 8 Magnesium Hardness of ground water samples in different areas at Srikakulam district

9.9 Sodium (Na)

Sodium naturally occurs in water 200 mg/l (Todd 1980; WHO 2004) has recommended has permissible limit to be present in water for domestic purposes. The natural contributors of sodium to the grounds water are the feldspar minerals present in the rocks of the region.

The concentration of sodium in the study area differs from 5.2 to 116.5 mg/l in summer at Sompeta and Kalingapatnam and 4.5–105 mg/l in winter at Dokulapadu and Naupada, respectively (Fig. 9).

9.10 Potassium (K)

Potassium generally appears to be within 10 mg/l in water (Todd 1980). Potassium is an essential component for humans, plants, and animals and determined in natural way life for the most part as of vegetation and soil. The principal source of potassium in the ground water includes rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. It is more plentiful in sedimentary rocks and commonly present in feldspar, mica and other clay minerals. This is a naturally occurring component; though, its concentration ruins moderately lower compared with Ca, Mg, and Na.

In the current study area the ground water samples differed from 4.3 to 12.5 mg/l in summer at Barua and Kotabommali and 6.7–10.8 mg/l in winter at Nuvvularevu and Naupada, respectively. The maximum permissible limit of potassium in the drinking water is 12 mg/l and it was found that 90% of all the study areas samples are underneath the permissible limit of WHO. Increased concentrations of sodium

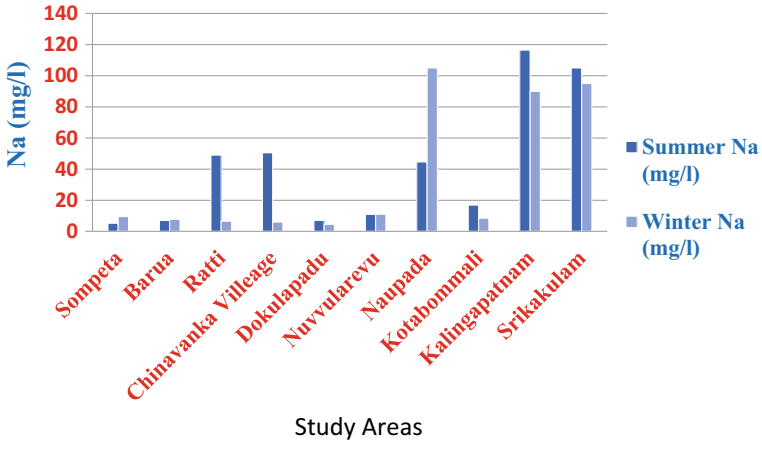

Fig. 9 Sodium of ground water samples in different areas at Srikakulam district

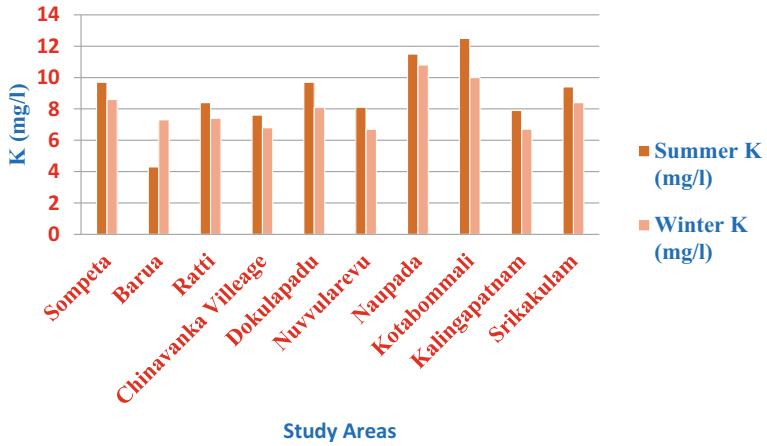

Fig. 10 Potassium of ground water samples in different areas at Srikakulam district

and potassium in water causes scale formation and corrosion of boilers. Feldspar minerals and potassium bearing micas are the natural sources in ground water (Fig. 10).

9.11 Iron

Most water bodies contain some iron because iron commonly present in igneous rocks and found in trace amounts in all sediments and sedimentary rocks. The content of iron in water is important because even small amounts cause serious effects on water usefulness for domestic and industrial purposes. The normal concentration of iron in drinking water is 0.3 mg/l.

Iron content in the study areas was observed maximum of 0.25 mg/l in summer, 0.22 mg/l in winter at Sompeta. In the other study areas, iron content was observed low. A limit of 0.3 mg/l has been prescribed by BIS (1991) for drinking water supplies. Iron naturally occurs in the ground water and the concentration of iron can be increased by using an iron bore and iron hand pump. Long-term consumption of drinking water with high concentration of iron may cause liver diseases. Iron content in all the sampling locations is well within the limits of BIS standards (Fig. 11).

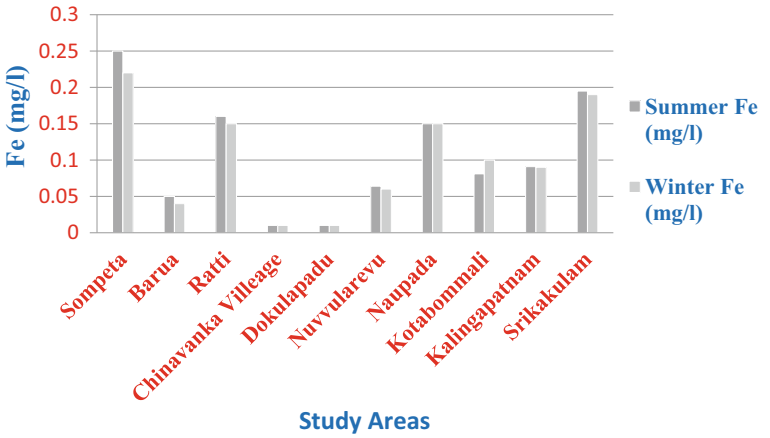

Fig. 11 Iron of ground water samples in different areas at Srikakulam district

9.12 Bicarbonate (HCO_3)

Bicarbonates and carbonates attribute the alkalinity of water and the maximum desirable limit of alkalinity is 600 mg/l (BIS 2004).

The value of HCO_3 is observed from 142 to 367 mg/l in summer at Baruva and Srikakulam and in winter 105–460 mg/l at Baruva and Kalingapatnam in winter, respectively, which is the domination, apart from the ground water, occurring near the coast. The higher concentration of HCO_3 in the water points to the dominance of mineral dissolution (Stumm and Morgan 1996). The high alkalinity above the permissible limits causes unpleasant taste to the water and bicarbonate along with calcium and magnesium forms crusts in pipes and retards flow of water through them.

9.13 Chlorides

Chloride is generally distributed in the ground water as salts of NaCl, KCl and $CaCl_2$ in addition to the sources chlorides are leached into the ground water from various rocks into the soil by weathering. Chloride ion is highly mobile and transported to closed basins or oceans. Chloride, in surface and ground water, comes from natural and anthropogenic sources such as mineral salts dissolutions, utilization of inorganic fertilizers, landfills, effluents from the septic tanks, animal feeds, effluents from industries, irrigation drainage and seawater intrusion in coastal areas. The maximum tolerable limit of chloride in drinking water is 1000 mg/l (BIS 2004) beyond which it imparts a salted taste to the water.

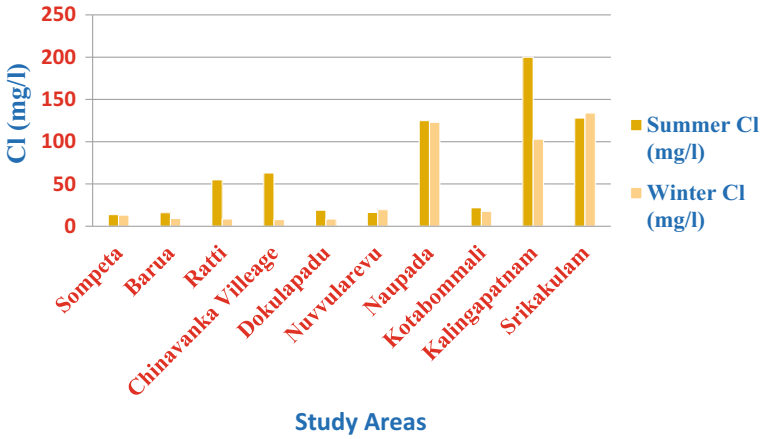

Fig. 12 Chlorides of ground water samples in different areas at Srikakulam district

It has been observed that chloride occur naturally in all types of waters. In the areas under study, the concentration of chlorides is varied from 13.8 to 200 mg/l in summer at Sompeta and Kalingapatnam and 7.98–134 mg/l in winter at Chinnavanka village and Srikakulam. The limits of 250 mg/l chlorides are recommended as desirable limit and 1000 mg/l as the permissible limit for drinking water (BIS 1991; WHO 1996). However, no adverse health effects on human have been reported from intake of Waters containing even higher content of chloride (Fig. 12).

9.14 Nitrate

Nitrate in natural water comes from organic sources or from industrial and agricultural chemicals where nitrate chemicals are highly soluble nitrate enters ground water from another part of nitrogen cycle in the earth's hydrosphere and biosphere. Nitrate increases the growth of algae which gives undesirable taste and odor. Concentration of nitrate in excess of 45 mg/l may cause Methemoglobinemia that is blue baby syndrome infants (Knobeloch et al. 2000; Kavitha and Kazi 2012) (Fig. 13).

The nitrate content in the study area is low in all the sampling location ranged from 11.7 to 16.4 mg/l in summer Nuvvularevu and Chinnavanka village and 10.4–16.1 mg/l in winter at Sompeta and Chnnavanka village, respectively. It is effective plant nutrient and moderately toxic. A limit of 45 mg/l has been prescribed by WHO (1996) and BIS (1991) for drinking water supplies. Continuous heavy doses of nitrates on ingestion may also cause carcinogenic disease.

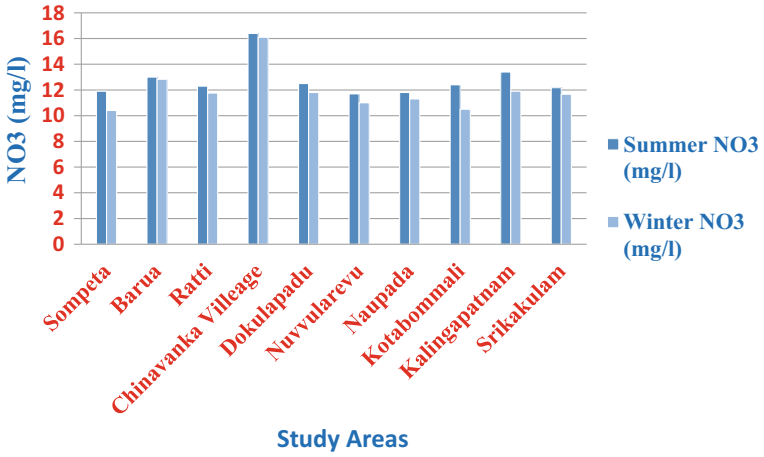

Fig. 13 Nitrate of ground water samples in different areas at Srikakulam district

9.15 Phosphate

Domestic, industrial and agricultural sewage are very important sources for phophorus in natural water. Organic phosphate is produced basically by biological process. They are contributed to sewage by body waste and food residues. Phosphorus is essential in metabolic cycle, so it is always present in animal waste. Orthophosphates and polyphosphates can be contributed by detergents. Excessive concentrations of phosphates may lead to algal growth.

Phosphate concentration in sampling areas is ranged from 0.7 to 1.56 mg/l at Naupada and Dokulapadu in summer and 0.12 to 1.9 mg/l at Chinnavanka village and Kotabommali in winter, respectively. Remaining all sampling sites the values are low (Fig. 14).

9.16 Sulphate

Sulphates occur in water largely in oxidized form, it also presents in the form of sulphides. The concentration of sulphate from 0.2 to more than 100,000 mg/l was found in nature. Large amount of sulphate has a cathartic effect on human beings. In combination with other ions gives bitter taste. Sulphates of calcium and magnesium cause hardness and scales formations occurred in steam boilers.

Sulfate content in the study area ranged from 3.0 to 34 mg/l in summer in Barua and in Srikakulam and in winter from 3.5 to 23.5 mg/l at Barua–Kotabommali, respectively. In all sampling stations, the value of sulfate is well within the permissible limit (200 mg/l) (Fig. 15; Tables 3 and 4).

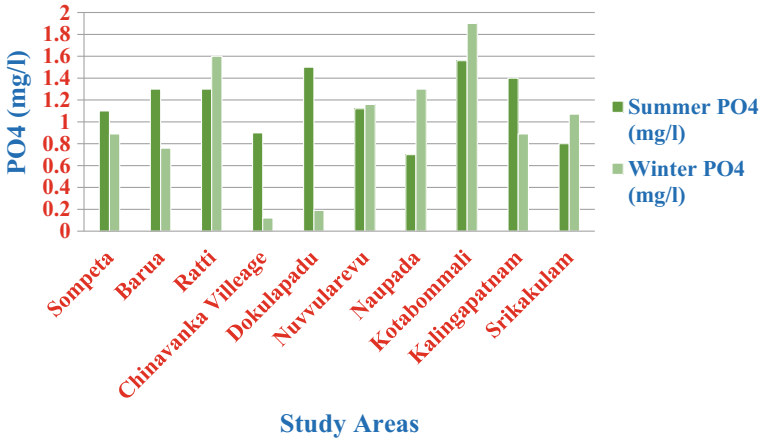

Fig. 14 Phosphate of ground water samples in different areas at Srikakulam district

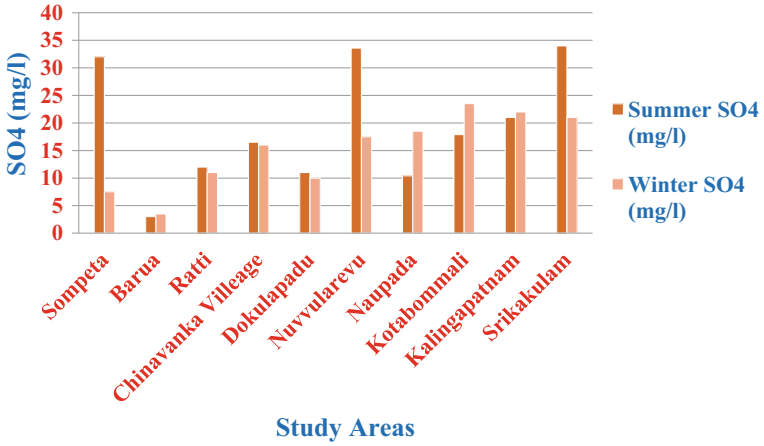

Fig. 15 Sulphate of ground water samples in different areas at Srikakulam district

9.17 Hydrological Facies

Natural water may be represented in three cationic constituents there are calcium, magnesium (Ca^{2+}, Mg^{2+}) and three anionic constituents are sulfates, chlorides (SO_4^{2-}, Cl^{-}) and those contributing to alkalinity, i.e., CO_3^{2-}, and HCO_3^{-} (kumar et al. 2014). Therefore, lineal plot is the suitable format for the representation of ground water. The trilinear diagram is presented by Piper. It comprises chiefly tribal domains consists of mainly three fields; there are one diamond-shaped field and two triangular fields. Different ground water samples can able to identify

Table 4 Physico—Chemical characteristics of ground water samples collected from different areas of Srikakulam District in Winter

SL	pH	EC (mmhos/cm)	TDS (mg/l)	Alkalinity (mg/l)	TH (mg/l)	CaH (mg/l)	MgH (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	CO_3	HCO_3	CI _ (mg/l)	NO_3 (mg/l)	$P0_4$ (mg/l)	SO_4 (mg/l)
SI	7.21	2.7	1257	359	111.3	71.3	40	9.5	8.6	0.22	123	236	13.1	10.4	0.89	7.5
S2	7.28	0.94	426.6	160	105.96	53.96	52	7.8	7.3	0.04	55	105	9.2	12.83	0.76	3.5
S3	7.2	1.4	653	179	143.01	73.01	70	6.5	7.4	0.15	59	120	8.6	11.76	1.6	11
S4	6.87	1.45	726.6	214	140.11	54.11	86	6	6.8	0.01	78	136	7.98	16.1	0.12	16
S5	7.4	1.55	826	232	160.39	70.39	90	4.5	8.1	0.01	77	155	8.52	11.8	0.19	10
S6	7.25	1.97	983.9	272	146	63	83	11	6.7	0.06	92	180	19.56	11	1.16	17.5
S7	7.84	0.81	423	197	80.6	17.6	63	105	10.8	0.15	67	130	123	11.3	1.3	18.5
S8	7.42	2.68	1474	694	130.89	54.89	76	8.5	10	0.1	234	460	17.65	10.5	1.9	23.5
S9	7.77	2	1100	214	123.96	71.96	52	90	6.7	0.09	71	143	103	11.9	0.89	22
S10	7.38	3	1650	493	223.8	155.8	68	95	8.4	0.19	165	328	134	11.66	1.07	21
Min	**6.87**	**0.81**	**423**	**160**	**80.6**	**17.6**	**40**	**4.5**	**6.7**	**0.01**	**55**	**105**	**7.98**	**10.4**	**0.12**	**3.5**
Max	**7.84**	**3**	**1650**	**694**	**223.8**	**155.8**	**90**	**105**	**10.8**	**0.22**	**234**	**460**	**134**	**16.1**	**1.9**	**23.5**
mean	**7.36**	**1.85**	**952**	**301.4**	**136.6**	**68.60**	**68**	**34.38**	**8.08**	**0.102**	**102.1**	**199.3**	**44.46**	**11.92**	**0.988**	**15.05**
SD	**0.28**	**2.16**	**420**	**170.29**	**38.32**	**34.79**	**16.51**	**43.17**	**1.41**	**0.08**	**57.13**	**113.22**	**52.80**	**1.64**	**0.56**	**6.72**

by their location in the diamond field. Cations are uttered as percentage of total cations in meq/l plot as a single point on the left triangle while anions plot in the right triangle. Similarities and differences among ground water samples can be revealed from the trilinear because water has similar qualities will tend to plot together as groups. Distinct ground water qualities can be quickly distinguished by their plotting in certain areas of the diamond field. The analytical values obtained from the ground water samples are plotted on Piper trilinear diagram to understand the hydro chemical regime of the study area. The diamond-shaped field of Piper diagram is further divided into four classes, namely, $Ca^{2+} - Mg^{2+} - Cl^{-} - SO_4^{2-}$, $Na^{+} - K^{+} - Cl^{-} - SO_4^{2-}$, $Na^{+} - K^{+} - Cl^{-} - HCO_3$ and $Ca^{2+} - Mg^{2+} - HCO_3^{-}$. In all sampling locations, majority of water samples belong to the $Ca^{2+} - Mg^{2+} - HCO_3^{-}$ category and in the post monsoon period there is a dominance of $Ca^{2+} - Mg^{2+}$ type water, due to this dominance of calcium and magnesium in water samples the quality of water is Poor. The piper trilinear illustration for ground water samples is presented in the Figs. 16 and 17.

9.18 Water Quality Index

The current study, 16 water quality parameters namely pH, Total Dissolved Solids, Alkalinity, Total Hardness, Calcium, Magnesium, Sodium, Potassium, Chlorides, Nitrates, Phosphates, Sulfates are measured for computing WQI and unit weight (Wi) of each parameter is obtained upon its weightage are shown in Table 4.8 and 4.9. The normal permissible limits of various parameters for drinking purpose are considered as recommended by World Health Organization (WHO) and Bureau of Indian Standards (BIS). The value of WQI in water sampling areas in between 41.21 as Good in Baruva and 63.06 as poor in Kotabommali, indicating that the water is suitable for human use. However, the water quality is rated as Good to poor in almost all areas of study. The status of the water quality indices are shown in Table 5, and the results are shown in Tables 6 and 7.

In the present study, WQI in summer is ranged from 41.21 (Baruva, grading is B-Good) to 63.06 (Kotabommali (S_8), grading is C-Poor). In winter season the water quality is ranged from 39.81 (Chinnavanka village (S_4), grading is B-Good) to 66.15 (Kotabommali (S_8), grading is C-Poor). Out of 10 sampling locations four locations, i.e., Baruva (S_2), Chinnavanka village (S_4) and Nuvvularevu (S_6) the water quality index is reported in B grade and quality of water is good and those locations are suitable of drinking. Whereas in other locations, i.e., Sompeta (S_1), Naupada (S_7), Kotabommali (S_8), Kalingapatnam (S_9), and Srikakulam (S_{10}), the water quality index is reported in C grade and quality of water is poor in both summer and winter.

The pH conspicuously shows that the ground water in the study area is slightly acidic in nature except for Chinnavanka village and the values are within the permissible limit. Conductivity indicating that all water samples exceeded the

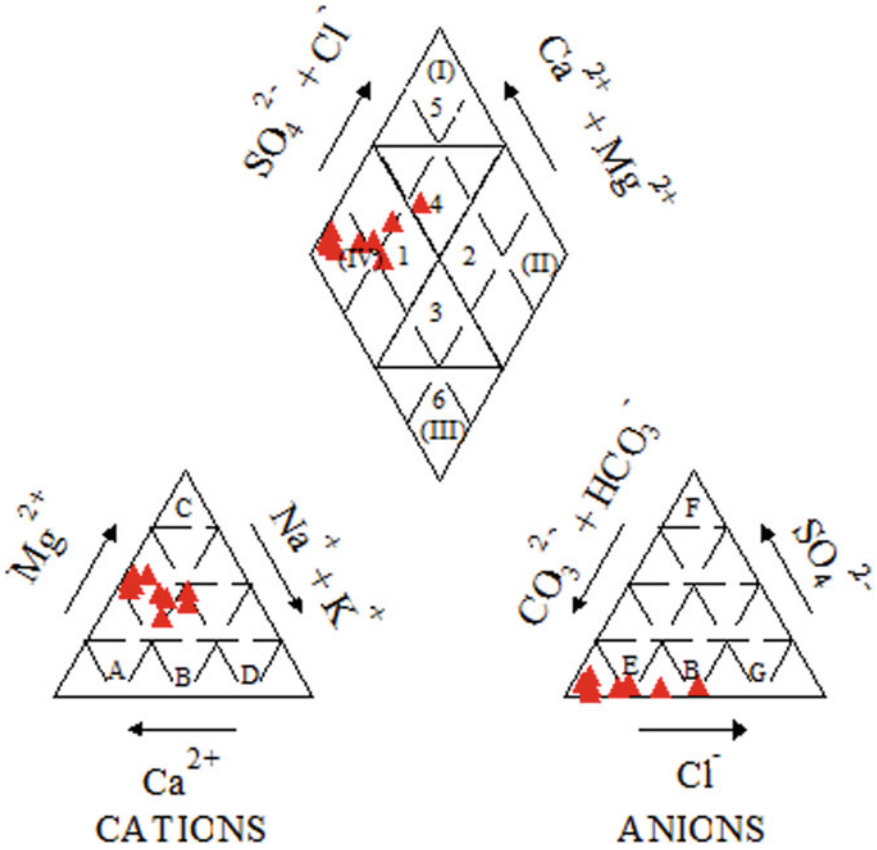

Fig. 16 Piper plot describing hydrological facies of the study area in Summer. A. Calcium type: (I) Ca–Mg–Cl–SO^{-}_{4} 1. $CaHCO_3$. B. No Dominant: (II) Na–K–Cl–SO_4 2. NaCl. C. Magnesium type: (III) Na–K–HNO_3 3. Mixed $CaNaHCO_3$. D. Sodium Type: (IV) Ca–Mg–HCO_3 4. Mixed CaMgCl. E. Bicarbonate Type: 5. CaCl. F. Sulphate type: 6. $NaHCO_3$. G.: Chloride type

desirable limit except at Naupada in both summer and winter seasons within the maximum permissible limit. Total dissolved solids, Hardness, Calcium, magnesium, sodium, potassium, iron, chlorides, nitrate, phosphate and sulphate are well within the permissible limit in both summer and winter seasons.

On the whole, the Water Quality Index indicates that the water quality was good in Baruava, Ratti, Chinnavanka village, Dokulapadu in both summer and winter, except when compared to winter the sampling area of Ratti become poor water quality than remaining locations.

The drastic increase in population demand for the supply of water has increased hence dependency on ground water has been increasing tremendously. In olden days, there used to be one open well for each house or at least one for four to five houses. Now, in a small area from the same aquifer several hundreds to thousands

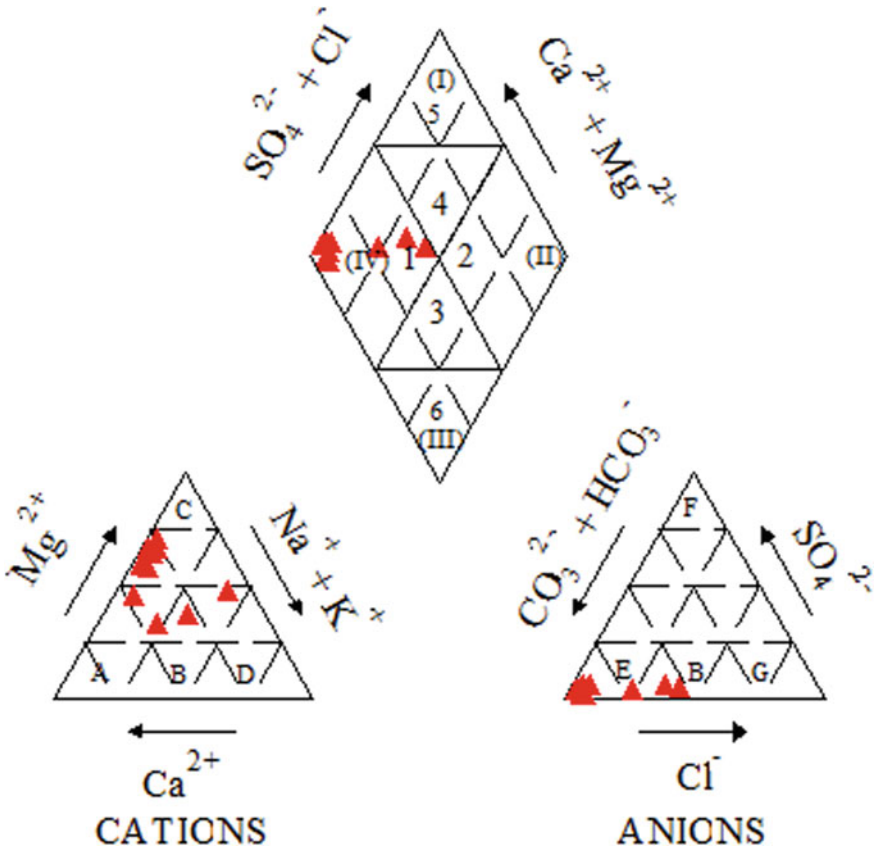

Fig. 17 Piper plot describing hydrological facies of the study area in Winter. A. Calcium type: (I) Ca–Mg–Cl–SO_4^- 1. $CaHCO_3$. B. No Dominant: (II) Na–K–Cl–SO_4 2. NaCl. C. Magnesium type: (III) Na–K–HNO_3 3. Mixed $CaNaHCO_3$. D. Sodium Type: (IV) Ca–Mg–HCO_3 4. Mixed CaMgCl. E. Bicarbonate Type: 5. CaCl. F. Sulphate type: 6. $NaHCO_3$. G. Chloride type

Table 5 Status of the water quality index

Water quality index level	Grade	Water quality status
0–25	A	Excellent
26–50	B	Good
51–75	C	Poor
76–100	D	Very poor
>100	E	Unsuitable for drinking

Table 6 Summer water quality index

Parameter	WHO standard	Wi	SI	S2	S3	S4	S5	S6	S7	S8	S9	S10
pH	8.5	0.11765	7.4	7.3	7.4	7	7.9	7.5	8.1	8.2	8	7.9
TDS (mg/1)	500	0.002	1490	559	830	1077	875	1058	450	1222	1152	1605
Alkalinity (mg/l)	200	0.005	443	210	297	257	269	325	269	372	238	542
TH (mg/l)	300	0.00333	211	153.96	153	145	125	160	153	145.19	133	141.98
Na (mg/1)	100	0.01	5.2	7.1	49	50.5	7.1	10.9	44.6	16.9	116.49	105
K (mg/1)	10	**0**.1	9.7	4.3	8.4	7.6	9.7	8.1	11.5	12.5	7.9	9.4
CI (mg/1)	250	0.004	13.8	16	55	63	19	16.4	125	21.9	200	128
NO_3 (mg/1)	45	0.02222	11.9	13	12.3	16.4	12.5	11.7	11.8	12.4	13.4	12.18
Phosphates (mg/1)	5	0.2	1.1	1.3	1.3	0.9	1.5	1.12	0.7	1.56	1.4	0.8
SO_4 (mg/1)	200	0.005	32	3	12	16.5	11	33.6	10.4	17.9	21	34
$\sum$ Wi		0.51587										
$\sum$ Qi*Wi			27.02	21.26	26.30	23.58	28.54	25.17	27.79	32.53	27.98	27.63
WQI			**52.38**	**41.21**	**50.99**	**45.71**	**55.33**	**48.79**	**53.87**	**63.06**	**54.23**	**53.56**
WQI grade			**C**	**B**	**B**	**B**	**C**	**B**	**C**	**C**	**C**	**C**

Table 7 Winter water quality index

Parameter	WHO standard	Wi	SI	S2	S3	S4	S5	S6	S7	S8	S9	S10
pH	8.5	0.11765	7.21	7.28	7.2	6.87	7.4	7.25	7.84	7.42	7.77	7.38
TDS (mg/l)	500	0.002	1257	426.6	653	726.6	826	983.9	423	1474	1100	1650
Alkalinity (mg/l)	200	0.005	359	160	179	214	232	272	197	694	214	493
TH (mg/l)	300	0.00333	114	137	125	140	117	158	146	137	125	149
Na (mg/l)	100	0.01	9.5	7.8	6.5	6	4.5	11	105	8.5	90	95
K(mg/l)	10	0.1	8.6	7.3	7.4	6.8	8.1	6.7	10.8	10	6.7	8.4
CI (mg/l)	250	0.004	13.1	9.2	8.6	7.98	8.52	19.56	123	17.65	103	134
NO_3 (mg/l)	45	0.02222	10.4	12.83	11.76	16.1	11.8	11	11.3	10.5	11.9	11.66
Phosphates (mg/l)	5	0.2	0.89	0.76	1.6	0.12	0.19	1.16	1.3	1.9	0.89	1.07
SO_4 (mg/l)	200	0.005	7.5	3.5	11	16	10	17.5	18.5	23.5	22	21
$\sum$ Wi		0.51587										
$\sum$ Qi*Wi			24.31	21.87	25.30	18.68	20.81	23.35	29.53	31.04	26.26	26.75
WQI			**51.82**	**46.62**	**53.92**	**39.81**	**44.35**	**49.77**	**62.94**	**66.15**	**55.97**	**57.01**
WQI grade			**C**	**B**	**C**	**B**	**B**	**B**	**C**	**C**	**C**	**C**

of people are depending on it which results in the decrease in the level of ground water or they even get dried up fast. Groundwater, even though second to rivers as a distributor of fresh water, is much the largest regulator of fresh water resources. Groundwater forms invisible, subsurface part of the natural water cycle, in which evaporation, precipitation, seepage, and discharge are the main components. In recent years, an increasing threat, to ground water quality due to human activities, has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial effluents, unexpectedly by subsurface or surface disposal of sewage and industrial wastes. Ground water is contaminated due to leachate of refuse dumps, waste water seepages, and spillages. The quality of ground water is of great importance in determining the suitability of particular ground water for a certain use (public water supply, irrigation, industrial applications, power generation, etc.).

To assess the quality of ground water, along with coastal areas at Srikakulam district, has been selected as study area. Based on preliminary survey ten locations were identified in three environmental backdrops, i.e., agricultural, industrial, and commercial areas along with coastal line to assess the quality of ground water at Srikakulam district into consideration. For these samples, physico-chemical parameters like pH, electrical conductivity, total dissolved solids, total hardness, calcium hardness, magnesium hardness, nitrates, chlorides, phosphates, sulphates, alkalinity, carbonate, and bicarbonates were examined. Hydro geological facies were analyzed for two seasons, i.e., summer and winter by using standard procedures and the aftermaths were compared with the BIS standards. Using hydrological facies for represented in three cationic constituents there are calcium, magnesium (Ca^{2+}, Mg^{2+}), and three anionic constituents are sulfates, chlorides (SO_4^{2-}, Cl^-) and those contributing to alkalinity, i.e., CO_3^{2-}, and HCO_3^-. Therefore, linear plot is the most suitable for the representation of ground water.

10 Conclusion and Suggestions

Water quality index (WQI) has been calculated for selected physico-chemical parameters like pH, total dissolved solids, alkalinity, nitrate, chloride, sulphate, total hardness, calcium with an objective to abstract multifaceted water quality data into simple form and can be easily usable by the public.

The physico-chemical analysis revealed that total dissolved solids, alkalinity, and total hardness are reported in higher concentrations in almost all water samples with few exceptions. Alkalinity reported high in all the sampling locations in both summer and winter seasons except in Baruva (S_2), Ratti (S_3), and Naupada (S_3) sampling stations in winter season. The values of alkalinity very high in summer compared to winter and it ranged from 160 to 694 mg/l. Moderate concentrations of alkalinity are desirable to drinking water to balance the corrosive effect of acidity. When it is present in excess amount arises health problem such as excessive drying

of the skin. This is due to the fact that tends to remove the natural skin secretions. The total hardness is reported in the range of 82–233 mg/l in all the sampling locations during winter and 109–266 mg/l in summer season. In all the sampling locations total hardness within the accessible limit as per ISI standard of 200 mg/l except Nuvvularevu (S_6) sampling location in summer and Srikakulam (S_{10}) samples location in winter. Generally the total hardness below 75 mg/l is considered as the best for drinking purposes. Above 75 mg/l is considered as moderately hard. Total hardness in water may cause cardiovascular diseases on prolonged consumption. Calcium, magnesium, sodium, potassium, iron, chlorides, nitrate, phosphate and sulphate are well within the permissible limit in both summer and winter seasons.

Water Quality Index (WQI) referred to the physico-chemical characteristics of water body to determine, how water can be used for potability and it can support ecosystems process. It was developed based on several water quality parameters and finally grading allotted for use of water for various purposes. In the present study WQI in summer is ranged from 41.21 (Baruva, grading is B-Good) to 63.06 (Kotabommali (S_8), grading is C-Poor). In winter season the water quality is ranged from 39.81 (Chinnavanka village (S_4), grading is B-Good) to 66.15 (Kotabommali (S_8), grading is C-Poor). Out of 10 sampling locations four locations, i.e., Baruva (S_2), Chinnavanka village (S_4), and Nuvvularevu (S_6) the water quality index is reported in B grade and quality of water is good and those locations are suitable of drinking. Whereas in other locations, i.e., Sompeta (S_1), Naupada (S_7), Kotabommali (S_8), Kalingapatnam (S_9), and Srikakulam (S_{10}) the water quality index is reported in C grade and quality of water is Poor in both summer and winter. The poor water quality is influenced by the excess presence of TH, TDS, and alkalinity. Hence applied proper water treatment methods are Reverse Osmosis, lime softening methods based on economical consideration before releasing to the public water supply system.

The hydrological facies indicates that the diamond-shaped field of Piper diagram is further bifurcated into four classes, namely, $Ca^{2+} - Mg^{2+} - Cl^{-} - SO_4^{2-}$, $Na^{+} - K^{+} - Cl^{-} - SO_4^{2-}$, $Na^{+} - K^{+} - Cl^{-} - HCO_3$ and $Ca^{2+} - Mg^{2+} - HCO_3^{-}$. Aamong all sampling locations majority of water samples belong to the $Ca^{2+} - Mg^{2+} - HCO_3^{-}$ type and in the post-monsoon period there is a dominance of $Ca^{2+} - Mg^{2+}$ type water in both summer and winter, due to this dominance of calcium and magnesium in water samples the quality of water is Poor in both seasons.

The presence of any water quality parameter in excess may cause health hazard on long-term and can degrade the quality of drinking water and may require treatment before releasing into public water system.

To keep the groundwater safe and clean:

- First priority in India goes to, creating awareness among the people to keep their surroundings clean and dispose the solid waste scientifically.
- The companies or factories responsible for pollution must be punished severely by the government.

- Government should come up with more innovative ideas and programs to keep the cities and villages clean.
- Effective treatment of sewage sludge, keeping separate bins for biodegradable and non-biodegradable waste, collection of waste and disposal of the waste should also be taken care off.

If every citizen of India takes care of their own surroundings and disposes of the waste systematically we can reduce all types of pollution to the maximum extent.

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Presence of Microplastic in Water Bodies and Its Impact on Human Health

Sreeraj Vijayaraman, Prasenjit Mondal, Abhishek Nandan and Nihal Anwar Siddiqui

Abstract Microplastics have been considered as a serious pollutant that has affected the environment over decades. Microplastics, being the smallest of particles, have been getting increased attention because of the serious threat that it causes to human health and wildlife. Because of its presence in sea salts, food safety is getting compromised. It has been found in some studies that microplastics are a threat to species in the marine environment and also drastically affect human health. By going across various studies, I have come to the conclusion that the issue of microplastics in freshwater systems is a topic that is needed to be addressed, also has a strong scope in research purpose. It has also been found out that freshwater systems may have identical properties that to marine systems in relation to the forces that transport microplastics. A deeper study was done which was needed to understand the relationship between plastic degradation and the different pollutants which get absorbed. Even though the studies leading to microplastics in freshwaters have been significantly looked in the previous years, the understanding regarding this issue is to be addressed, and prior importance is needed to be given to counter this growing menace. This paper has mainly concentrated on to give a brief idea about the main problems that are arising due to the microplastics and how it is affecting the aquatic life and polluting the river bodies.

Keywords Microplastics · Pollution sources · Water pollution and human health

1 Introduction

Plastic pollution has been a big problem and has managed to damage the environment over the past decades. Since then, different studies have been done to address the issues related to plastic pollution (Prata 2018). Microplastics have a

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significant small size (less than 5 mm). Microplastics are found in abundance because of increasing inappropriate plastic disposal and because of low biodegradation rates. Plastics in marine environments include small segments which are found in coastal habitats, deep sea, as well as freshwater lakes. Kara Lavender Law, who is an oceanographer at the Sea Education Association in Woods Hole once, said plastics are now found in stranger places, referring to the lack of plastic disposal in the environment. She also warns about the microplastic content in salts which humans consume and the health threats it may cause (Yeager 2015).

The statistics in Fig. 1 provide vital information about the plastic production that has been increasing throughout the years since 1950 (Geyer et al. 2017).

There are different types of microplastics, which are categorised into on the basis of their properties, texture, size, which vary into different fibres, microbeads, fragments, nurdles and foam which are shown in Table 1.

The major types of microplastics are mainly classified above according to their properties (Rochman et al. 2017). Sea salt is composed of more than 90% from pure sodium chloride (40% Na, 60% Cl) and is an indispensable product. The name of the crystalline substance comes from combining two Greek words: halos (salt, sea, salty) and lithos (rock, stone). Once known as the "white gold", today it is referred to as "black death". As a consumer product, salt comes on the market in several forms: rock salt, evaporated salt, iodised salt, Dead Sea salt, Himalaya salt and sea salt. Flavoured salts and salts aromatised with herbs and vegetables also find common use (Śmiechowska 2018). Deluxe salts are those that are utilised in regional cuisines and are becoming increasingly significant owing to culinary tourism. Microplastics, when ingested, can damage the digestive tract of both humans and animals because of the chemical and the major contaminants in the plastics.

Microplastics can be divided into various categories on the basis of the toxicology they produce and the size. Primary microplastics are small fragments, which are the products from manufacturing. These types of microplastics are used in some

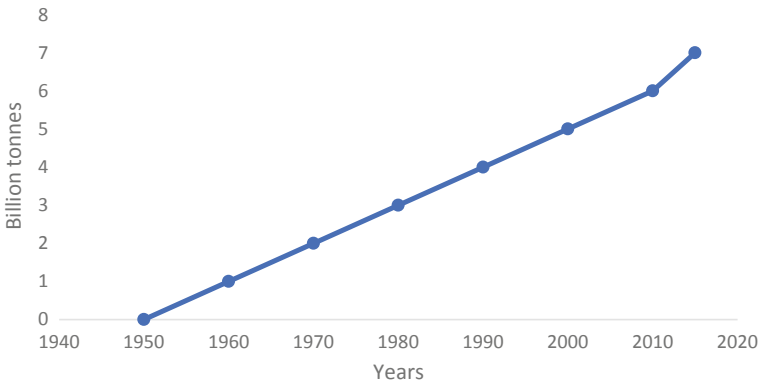

Fig. 1 Increasing trend of plastic production

Table 1 Size of microplastics

Microplastics	Size
Polyethylene terephthalate	Less than 500 nm
Polyethylene	88 μm
Polyvinyl chloride	According to the form (rigid or flexible)
Polystyrene	60 mm

drugs, cleansers, toilet utilities and cosmetics, whereas the secondary microplastics are initially formed from the breakdown of larger plastic contents, which are present in the marine systems (Boucher and Friot 2017).

Marine organisms are more vulnerable to marine plastics, because of the small size of the microplastics, which can be consumed easily. Studies have shown that microplastics exist in both marine and abiotic sea products (Zhang et al. 2018). Salt, which is essential commodity of preparing food, has an important role in the human organism, which has caused negative influence because of higher consumption rates, which affects the human health drastically (Sruthy and Ramasamy 2017).

Looking at the size, texture and their nature of breakdown into smaller items, it is not at all easy to completely get rid of microplastics (Eerkes-Medrano et al. 2015). The microplastic identification techniques and the microplastic reducing measures play a vital role, in dealing with this problem. The most effective measure should be given the highest priority, and the solution, if implemented properly can be a revolutionary idea, which can change the current scenario that mother earth is facing.

2 Microplastics in Environment

2.1 Microplastics in Coastal Areas

A study was conducted by group of experts in the beach sides of Alaska, West Coast and the pacific islands, United states of America to analyse and identify the amount of microplastics present in around 37 beaches across the country. Microplastics, in the form of micro fibres, were the most dominant which was found and amounted up to 97% as depicted in Table 2 (Yu et al. 2018). Also, in the south-east coast of India, from around 25 beaches, in where a shocking observation

Table 2 Microplastic content in various water sources

Regions	Microplastic content (in percentage) (%)
Alaska, Pacific, United states of America	97
South-east coast of India	47
Lake Ontario, United states of America	80

was found that, 10.1% of microplastics were found in over 79 species of animals (Karthik et al. 2018).

It is found that in the beach environment, degradation processes occur in a swift manner, because of the presence of sunlight and high temperatures. Plastic becomes light, and it tends to break down into smaller pieces on the hot surface of sand. These plastics are picked up by the high winds they travel onto the oceans creating garbage patches (Hidalgo-Ruz et al. 2012). Beach pollution has contributed extensively in microplastic pollution, and the less enthusiastic clean-up efforts have resulted in further pollution. This study can help in identifying the risks related to marine systems that microplastics can cause the areas affected and the problems that arise because of it.

2.2 *Microplastics in Freshwater*

The main freshwater bodies like lakes, rivers are well known to be polluted because of anthropogenic activities and because of the improper disposal of microplastics. The information and studies related to microplastics in freshwater bodies are limited. Plastics of different sizes and properties are disposed everywhere in land, and mostly in freshwater environments, thus contributing to extensive uncontrollable water pollution (Li et al. 2018).

Microplastics are found in all continents across the world, and the once considered freshwater rivers have reached a level of getting endangered. This has gradually affected the flora and fauna. Almost most of the rivers are polluted around the world, and Fig. 2 explains the damage that has been done to the rivers because of plastic dumping.

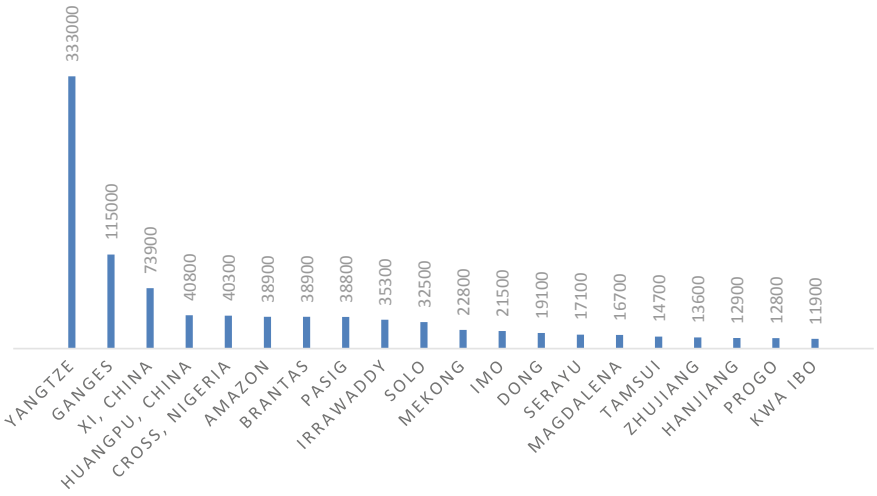

Fig. 2 (Numbers are given in tonnes) River pollution statistics (Lebreton et al. 2017)

Microplastics, due to their small size (less than 5 mm), have the tendency to stay in the freshwater bodies. The main source of these river pollution mainly comes from the flow of water from waste water treatment plants, which contain main portions of microplastics. The governments and the authorities have understood the growing concerns of rise in microplastics as a new contaminant (Li et al. 2018). Earlier studies have indicated this growing pollution, but value was not given resulting to further depletion. Primary microplastics are the most abundant type found in the freshwater bodies, and the secondary type is not known in the basis of contributing to extensive pollution.

2.3 Effects on Human Beings

Microplastics affect human beings in mainly four ways. It is mainly by drinking the water, consumption of fish products, usage of cosmetics and by inhalation (Revel et al. 2018). It is also found in other products like beer, table salts, but the health effects due to consumption of these are negligible (Liebezeit and Liebezeit 2014).

A number of studies have shown there are microplastics present in food, and it is still unclear what the chronic effect they may have on human health. Phthalates, which are mainly used to make plastic flexible, have been shown to increase the growth of breast cancer cells. However, this research was carried out in a petri dish, so the results cannot be generalised to humans. It has also been found that the microplastics in the body have the capability to get into digestive glands (Devriese et al. 2017).

A study was conducted to study the effects of microplastics that were found while experimenting mice in the laboratory. When fed to mice, the microplastics accumulated in the liver, kidneys and intestines, and increased levels of oxidative stress molecules in the liver. They also increased the level of a molecule that may be toxic to the brain (Tang 2017). Microparticles including microplastics have been shown to pass from the intestines into the blood and potentially into other organs.

But the scenario in human beings has shown significant risks that can affect human health. One study found that plastic fibres were present in most parts of the human lungs (Hoet et al. 2004). The researchers proposed this may be due to microplastics present in the air. Some studies have shown that microplastics in the air may cause lung cells to produce inflammatory chemicals. However, this has only been shown in test-tube study. Bisphenol-A (BPA) is one of the best-studied chemicals found in plastic. It is usually found in plastic packaging or food storage containers and can leak out into food. Some evidence has shown that Bisphenol-A can interfere with reproductive hormones, especially in women.

2.4 The Indian Scenario

A New Delhi-based company, toxics links have confirmed the presence of microplastics through their report (https://www.downtoearth.org.in/news/environment/forest-fires-in-india-increased-by-125-per-cent-in-last-two-years-60349) in Indian cosmetics like nail paints, scrubbers, face washes and other cosmetics as depicted in Table 3.

After releasing this astonishing report, Priti Mahesh the chief programme coordinator of toxics link said, "The common man should be made aware of the ingredients of the product they are using, and the hour has passed where powerful laws should be made to address this issue".

A research team consisting of Ramasamy and Sruthy S from The School of Environmental Sciences at Mahatma Gandhi University, Kottayam, reported in 2016 the first-ever study on microplastics in the sediments of a lake in the international journal Environmental Pollution (Shini Sruthy 2012). The researchers collected sediment samples from ten locations above and below the Thanneermukkom Bund. The results were found to be alarming. All the samples examined by the team had microplastic content indicating its extensive distribution in the lake. The abundance of microplastics recorded from the sediment samples of the lake was found to be in bigger size. This is comparable with the reports available across the globe, and it is also on the higher side of a few reports.

The National Green Tribunal, in 2017, had passed an order (https://www.downtoearth.org.in/news/environment/ngt-orders-centre-to-test-cosmetics-containing-microbeads-56781) to the central government of India, to test the presence of microbeads in cosmetic substances. As far as the study that has taken place in India, regarding microplastics, no significant breakthrough was found to counter this issue.

It is also found that Mumbai and Kerala are the most affected states (https://www.downtoearth.org.in/news/water/mumbai-kerala-most-affected-by-marine-litter-microplastics-are-a-major-threat-57507) of plastic pollution in the country. The other area to be focussed upon is the holy river Ganges, which flows through both India and Bangladesh. The statistics from Fig. 2 demonstrate that 115,000 billion tonnes of plastics are present in this river (Schmidt et al. 2017). It has been noted that 55% of microplastic content is present out of it.

Table 3 Presence of microplastic content in cosmetic products

Product	Microplastic content (%)
Face wash	50
Facial scrubs	67
Other products	31

2.5 Detection of Microplastics

Different methods have been identified by researches across the world for detecting microplastics, in which many methods differ from one another according to the properties of the microplastics. Sampling has been a major method used in for identifying the microplastics, and the usage of control samples is said to be mostly effective in case of identifying the contamination (Löder and Gerdts 2015).

Other sampling methods like water and sediment sampling have been widely used and both have benefits which can lead in identification of microplastics. Water sampling has different types distinguished by the way the process is done. It can be mostly done with pumps, sieving and plankton nets, whereas the sediment sampling can make the use of beach sediment collection process and seabed collection (Prata 2018).

Visual sorting, Fourier transform infrared spectroscopy and Raman spectroscopy have been considered as the current major methods used to extract microplastics (Mai et al. 2018).

There is a process of manual picking which can be done to sort out microplastics one by one, but it could lead to a more time-consuming process, and it is not highly recommended. When going by the investigation for detecting the amount of microplastics, many techniques are usable, but the most accurate and effective methods are yet to be figured out.

"Nile red" can be used to differentiate plastics effectively, by the usage of the fluorescent dye that gives a light upon coming into contact with the contaminated material. The confirmation tests have shown that the dye was very much effective in extracting microplastics, in a more easier way, and it has also worked out for different plastic polymers (Shim et al. 2017).

3 Summary

The topic related to microplastics has a wide range of scope, and considering its current status, it is high time that more research works and studies should be brought to the limelight. Marine systems and the freshwater bodies are getting contaminated day by day, and the focus to conserve the natural systems is getting diverted due to rising anthropogenic activities. A wide range of studies is to be included regarding toxicology, chemistry, and microplastic extracting techniques to counter this issue. The understanding on the issue of microplastics is now getting attention as the planet is undergoing significant changes like global warming.

Many research works are not getting the completion because of the lack of information available. The data which are found by various organisation are not accurate, and thus, it is affecting the risk assessment of the microplastic content in water bodies. This issue needs to be given valid importance, and it should be in the priority list of world leaders. National level attention should be given to this issue,

and people should be made aware of the products containing microplastic, cosmetics as well as strong screening process should be done before making it available to the public.

Looking onto the main consequences that microplastics can produce in the human body, these particles have properties which have the potential to act with the organic material due to their large surface area. Once, the microplastics get into the body, some may have different shapes and properties, which will make the removal of the microplastics from the respiratory system due to the microplastic's complex polymeric structure (Prata 2018). This should not be considered as a small issue as it poses significant health risks, especially in children and vulnerable persons. The microplastics in addition to the other pollutant gases from the environment will be more than enough for the human body to be in danger.

Highly alarming news is coming out every day regarding water pollution, plastics play the major role in this, and a combined effort from all the stakeholders needs to be given to counter this menace. Around 1.1–8.8 million metric tonnes of plastic enter the sea, every year. If this is the trend, some of the major water bodies will become highly contaminated, and it is the need of the hour, to bring up more research and study to completely bring out a solution to this issue.

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Assessment of the Ambient Air Quality of a Highly Industrialized Suburb of a Typical Indian City Part 1: Assessment of Quality

Tasneem Abbasi, Faisal I. Khan, Tabassum-Abbasi and S. A. Abbasi

Abstract A study is presented which is specific to a highly industrialized suburb of Chennai, India, but is illustrative of similar regions that are present in most large cities of India as also in other developing countries. The study area covered by us consists of a large-scale petroleum refinery and several downstream petrochemical industries situated cheek-by-jowl in a cluster called the Manali Industrial Complex. Its airshed was continuously monitored with the help of eleven ambient air quality monitoring stations, set on the basis of the wind roses of the study area in different seasons. The findings have been discussed in terms of the compatibility of the airshed with the ambient air quality standard set by India's Central Pollution Control Board.

Keywords Airshed · Ambient air quality monitoring · Pollution levels

1 Introduction

Environmental protection is one of the articles of faith of the constitution of India. In keeping with its environmental consciousness, India was among the first countries to set up a full-fledged ministry of environment (Abbasi and Abbasi 2018).

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Elaborate standards to protect the quality of air, water and soil were set and different regulatory agencies were put in place from early 1970s onwards. Over the years, more and more measures have been stipulated to check the growing levels of pollution, but how effective these measures have been? This paper presents one of the studies conducted by us to find this out.

2 The Study Area

The study area comprising of Manali Industrial Complex (MIC) and its surrounding is situated very close to the sea on the East Coast of Peninsular India, 20 km north of downtown Chennai (Fig. 1). As such, the meteorology of the area is subject to coastal effects characterized by rapid changes in wind directions and high relative humidity.

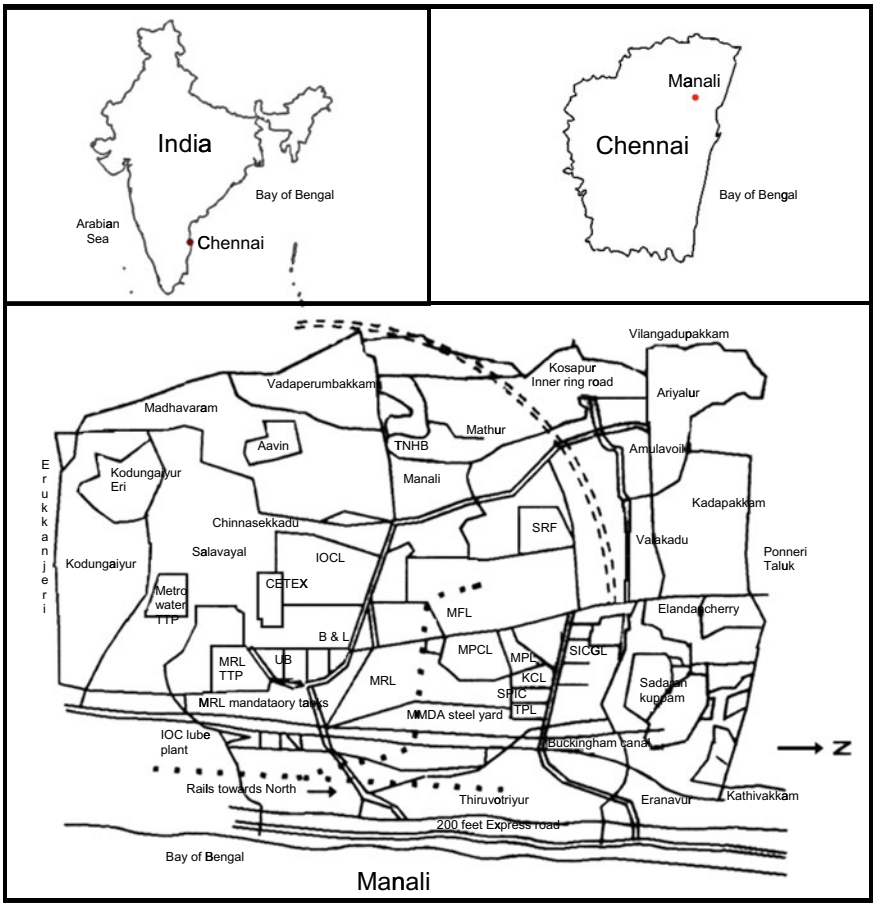

Fig. 1 Study area

At the time of performing this study, MIC had over ninety stacks of which some 63% had a height of 30–50 m, whereas 16% were 50 m or taller.

The terrain at MIC and surrounding areas is relatively flat at the mean sea level of 3.15 m. The population of the area encompassing 10 km radius from the centre of the MIC is about 5 million. It includes several populous villages engaged in the cultivation of rice, maize and ragi. The terrain is interspersed with ponds, neighbourhoods, canal and tracts of barren land. A visitor to the area is likely to notice murky plumes of emissions coming out of the stacks (Plate 1) and may even pass through a plume which might have come close to the ground. The mean roughness factor is 0.3 m. The region is semi-arid, with average annual precipitation of the order of 100–125 cm. There is sparse rainfall during the south-east monsoon (July–September) and more intense during north-east monsoon (October–November). The ambient temperatures are characteristic of humid tropics with very low diurnal variation; peak day temperatures generally hover between 32 and 37 °C, rarely falling below 30 °C except in December and January.

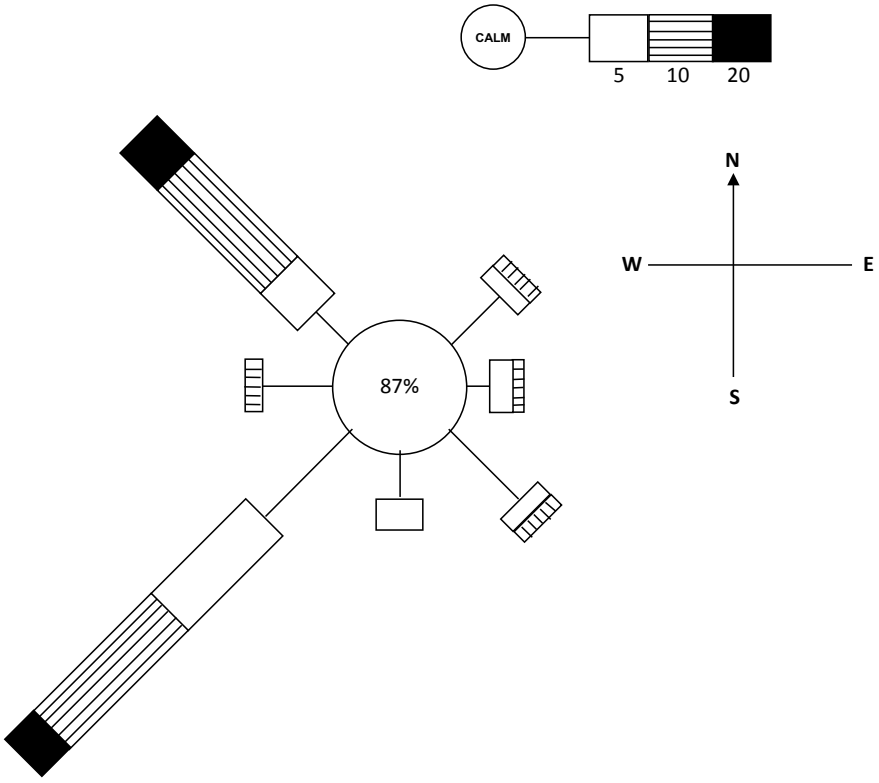

Fig. 2 Wind roses during winter

3 Wind Roses

The wind roses, drawn on the basis of meteorological data of nine-year span, are shown in Figs. 2, 3, 4 and 5.

4 Settling up of Air Quality Sampling Stations

A network of eleven sampling stations, each equipped with high-volume samplers, and concurrently operated, was set-up in and around Manali Industrial Complex (MIC) to monitor air quality. Based on wind roses, the stations were positioned to representatively monitor ambient air quality covering industrial, residential and 'sensitive' locations at various predominant wind directions throughout the year. Sampling was conducted during days as well as nights. The sampling covered four seasons: summer (March–May), pre-monsoon (June–August), monsoon (September–November) and post-monsoon or 'winter' (December–February) for two successive years. A brief description of the sampling stations is given in Table 1. The locations are depicted in Fig. 6. A noteworthy feature of this air quality study is that we have monitored chlorine and ammonia besides SPM, SO_x and NO_x.

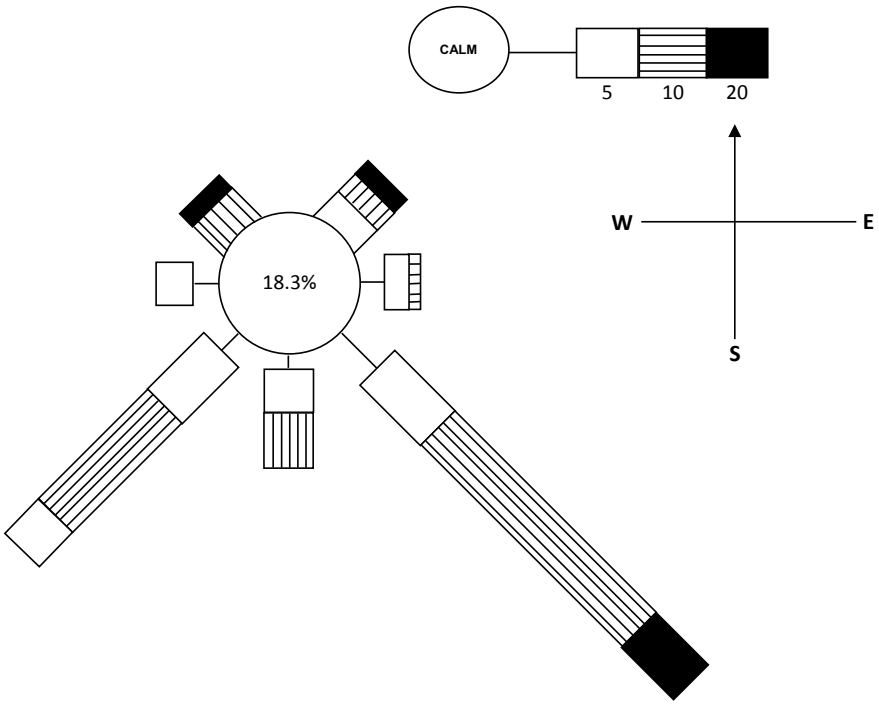

Fig. 3 Wind roses during summer

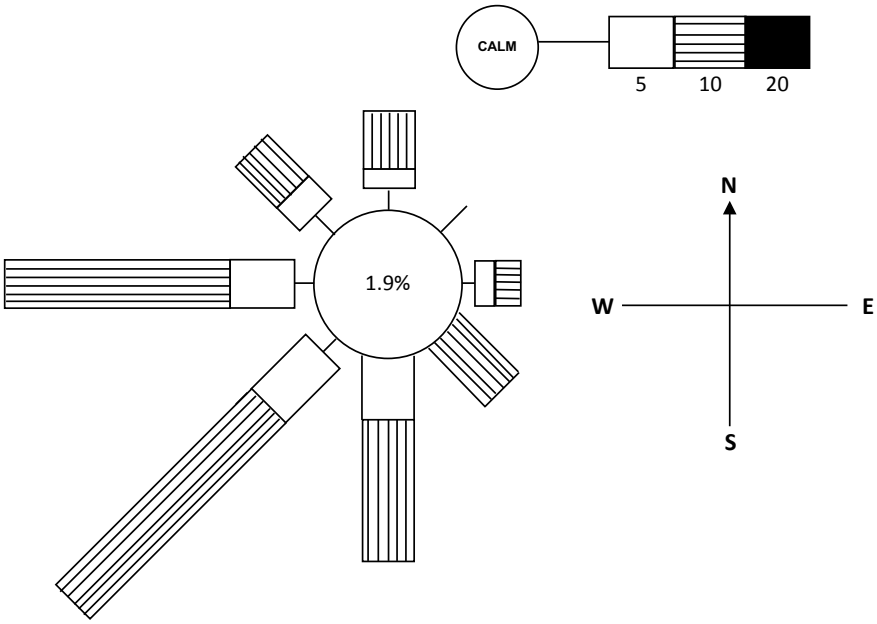

Fig. 4 Wind roses during pre-monsoons

5 Sampling and Analysis

High-volume samplers manufactured by Vayubodhan, New Delhi, were used in accordance with the procedures stipulated by the American Public Health Association (Katz 1977) and Bureau of Indian Standards. Each contiguous high-volume air sampling spanned 8 h, and three such samples were collected in succession on every sampling day, in shifts spanning 06–14 h, 14–22 h and 22–06 h. Overall, some 13,900 air samples were collected, each covering five parameters. The mode of analysis was also in strict conformity with the relevant BIS stipulations as endorsed by Central Pollution Control Board (CPCB).

Very rigorous quality control was exercised to achieve authenticity in the sampling as well as analysis (Abbasi and Abbasi 2011, 2019). To further check upon the quality of our monitoring, we had a test run, a sampling station by positioning it close to the National Ambient Air Quality Monitoring (NAAQM) station set by the Central Pollution Control Board (CPCB). Typical data generated by us, in that reconnaissance, together with the NAAQM data for the corresponding periods, are presented in Table 2. The agreement indicates that the experimental work of this team compared favourably with the CPCB findings. A note on the findings of other agencies, which had done ambient air quality surveys for preparing feasibility reports for some individual industries, is presented below.

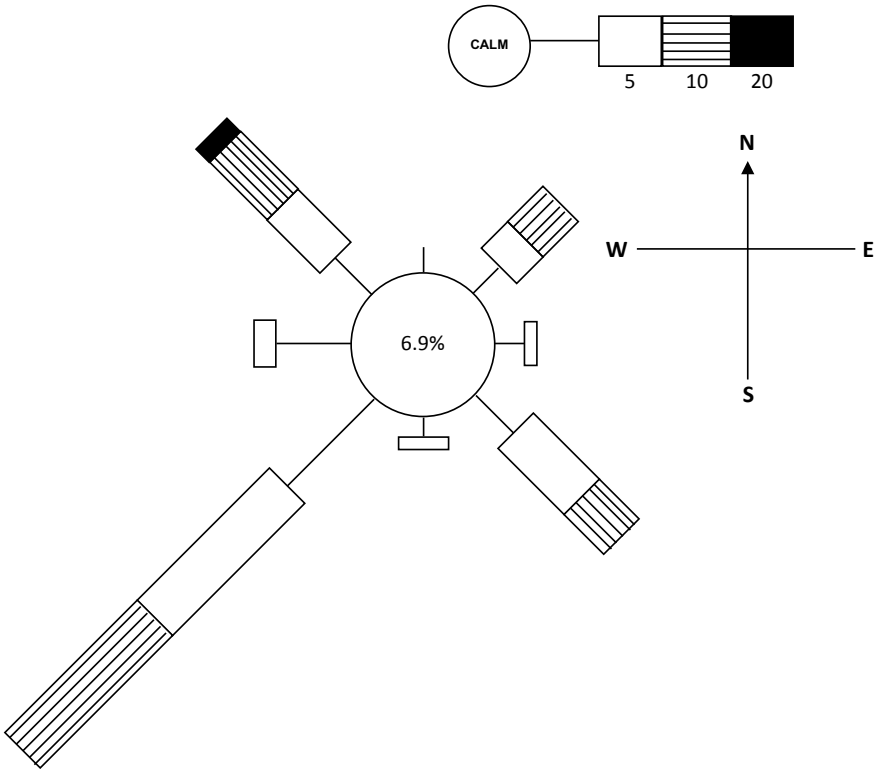

Fig. 5 Wind roses during post-monsoons

Table 1 Brief description of the sampling sites[a]

Sample No.	Sampling site	Description
MS1	Chinnasekkadu	On top of the house, backside of IOCL
MS2	Periyasekkadu	On top of the house
MS3	Manali Fire Station	On top of the office, 0.3 km from MFL
MS4	Manali school	On top of the school
MS5	TNHB (Periyamathur)	On top of the office, 0.4 km from NAPCO
MS6	Chinnamathur	On top of the house
MS7	Amulavoyal	On top of the house
MS8	Madhavaram	Open area on the ground, 3.5 km from IOCL
MS9	Vaikkadu	On top of the house
MS10	Sadayankuppam	On top of the house
MS11	Thiruvottriyur	On top of the house, 1.5 km from CPCL

[a]The samplers were placed scrupulously according to the norms, adequately above the ground level, free from lateral obstructions and local disturbances

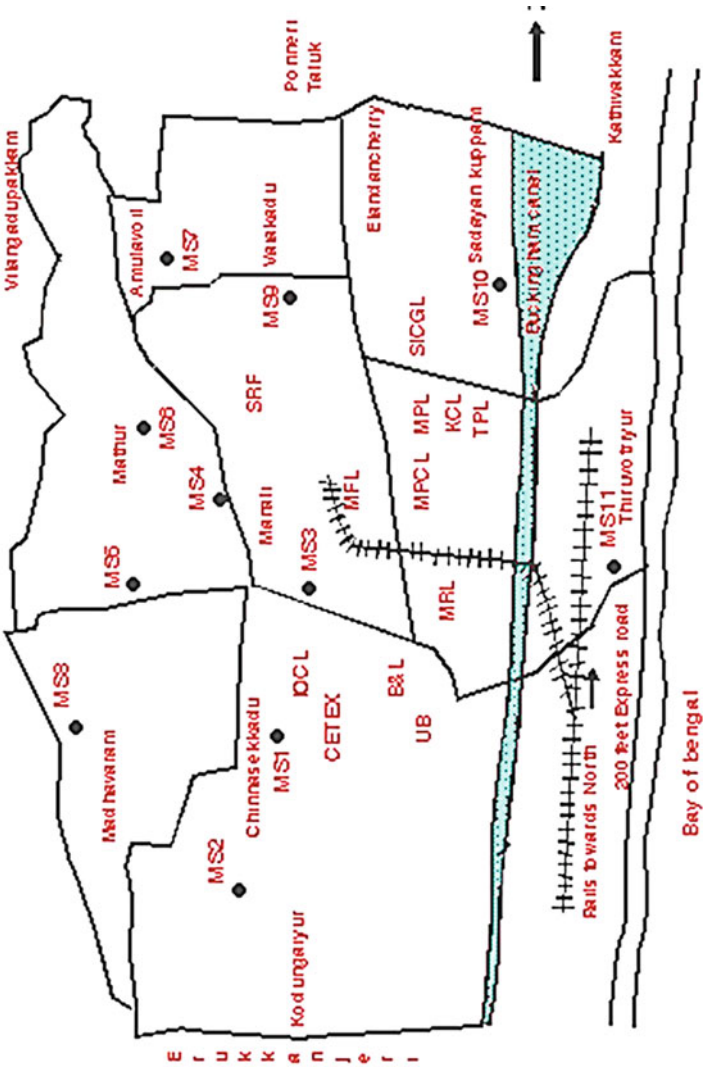

Fig. 6 Location of air quality monitoring stations [•]

Table 2 Test runs to compare the ambient air quality data generated by CPET with the NAAQM data

Sample number	SO_x, μg/m^3		NO_x, μg/m^3		SPM, μg/m^3	
	CPET	NAAQM	CPET	NAAQM	CPET	NAAQM
1	6.6	8.2	9.7	9.2	102.2	87.6
2	10.5	11.3	14.5	13.3	126.1	102.6
3	8.3	7.3	12.7	16.2	106.1	130.0
4	12.3	4.6	19.4	17.2	210.6	199.3
5	7.9	5.0	3.6	4.5	61.9	72.6
6	6.0	5.0	5.0	5.5	133.1	129.6
7	6.7	9.0	10.6	8.3	225.0	190.0
8	143.3	126.0	24.3	26.5	142.4	100.0
9	5.6	3.7	11.9	7.8	217.3	183.6
10	25.3	26.5	10.6	6.0	188.3	67.6
11	51.3	55.5	23.3	22.1	114.3	128.0
12	10.5	10.1	6.1	7.2	109.1	103.3
13	8.9	9.2	8.3	9.9	106.3	93.3
14	31.2	34.5	9.1	6.5	120.3	97.0
15	19.8	13.9	6.6	9.7	78.7	76.3
16	35.6	34.6	15.2	13.9	177.3	144.3
17	20.1	17.4	4.4	3.2	175.1	158.5
18	16.1	15.5	8.7	2.0	25.6	77.5
19	48.5	50.5	4.5	5.2	83.5	68.0

6 Existing Surveys: An Overview

In the course of examining data generated in the past by other agencies—we came across results of ambient air quality (AAQ) surveys done by a few consultancy firms in the course of preparing feasibility reports for individual industries. The findings were carefully assessed. It was seen that: (a) quite often sampling stations were located either too close to, or too far from, the emission source; (b) often the stations were not placed in predominant wind directions; and (c) appropriate standards were not always used to decide upon the fitness of ambient air. Hence, the reported work scarcely represents the airshed. Some **illustrative examples** are given below.

(i) In one of the studies, out of 14 stations set for monitoring, three were placed too close (within 0.2 km radial distance from the zone of the most dense concentration of stacks) and ten too far (more than 5 km) away. The plumes from the stacks may most often reach the ground within the area between 0.5 and 4 km radius. This positioning would miss the locations where the ambient air quality is really bad. Even then, it is seen that at station A3 10% of samples had SPM concentration more than 245 μg/m^3, thus exceeding

CPCB norms of appropriate air quality (as per which 2% of the samples should not have higher than permissible level of any pollutant). Likewise, in another study, four stations were placed for AAQ monitoring, out of which one was too close and one too far away.

(ii) Quite often, the samplers were not placed on the basis of wind directions. For example in the study mentioned above during September–October, the predominant wind direction is SW, but only two stations (A1 and A7) out of seven locations monitored during that season were in the downwind direction. The remaining five stations were either upwind or in the crosswind direction as shown in Fig. 7. Similarly in the other study, only one station was in downwind direction out of four stations monitored during all the four seasons. During pre-monsoon and monsoon seasons, the predominant wind direction is SW, but except the location MA5 all other samplers were in either upwind or crosswind directions as shown in Fig. 8.

(iii) To assess the pollution level, most of the agencies have used only the permissible limit for industrial zone and have calculated the percentage of samples polluted solely on that basis. But for AAQ stations located in residential or 'sensitive' locations, appropriate standards set for those types of locations ought to have been used. In a typical study, most of the samples exceeded the limit for SPM set for residential areas at locations A2–A7. The percentage of samples found polluted were 70% in A2, 16% in A3, 50% in A4, 50% in A5 and 70% in A7 (Table 3-4A; page 3.22) of the said report. In another study, it was reported that all the samples were within CPCB limits which are not really so. For example, in the following places during summer the percentage of samples exceeded the prescribed limits for residential areas: Manali village (>90%), Sathangadu (>90%), Redhills (>90%), Kadapakkam (>90%), Thiruvottriyur (>75%), Ennore school (>75%), Sadayankuppam (>50%), Vadaperumbakkam (>50%) and Jyothinagar (>20%).

Therefore, we believe, an extensive ambient air quality survey, as done and now being reported by us, was necessary to accurately gauge the impact of the Manali Industrial Complex on the airshed of the study area.

7 Results and Discussion

The experiments have led to data on the ambient air quality in terms of concentrations of five different parameters in three different samples over each 24-h span, taken during days as well as nights, at eleven different locations and in four different seasons. This all adds to a very large body of basic data which the authors can provide on request. Here, to resolve this enormous mass of information into an easy-to-comprehend and easy-to-interpret form, all the data have been processed in terms of the compliance of different individual parameters and different total samples with the relevant National Ambient Air Quality (NAAQ) Standards.

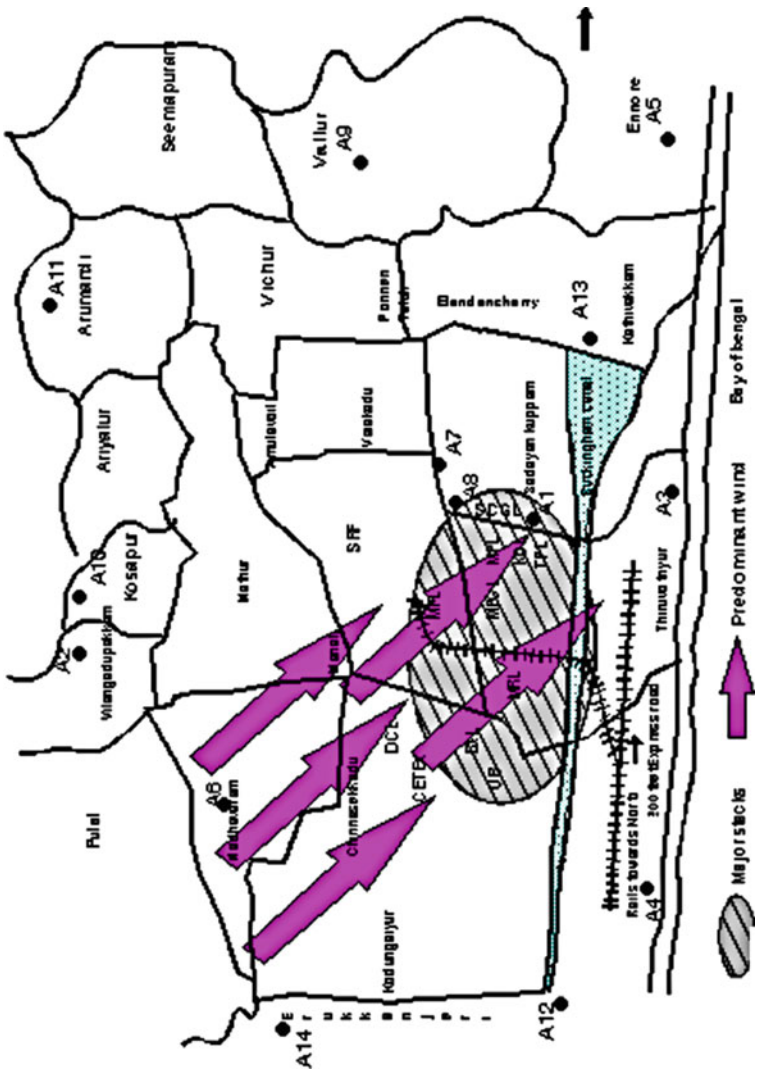

Fig. 7 Illustrative example of improper positioning of sampling locations with respect to predominant wind directions during pre-monsoon and monsoon: example I

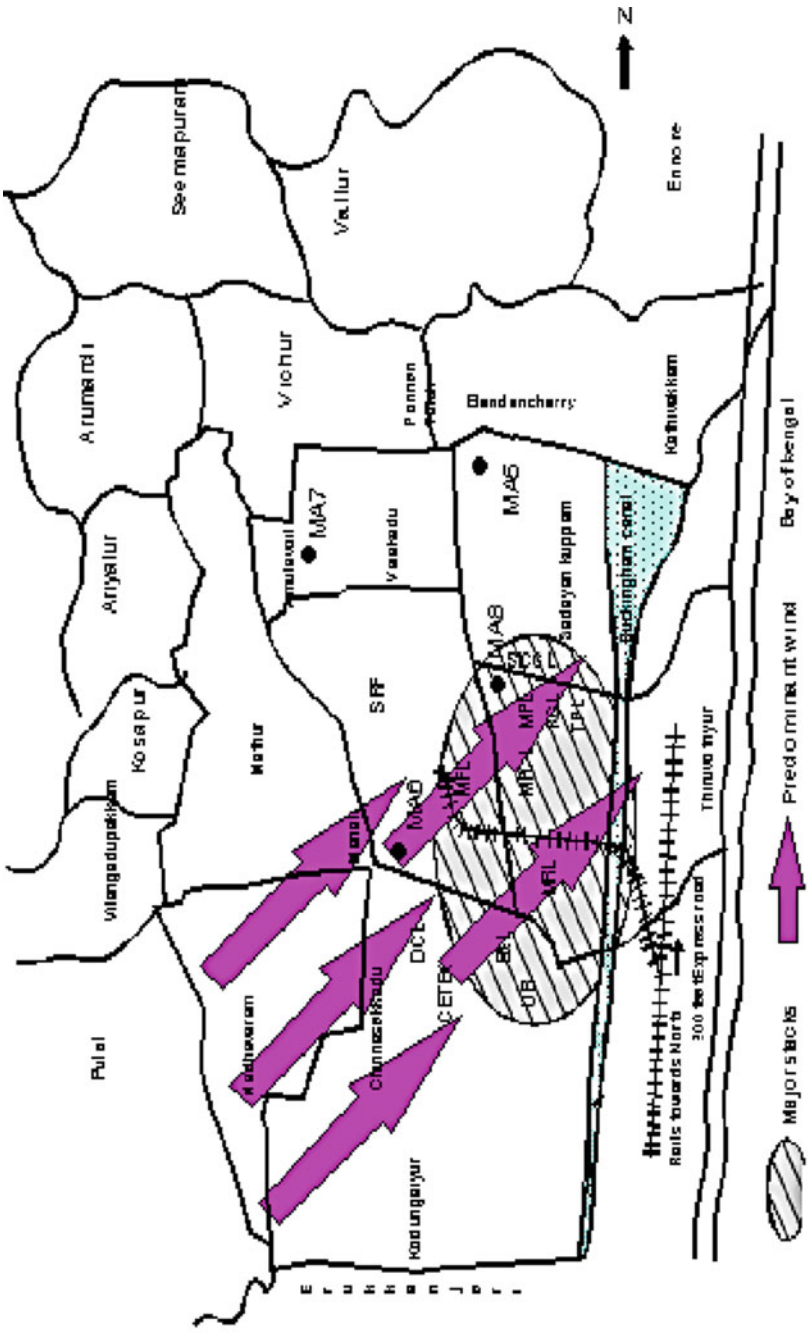

Fig. 8 Illustrative example of improper positioning of sampling locations with respect to predominant wind directions during pre-monsoon and monsoon: example II

Table 3 National Ambient Air Quality Standards as per Air Act and EPA Notification GSR 176 E of 2 April 1996 (Abbasi and Abbasi 2018)

Pollutant[a]	Concentration in ambient air, μg/m^3		
	Sensitive location	Residential, rural and other	Industrial
SO_x	30	80	120
NO_x	30	80	120
SPM	100	200	500
Ammonia	@	@	@
Chlorine	@	@	@

[a]24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time it may exceed but not on two consecutive days
@The standards for these two have not been announced as yet

The standards are summarized in Table 3. As per Central Pollution Control Board (CPCB) norms, a location is considered polluted if 24 hourly/8 hourly air quality values exceed the relevant standard in more than 2% of the samples (CPCB 2012; Abbasi and Abbasi 2018).

7.1 Studies on SO_x

7.1.1 SO_x: Pre-monsoon

As may be seen from Table 3, the National Ambient Air Quality Standards for SO_x are: 120 μg/m^3 for industrial locations, 80 μg/m^3 for residential or rural locations and 30 μg/m^3 for sensitive locations. Further, as per the norms of CPCB, these standards should not exceed in the relevant locations for more than 2% of the samples in a year.

But, as is revealed from Table 4, in ten of the eleven stations, the air quality is unacceptable vis-a-vis SO_x, as in more than 2% of the samples the SO_x levels are higher than the standards applicable to industrial location.

However, the study area also encompasses residential locations as also 'sensitive' locations such as schools and hospitals (primary health centres). When we apply the air quality standards appropriate to such locations, it is revealed that in all the eleven stations, the CPCB norms (of not more than 2% samples exceeding the prescribed limits) are surpassed. The extent of SO_x pollution in terms of compliance with residential or sensitive locations is most marked at the sampling stations situated at Chinnamathur, TNHB, Madhavaram and Vaikkadu where more than half the samples exceed the prescribed limits. In terms of the standards for sensitive locations, which are the most stringent, the non-compliance of the air samples is even more marked: 88.7% samples exceed his limit at Periyasekkadu, followed by 85.6% at Chinnamathur and 81.7% at TNHB.

Table 4 Percentage of samples polluted during pre-monsoon

S. No.	Location	Samples during	% of samples polluted											
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
1	Chinnasekkadu	Day	5.7	24.5	56.6	0.0	0.0	34.0	0.0	17.0	41.5	5.7	34.0	66.0
		Night	7.5	30.2	66.0	0.0	0.0	37.7	0.0	22.6	47.2	7.5	41.5	73.6
		Total	6.6	27.4	61.3	0.0	0.0	35.8	0.0	19.8	44.3	6.6	37.7	69.8
2	Periyasekkadu	Day	7.5	22.6	86.8	0.0	0.0	41.5	0.0	18.9	41.5	7.5	28.3	88.7
		Night	7.5	24.5	90.6	0.0	0.0	50.9	0.0	30.2	52.8	7.5	32.1	94.3
		Total	7.5	23.6	88.7	0.0	0.0	46.2	0.0	24.5	47.2	7.5	30.2	91.5
3	Manali Fire Station	Day	0.0	7.5	66.0	0.0	7.5	71.7	1.9	52.8	84.9	1.9	56.6	84.9
		Night	0.0	22.6	79.2	0.0	1.9	77.4	0.0	58.5	90.6	0.0	62.3	94.3
		Total	0.0	15.1	72.6	0.0	4.7	74.5	0.9	55.7	87.7	0.9	59.4	89.6
4	Manali School	Day	24.5	37.7	71.7	0.0	0.0	28.3	0.0	24.5	50.9	24.5	56.6	83.0
		Night	18.9	28.3	60.4	0.0	0.0	22.6	0.0	18.9	41.5	18.9	39.6	67.9
		Total	21.7	33.0	66.0	0.0	0.0	25.5	0.0	21.7	46.2	21.7	48.1	75.5
5	TNHB	Day	17.3	53.8	76.9	0.0	0.0	34.6	0.0	25.0	69.2	17.3	61.5	82.7
		Night	23.1	69.2	86.5	0.0	0.0	48.1	0.0	34.6	75.0	23.1	73.1	86.5
		Total	20.2	51.2	81.7	0.0	0.0	41.3	0.0	29.8	72.1	20.2	67.3	84.6
6	Chinnamathur	Day	21.2	48.1	82.7	0.0	0.0	50.0	0.0	11.5	78.8	21.2	53.8	86.5
		Night	26.9	57.7	88.4	0.0	0.0	73.1	0.0	25.0	82.7	26.9	59.6	92.3
		Total	24.0	52.9	85.6	0.0	0.0	61.5	0.0	18.3	80.8	24.0	56.7	89.4
7	Amulavoyal	Day	9.4	41.5	54.7	0.0	0.0	30.1	0.0	39.6	49.1	9.4	47.2	62.3
		Night	15.1	45.3	62.3	0.0	0.0	35.8	0.0	34.0	47.2	15.1	52.8	73.6
		Total	12.3	43.4	58.5	0.0	0.0	33.0	0.0	36.8	48.1	12.3	50.0	67.9

(continued)

Table 4 (continued)

S. No.	Location	Samples during	% of samples polluted										
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
8	Madhavaram	Day	3.8	48.1	57.7	0.0	0.0	40.4	0.0	23.1	48.1	3.8	61.5	73.1
		Night	11.5	53.8	73.1	0.0	0.0	34.6	0.0	28.8	53.8	11.5	69.2	76.9
		Total	7.7	51.0	65.4	0.0	0.0	37.5	0.0	26.0	51.0	7.7	65.4	75.0
9	Vaikkadu	Day	11.3	49.1	73.6	0.0	0.0	32.1	0.0	34.0	56.6	11.3	54.7	79.2
		Night	17.0	54.7	79.2	0.0	0.0	39.6	0.0	35.8	66.0	17.0	60.4	81.1
		Total	14.2	51.9	76.4	0.0	0.0	35.8	0.0	34.9	61.3	14.2	57.5	80.2
10	Sadayankuppam	Day	5.7	34.0	56.6	0.0	0.0	34.0	0.0	22.6	47.2	5.7	37.7	60.4
		Night	11.3	39.6	66.0	0.0	0.0	35.8	0.0	18.9	52.8	11.3	43.4	67.9
		Total	8.5	36.8	61.3	0.0	0.0	34.9	0.0	20.8	50.0	8.5	45.6	64.2
11	Thiruvottriyur	Day	18.9	43.4	60.4	0.0	0.0	37.7	0.0	28.3	56.6	18.9	52.8	66.0
		Night	13.2	37.7	56.6	0.0	0.0	30.2	0.0	24.5	49.1	13.2	49.1	60.4
		Total	16.0	45.6	58.5	0.0	0.0	34.0	0.0	26.4	52.8	16.0	50.9	63.2

7.1.2 SO_x: Monsoon

During 'monsoon' (September–November), too, all but one sampling station has recorded unacceptable air quality as per NAAQ Standards of SO_x levels and the CBCB norm of a number of above-limit samples tolerable at a given location (Table 5). The most liberal of the three standards, applicable to industrial locations, is exceeded to the extent of ~38% at Manali Fire Station and Amulavoyal. At Vaikkadu and TNHB, the non-compliance is in 25 and 21.4% of the samples, respectively. The residential/rural and sensitive locations in the study area receive unacceptable SO_x levels much more frequently, as reflected in the high percentage of samples exceeding the limits set for such locations at all but one of the stations.

7.1.3 SO_x: Post-monsoon (or 'Winter')

The SO_x levels are generally lesser during the post-monsoon months (December–February) due, perhaps, to the generally more unstable atmospheric conditions in these months enabling quicker dispersion of pollutants than in the pre-monsoon and monsoon months of June–November when often the sky is overcast with lesser movements of air. Even then, the fraction of samples found polluted (Table 6) as per the standards for industrial locations exceed CPCB norms at nine of the stations. In terms of the standards applicable to residential/rural locations and sensitive locations, the non-compliance is more blatant even though lesser in magnitude than in the previous two seasons.

7.1.4 SO_x: Summer

The summer (March–May) in the study area is characterized by increasing ambient temperatures and correspondingly increasing relative humidity (Table 7). Further, the effect of south-west monsoon settling in the west of the Western Ghats off-and-on spills over to the study area which is situated east of the Ghats, resulting in cloudy skies. These factors may combine to create a less favourable climate for the dispersion of air pollutants than was possible in the preceding months, assuming that all other factors—especially the source strength—had remained constant.

During this study, the air quality with reference to SO_x in summer has, expectedly, deteriorated. All the eleven sampling stations reflect air quality which is unacceptable vis-a-vis SO_x levels as per the CPCB norms. The impact at Chinnasekkadu, Manali School and Amulavoyal is particularly severe. In three other stations (Periyasekkadu, TNHB and Chinnamathur), too, 20% or more samples have SO_x levels higher than permissible for industrial locations. In terms of standards for residential/commercial and sensitive locations, the proportion of polluted samples is even higher; the situation at Chinnasekkadu, Periyasekkadu, Manali School, TNHB, Chinnamathur and Amulavoyal is being particularly bad.

Table 5 Percentage of samples polluted during monsoon

S. No.	Location	Samples during	% of samples polluted											
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
1	Chinnasekkadu	Day	5.8	38.5	84.5	0.0	0.0	38.4	0.0	26.9	73.1	5.8	48.1	90.3
		Night	11.8	47.1	94.1	0.0	0.0	43.1	0.0	35.3	84.3	11.8	54.9	94.1
		Total	8.7	42.7	89.3	0.0	0.0	40.7	0.0	31.1	78.6	8.7	51.4	92.2
2	Periyasekkadu	Day	9.6	42.3	76.9	0.0	0.0	34.6	0.0	23.1	61.5	9.6	53.8	84.6
		Night	15.7	47.1	84.3	0.0	0.0	39.2	0.0	29.4	68.6	15.7	58.8	94.1
		Total	12.6	44.7	80.6	0.0	0.0	36.9	0.0	26.2	65.0	12.6	56.3	89.3
3	Manali Fire Station	Day	0.0	5.8	36.5	0.0	0.0	17.6	0.0	30.1	57.7	0.0	34.6	76.9
		Night	0.0	17.6	58.8	0.0	0.0	19.6	0.0	49.0	62.7	0.0	58.8	90.2
		Total	0.0	11.7	47.6	0.0	0.0	18.4	0.0	39.8	60.2	0.0	46.6	83.5
4	Manali School	Day	34.6	38.5	100	0.0	0.0	11.5	0.0	23.1	67.3	34.6	50.0	100
		Night	43.1	58.8	100	0.0	0.0	19.6	0.0	19.6	78.4	58.8	60.8	100
		Total	38.8	48.5	100	0.0	0.0	15.5	0.0	21.4	72.8	46.6	55.3	100
5	TNHB	Day	19.2	69.2	90.4	0.0	0.0	59.6	0.0	34.6	73.1	19.2	73.1	94.2
		Night	23.5	78.4	96.1	0.0	0.0	68.6	0.0	41.2	88.2	23.5	84.3	98.0
		Total	21.4	73.8	93.2	0.0	0.0	64.1	0.0	37.9	80.6	21.4	78.6	96.1
6	Chinnamathur	Day	11.5	19.2	28.8	0.0	0.0	7.7	0.0	21.1	25.0	11.5	28.8	34.6
		Night	15.7	25.5	35.2	0.0	0.0	15.7	0.0	19.6	29.4	15.7	35.3	39.2
		Total	13.5	22.3	32.0	0.0	0.0	11.7	0.0	20.4	27.2	13.5	32.0	36.9
7	Amulavoyal	Day	30.8	67.3	84.6	0.0	0.0	15.3	0.0	23.1	86.5	30.8	71.1	92.3
		Night	46.2	92.3	100	0.0	0.0	23.1	0.0	44.2	100	46.2	96.2	100
		Total	38.5	79.8	92.3	0.0	0.0	19.4	0.0	33.7	93.3	38.5	83.7	96.2

(continued)

Table 5 (continued)

S. No.	Location	Samples during	% of samples polluted										
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
8	Madhavaram	Day	3.8	38.5	69.2	0.0	0.0	53.8	0.0	30.8	73.1	3.8	48.1	76.9
		Night	9.8	45.1	78.4	0.0	0.0	58.8	0.0	33.3	82.4	9.8	54.9	88.2
		Total	6.8	41.7	73.8	0.0	0.0	56.3	0.0	32.0	77.7	6.8	51.5	82.5
9	Vaikkadu	Day	23.1	53.8	96.2	0.0	0.0	11.5	0.0	23.1	57.7	23.1	59.6	96.2
		Night	26.9	57.7	100	0.0	0.0	23.1	0.0	34.6	67.3	26.9	71.2	100
		Total	25.0	55.8	98.1	0.0	0.0	17.3	0.0	28.8	62.5	25.0	65.4	98.1
10	Sadayankuppam	Day	9.6	48.1	76.9	0.0	0.0	19.2	0.0	28.8	73.1	9.6	53.8	84.6
		Night	13.5	55.7	86.5	0.0	0.0	15.4	0.0	30.8	76.9	13.5	61.5	88.5
		Total	11.5	51.9	81.7	0.0	0.0	17.3	0.0	29.8	75.0	11.5	57.6	86.5
11	Thiruvottriyur	Day	7.7	28.8	42.3	0.0	0.0	34.6	0.0	23.1	36.5	7.7	34.6	50.0
		Night	3.8	23.1	38.5	0.0	0.0	28.8	0.0	19.2	38.5	3.8	30.8	42.3
		Total	5.8	26.0	40.4	0.0	0.0	31.7	0.0	37.5	37.5	5.8	32.7	46.2

Table 6 Percentage of samples polluted during post-monsoon

S. No.	Location	Samples during	% of samples polluted											
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
1	Chinnasekkadu	Day	19.2	48.1	57.7	0.0	0.0	38.5	0.0	25.0	42.3	19.2	53.8	61.5
		Night	11.5	57.7	67.3	0.0	0.0	19.2	0.0	28.8	48.1	11.5	67.3	73.1
		Total	15.4	52.9	62.5	0.0	0.0	28.8	0.0	26.9	45.4	15.4	60.6	67.3
2	Periyasekkadu	Day	9.6	44.2	53.8	0.0	0.0	28.8	0.0	24.0	73.1	9.6	50.0	76.9
		Night	15.4	50.0	57.7	0.0	0.0	38.5	0.0	28.8	71.2	15.4	73.1	80.8
		Total	12.5	47.1	55.8	0.0	0.0	33.7	0.0	26.9	72.1	12.5	61.5	78.8
3	Manali Fire Station	Day	9.6	15.4	34.6	0.0	0.0	19.2	0.0	19.2	57.7	9.6	28.8	80.8
		Night	7.7	9.6	38.5	0.0	0.0	9.6	0.0	21.2	61.5	7.7	23.1	69.2
		Total	8.7	12.7	36.5	0.0	0.0	14.4	0.0	20.2	59.6	8.7	26.0	75.0
4	Manali School	Day	3.8	17.3	75.0	0.0	0.0	38.5	0.0	57.7	100	3.8	65.4	100
		Night	19.2	38.5	80.8	0.0	0.0	23.1	0.0	67.3	96.2	19.2	61.5	96.2
		Total	11.5	27.9	77.9	0.0	0.0	30.8	0.0	62.5	98.1	11.5	63.5	98.1
5	TNHB	Day	0.0	9.6	38.5	0.0	0.0	63.5	0.0	26.9	61.5	0.0	30.5	92.3
		Night	11.5	19.2	48.1	0.0	0.0	67.3	0.0	30.8	69.2	11.5	44.2	84.6
		Total	5.8	14.4	43.3	0.0	0.0	65.4	0.0	28.8	65.4	5.8	37.5	88.5
6	Chinnamathur	Day	11.5	38.5	67.3	0.0	0.0	28.8	0.0	28.8	61.5	11.5	48.1	73.1
		Night	15.4	48.1	76.9	0.0	0.0	30.8	0.0	32.7	76.9	15.4	53.8	86.5
		Total	13.5	43.3	72.1	0.0	0.0	29.8	0.0	30.8	69.2	13.5	51.0	79.8
7	Amulavoyal	Day	0.0	23.5	54.9	0.0	0.0	19.6	0.0.	15.7	39.2	0.0	25.5	68.6
		Night	0.0	27.5	58.8	0.0	0.0	29.4	0.0	13.7	49.0	0.0	31.4	78.4
		Total	0.0	25.5	56.9	0.0	0.0	24.5	0.0	14.7	44.1	0.0	28.4	73.5

(continued)

Table 6 (continued)

S. No.	Location	Samples during	% of samples polluted											
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
8	Madhavaram	Day	11.5	48.1	57.6	0.0	0.0	48.1	0.0	5.8	67.3	11.5	51.9	67.3
		Night	9.6	53.8	61.5	0.0	0.0	46.2	0.0	3.8	57.7	9.6	53.8	61.5
		Total	10.6	51.0	59.6	0.0	0.0	47.1	0.0	4.8	62.5	10.6	52.9	64.4
9	Vaikkadu	Day	0.0	27.5	39.2	0.0	0.0	45.1	0.0	21.6	39.2	0.0	31.4	54.9
		Night	0.0	31.4	47.1	0.0	0.0	43.1	0.0	23.5	41.2	0.0	39.2	58.8
		Total	0.0	29.4	43.1	0.0	0.0	44.1	0.0	22.5	40.2	0.0	35.3	56.9
10	Sadayankuppam	Day	5.9	31.4	58.8	0.0	0.0	29.4	0.0	19.6	39.2	5.9	35.3	62.7
		Night	11.8	39.2	64.7	0.0	0.0	33.3	0.0	23.5	49.0	11.8	39.2	68.7
		Total	8.8	35.3	61.8	0.0	0.0	31.4	0.0	21.6	44.1	8.8	37.3	65.7
11	Thiruvottriyur	Day	2.0	2.0	49.0	0.0	0.0	39.2	0.0	15.7	41.2	2.0	25.5	54.9
		Night	3.9	3.9	35.3	0.0	0.0	29.4	0.0	15.7	35.3	3.9	23.5	39.2
		Total	2.9	2.9	42.2	0.0	0.0	34.3	0.0	15.7	38.2	2.9	24.5	47.1

Table 7 Percentage of samples polluted during summer; the columns of I, R and S represent samples polluted as per norms for industrial, residential and sensitive locations, respectively

S. No.	Location	Samples during	% of samples polluted											
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
1	Chinnasekkadu	Day	28.3	52.8	100	0.0	3.7	52.8	0.0	22.6	66.0	28.3	60.4	100
		Night	34.6	67.3	100	0.0	7.7	57.7	0.0	25.0	71.2	34.6	73.1	100
		Total	31.4	60.0	100	0.0	5.7	55.2	0.0	23.8	68.6	31.4	66.7	100
2	Periyasekkadu	Day	18.9	37.7	94.3	0.0	0.0	49.1	0.0	22.6	90.6	18.9	41.5	96.2
		Night	23.1	48.1	98.1	0.0	1.9	55.8	0.0	30.8	100	23.1	53.8	100
		Total	21.0	42.9	96.2	0.0	1.0	52.4	0.0	26.7	95.2	21.0	47.6	98.1
3	Manali Fire Station	Day	37.7	66.0	90.6	0.0	11.5	66.0	0.0	37.7	52.8	37.7	79.2	94.3
		Night	34.6	69.2	86.5	0.0	0.0	53.8	0.0	34.6	50.0	34.6	73.1	90.4
		Total	36.2	67.6	88.6	0.0	5.7	60.0	0.0	36.2	51.4	36.2	84.6	92.4
4	Manali School	Day	7.5	28.3	75.5	0.0	0.0	66.0	0.0	37.7	86.8	7.5	41.5	94.3
		Night	3.8	19.2	73.1	0.0	0.0	57.7	0.0	30.8	80.8	3.8	30.8	92.4
		Total	5.7	23.8	74.3	0.0	0.0	61.9	0.0	34.3	83.8	5.7	36.2	93.3
5	TNHB	Day	26.9	57.7	100	0.0	0.0	50.0	0.0	0.0	76.9	26.9	57.7	100
		Night	15.4	50.0	96.2	0.0	1.9	48.1	0.0	0.0	82.7	15.4	50.0	100
		Total	21.2	53.8	98.1	0.0	1.0	49.0	0.0	0.0	79.8	21.2	53.8	100
6	Chinnamathur	Day	23.1	48.1	92.3	0.0	0.0	38.5	0.0	13.5	50.0	23.1	57.7	100
		Night	26.9	51.9	100	0.0	3.8	50.0	0.0	19.2	67.3	26.9	67.3	100
		Total	25.0	50.0	96.2	0.0	1.9	44.2	0.0	16.3	58.7	25.0	62.5	100
7	Amulavoyal	Day	24.5	49.1	84.9	0.0	0.0	47.2	0.0	11.3	50.9	24.5	56.6	92.5
		Night	38.5	73.1	100	0.0	0.0	57.7	0.0	23.1	65.4	38.5	73.1	100
		Total	31.4	61.0	92.4	0.0	0.0	52.4	0.0	17.1	58.1	31.4	64.8	96.2

(continued)

Table 7 (continued)

S. No.	Location	Samples during	% of samples polluted										
			SO_x			NO_x			SPM			Overall quality		
			I	R	S	I	R	S	I	R	S	I	R	S
8	Madhavaram	Day	3.8	38.4	53.8	0.0	0.0	48.1	0.0	9.6	48.1	3.8	42.3	57.7
		Night	5.8	34.6	57.7	0.0	0.0	53.8	0.0	15.4	53.8	5.8	46.2	61.5
		Total	4.8	36.5	55.8	0.0	0.0	51.0	0.0	12.5	51.0	4.8	44.2	59.6
9	Vaikkadu	Day	7.5	39.6	60.4	0.0	0.0	34.0	0.0	22.6	52.8	7.5	45.3	64.2
		Night	11.5	44.2	76.9	0.0	0.0	44.2	0.0	28.8	67.3	11.5	53.8	80.8
		Total	9.5	41.9	68.6	0.0	0.0	39.0	0.0	25.7	60.0	9.5	49.5	72.4
10	Sadayankuppam	Day	3.8	18.9	47.2	0.0	0.0	32.1	0.0	7.5	37.7	3.8	22.6	52.8
		Night	5.8	28.8	50.0	0.0	0.0	34.6	0.0	15.4	48.1	5.8	34.6	57.7
		Total	4.8	23.8	48.6	0.0	0.0	33.3	0.0	11.4	42.9	4.8	28.6	55.7
11	Thiruvottriyur	Day	9.4	37.7	66.0	0.0	0.0	69.8	0.0	5.7	47.2	9.4	39.6	71.7
		Night	15.4	34.6	57.7	0.0	0.0	61.5	0.0	1.9	46.2	15.4	34.6	67.3
		Total	12.4	36.2	61.9	0.0	0.0	65.7	0.0	3.8	46.7	12.4	37.1	69.5

7.2 Studies on NO_x

NO_x is not a pollutant of as serious concern in the study area as is SO_x. In none of the samples NO_x levels that were higher than permissible for industrial locations, have been recorded. During the monsoon and post-monsoon seasons, NO_x is within acceptable levels for residential/commercial locations as well (Tables 4, 5, 6 and 7). Only during summer, Chinnasekkadu and Manali School and during post-monsoon Manali School stations receive NO_x levels higher than permissible for residential/ rural locations. The possible reason for NO_x levels being significantly lower than SO_x levels is that the former is generally contributed by vehicular exhaust and the traffic density in the study area is not excessively high. Hence, the prime contributor to ambient air pollution is industrial emissions.

7.3 Studies on SPM

At all sampling stations, except one—that too in only one of the four seasons studied—SPM levels are higher than permissible for residential/commercial or 'sensitive' locations (Tables 4, 5, 6 and 7). The sole exception is TNHB during summer. This is an exceedingly undesirable situation as several densely populated villages and other residential areas lie within the impact area studied by us. The area also contains sensitive locations such as schools and primary health centres. Indeed, some of the highest SPM levels have been recorded at Manali School, during pre-monsoon (Table 4), when more than half the samples exceeded the standards for residential/ rural locations and 87.7% samples exceed the standards for 'sensitive' location (which, by definition, Manali School is). The school has also recorded unacceptable SPM levels during all other seasons (Tables 4, 5, 6 and 7). Among other stations seriously affected by SPM levels, higher than permissible for residential/commercial locations are Manali Fire Station (especially during the post-monsoon months), Chinnasekkadu and Periyasekkadu (all year round), Amulavoyal (especially during pre-monsoon and monsoon) and Vaikkadu (more than 22% samples polluted all year round). The sensitive locations receive unacceptable SPM levels even more frequently, over half the time in the majority of cases.

7.4 Overall Air Quality

The gist of the entire ambient air quality survey is presented in Table 8. This table has been culled from the raw data provided in Abbasi et al. (2013). It may be seen that only at one of the eleven sampling locations—Manali Fire Station—the air pollution was within the acceptable limits set by CPCB during pre-monsoon and

Table 8 Air samples (%) found polluted in and around Manali Industrial Complex

Stations	Season											
	Post-monsoon, %			Summer, %			Pre-monsoon, %			Monsoon, %		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Chinnasekkadu	53.8	67.3	60.6	60.4	73.1	66.7	34.0	41.5	37.7	48.1	54.9	51.4
Periyasekkadu	50.0	73.1	61.5	41.5	53.8	47.6	28.3	32.1	30.2	53.8	58.8	56.3
Manali School	100.0	96.2	98.1	94.3	90.4	92.4	83.0	67.9	75.5	100.0	100.0	100.0
Manali Fire Station	9.6	7.7	8.7	7.5	3.8	5.7	1.9	0.0	0.9	0.0	0.0	0.0
TNHB	30.8	44.2	37.5	57.7	50.0	53.8	61.5	73.1	67.3	73.1	84.3	78.6
Chinnamathur	48.1	53.8	51.0	57.7	67.3	62.5	53.8	59.6	56.7	28.8	35.3	32.0
Amulavoyal	25.5	31.4	28.4	56.6	73.1	64.8	47.2	52.8	50.0	71.1	96.2	83.7
Madhavaram	51.9	53.8	52.9	42.3	46.2	44.2	61.5	69.2	65.4	48.1	54.9	51.5
Vaikkadu	31.4	39.2	35.3	45.3	53.8	49.5	54.7	60.4	57.5	59.6	71.2	65.4
Sadayankuppam	35.3	39.2	37.3	22.6	34.6	28.6	37.7	43.4	45.6	53.8	61.5	57.6
Thiruvottriyur	25.5	23.5	24.5	39.6	34.6	37.1	52.8	49.1	50.9	34.6	30.8	32.7

monsoon seasons. At all other sampling locations and in all seasons, the air was polluted above the said norms.

The airshed patterns are further illustrated in Figs. 9, 10 and 11. In summary:

(a) During pre-monsoon, high concentrations of air pollutants are observed in the sampling stations situated in the north-east direction. The isoconcentration profiles for SO_x and SPM (Figs. 9 and 10) indicate pollutant levels far above the limits permitted by Central Pollution Control Board (CPCB) and encompass residential areas such as Sadayankuppam, Amulavoyal and Vaikkadu.
(b) Incidence of high concentration of NO_x is limited to a relatively smaller area.
(c) In the post-monsoon months, the concentration contours for SO_x (Fig. 11) over the residential areas of Manali, Chinnasekkadu, Periyasekkadu, Madhavaram and Selavayal indicated levels exceeding the prescribed limits of CPCB.
(d) During the post-monsoon months, the concentrations of NO_x and SO_x are lower, compared to the pre-monsoon, yet these concentrations are above CPCB's prescribed limits.
(e) In monsoon, the isopleths for SO_x indicate that the pollutant levels exceed the CPCB standards. They envelop wider area than in other seasons, including residential areas of Manali, Chinnasekkadu, Sadayankuppam, Amulavoyal and Vaikkadu.
(f) During summer, the rate of aerial dilution appears to be maximum, and concentrations of the pollutants are lower compared to any other seasons. Even then, the concentrations of SO_x are higher than the CPCB's prescribed limit.

7.5 *Ammonia and Chlorine*

Ambient air quality standards for SPM, NO_x and SO_x are available with CPCB. But for Cl_2 and NH_3, the ambient air quality standards are not available as yet. We tried hard to procure these from CPCB and US Environmental Protection Agency (USEPA) but were not successful. For this reason, we have not included these two variables in our computations of overall air quality discussed in the preceding section. The discussion in this section is indicative of how the air quality picture *may* look once we take these two variables also into account.

For the present, we have derived tentative standards for these chemicals on the basis of the logic that has gone in the setting up of standards for SO_x and NO_x. We found that ambient standards (AS) for SO_x and NO_x are related to their threshold lethal values (TLVs) by the empirical formulae:

AS1 = 0.025 * TLV (industrial area)
AS2 = 0.015 * TLV (residential area)
AS3 = 0.006 * TLV (sensitive area)

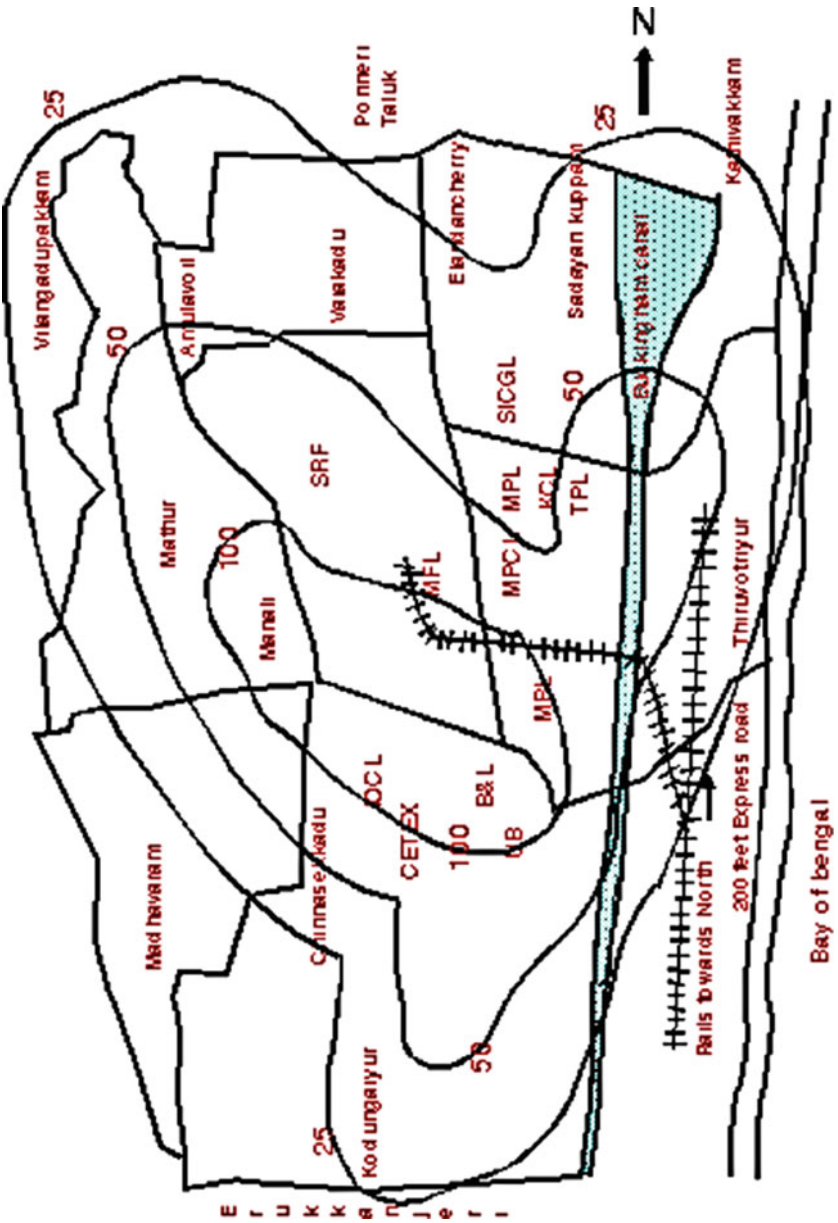

Fig. 9 Isopleths of SO_x ($\mu g/m^3$) during pre-monsoon

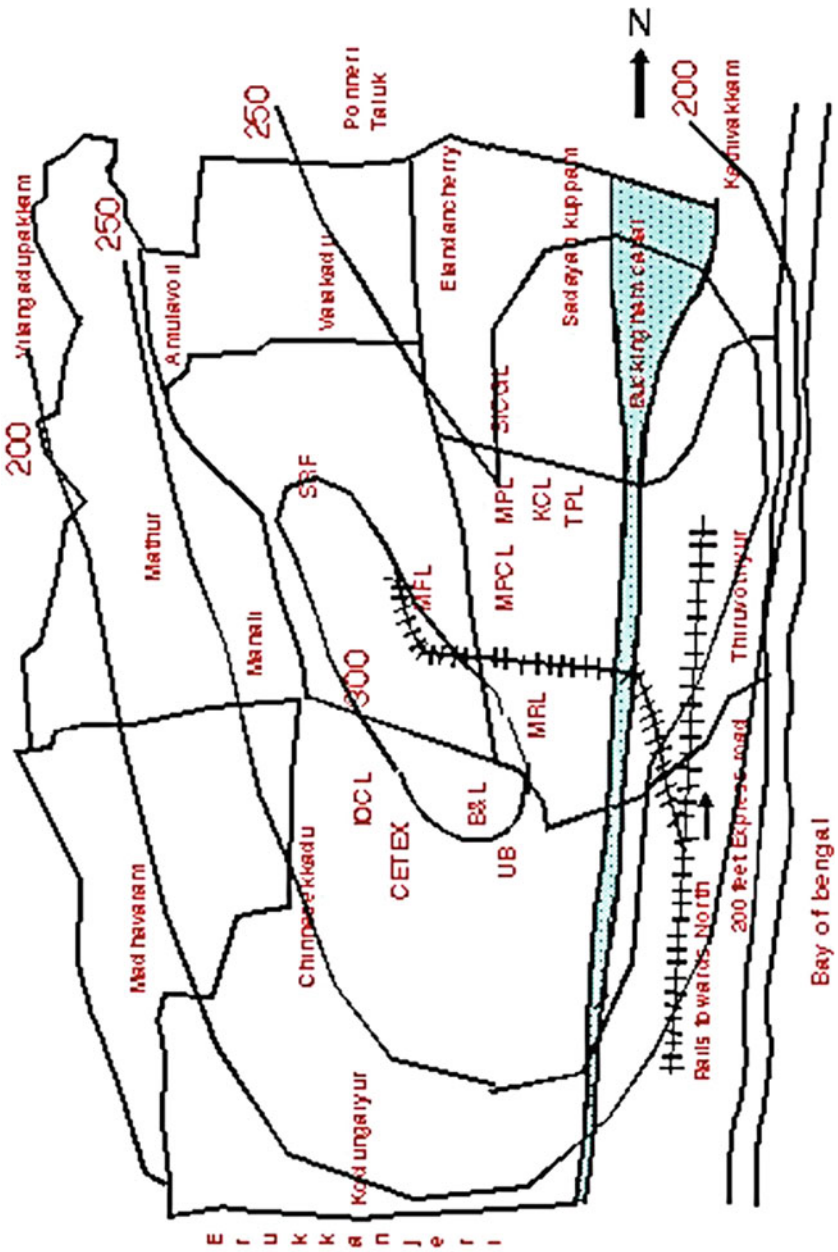

Fig. 10 Isopleths of SPM ($\mu g/m^3$) during pre-monsoon

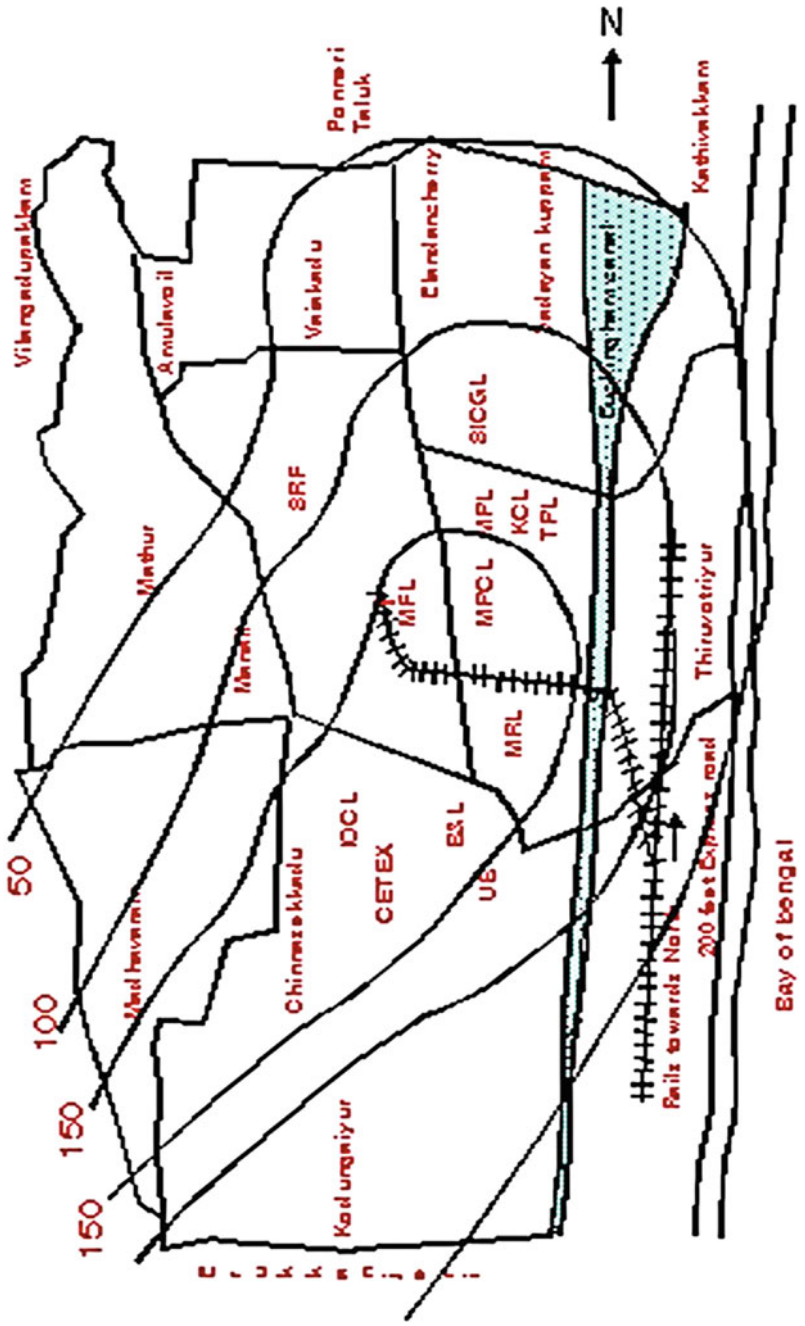

Fig. 11 Isopleths of SO_x ($\mu g/m^3$) during post-monsoon

Table 9 Tentative CPET standards for chlorine and ammonia

Area	Cl_2 (ppm)	NH_3 ($\mu g/m^3$)
Industrial and mixed use	0.025	375
Residential and rural area	0.015	225
Sensitive area	0.006	90

The ambient standards derived on the basis of these formulae for ammonia and chlorine are given in Table 9. We have termed them '*Tentative CPET (TCPET) standards*', where CPET represents Centre for Pollution Control and Energy Technology. For interpreting the results, we have used these TCPET standards.

7.5.1 Ammonia

The gist of the monitoring is as follows:

(a) In a large number of situations (Tables 10, 11, 12 and 13), more than 50% of samples had ammonia levels exceeding the TCPET limits.
(b) The most affected areas due to high NH3 concentration are Vaikkadu, Chinnasekkadu, Amulavoyal and Manali (Fig. 12). All-in-all the ambient air concentration of ammonia was significantly higher than the TCPET standards.

7.5.2 Chlorine

The monitoring reveals that:

(a) During monsoon, the concentration of Cl_2 exceeds up to 3 times the TCPET limits (Fig. 13).
(b) The areas under the impact of severe pollution load due to Cl_2 are the same as under NH_3 concentration (Tables 10, 11, 12 and 13).

7.6 Overall Seasonal Pattern

The following patterns emerge from the mass of data generated by us (Abbasi et al. 2013).

(1) In general, the concentrations of various pollutants are at their highest during post-monsoon and lowest during summer.
(2) The main pollutants at the residential and industrial area are NH_3, Cl_2, SO_x and SPM.

Table 10 Ambient air samples exceeding TCPET limits for chlorine and ammonia: pre-monsoon

S. No.	Season/months	Location	Samples during	% of samples exceeding TCPET limits					
				Cl_2			NH_3		
				I	R	S	I	R	S
1	Pre-monsoon June–August	Chinnasekkadu	Day	23	29	41	33	39	46
			Night	29	33	44	41	45	50
			Total	26	31	42	37	42	48
2		Periyasekkadu	Day	5	13	17	10	18	21
			Night	9	19	28	14	14	19
			Total	7	16	22.5	12	16	20
3		Manali School	Day	52	64	63	71	75	76
			Night	60	69	69	75	79	80
			Total	56	66.5	66	73	77	78
4		Manali Fire Station	Day	30	36	40	34	37	40
			Night	24	30	32	42	44	44
			Total	27	33	36	38	40	42
5		**TNHB**	Day	10	29	36	10	19	27
			Night	6	16	29	14	24	32
			Total	8	22	32.5	12	21.5	29.5
6		Chinnamathur	Day	4	13	39	13	16	34
			Night	6	17	38	19	21	39
			Total	5	15	38.5	16	18.5	36.5
7		Amulavoyal	Day	53	55	76	70	73	75
			Night	58	60	69	74	77	80
			Total	55.5	57.5	72.5	72	75	77.5
8		Madhavaram	Day	31	37	38	38	46	47
			Night	27	33	32	34	42	42
			Total	29	35	35	36	44	45
9		Vaikkadu	Day	59	60	63	70	73	75
			Night	63	64	67	74	77	79
			Total	61	62	65	72	75	77
10		Sadayankuppam	Day	60	65	69	73	74	76
			Night	53	60	65	70	70	71
			Total	56.5	62.5	67	71.5	72	73.5
11		Thiruvottriyur	Day	54	68	67	71	71	75
			Night	59	64	71	77	75	79
			Total	56.5	66	69	74	73	77

I Industrial zone
R Residential zone
S Sensitive zone

Table 11 Ambient air samples exceeding TCPET limits for chlorine and ammonia: monsoon

S. No.	Season/months	Location	Samples during	% of samples exceeding TCPET limits					
				Cl_2			NH_3		
				I	R	S	I	R	S
1	Post-monsoon December–February	Chinnasekkadu	Day	56	75	97	78	86	95
			Night	53	72	93	74	81	91
			Total	54.5	73.5	95	76	83.5	93
2		Periyasekkadu	Day	10	17	34	12	22	51
			Night	6	13	30	16	26	57
			Total	8	15	32	14	24	54
3		Manali School	Day	58	76	94	77	87	96
			Night	54	72	90	73	83	92
			Total	56	74	92	75	85	94
4		Manali Fire Station	Day	20	32	41	38	48	63
			Night	24	36	45	42	52	67
			Total	22	34	43	40	50	65
5		**TNHB**	Day	0	10	16	18	30	48
			Night	4	14	20	14	34	52
			Total	2	12	18	16	32	50
6		Chinnamathur	Day	20	40	60	30	46	64
			Night	23	36	64	34	50	60
			Total	21.5	38	62	32	48	62
7		Amulavoyal	Day	9	22	33	18	30	42
			Night	5	18	29	16	27	38
			Total	7	20	31	17	28.5	40
8		Madhavaram	Day	15	28	40	24	38	56
			Night	18	33	41	20	36	50
			Total	16.5	30.5	39.5	22	37	53
9		Vaikkadu	Day	57	73	89	73	81	94
			Night	60	76	94	75	87	98
			Total	58.5	74.5	91.5	74	84	96
10		Sadayankuppam	Day	52	72	98	75	90	97
			Night	58	76	94	71	87	93
			Total	55	74	96	73	88.5	95
11		Thiruvottriyur	Day	57	77	95	78	88	93
			Night	53	73	91	72	84	90
			Total	55	75	93	75	86	91.5

I Industrial zone
R Residential zone
S Sensitive zone

Table 12 Ambient air samples exceeding TCPET limits for chlorine and ammonia: post-monsoon

S. No.	Season/months	Location	Samples during	% of samples exceeding TCPET limits					
				Cl_2			NH_3		
				I	R	S	I	R	S
1	Monsoon September–November	Chinnasekkadu	Day	56	74	89	75	87	95
			Night	59	78	94	79	90	98
			Total	57.5	76	91.5	77	88.5	96.5
2		Periyasekkadu	Day	9	18	40	17	35	53
			Night	7	14	35	12	29	49
			Total	8	16	37.5	14.5	32	51
3		Manali School	Day	58	78	92	78	90	98
			Night	54	74	94	73	87	92
			Total	56	76	93	75.5	88.5	95
4		Manali Fire Station	Day	20	34	50	35	55	62
			Night	25	39	57	40	58	66
			Total	22.5	35.5	53.5	37.5	56.2	64
5		**TNHB**	Day	5	10	35	12	28	48
			Night	9	14	39	18	34	52
			Total	7	12	37	15	31	50
6		Chinnamathur	Day	22	40	61	30	48	59
			Night	26	44	64	35	52	61
			Total	24	42	62.5	32.5	50	60
7		Amulavoyal	Day	7	19	40	22	39	61
			Night	6	15	36	18	34	62
			Total	6.5	17	38	20	36.5	61.5
8		Madhavaram	Day	16	18	39	27	44	67
			Night	12	22	43	31	49	70
			Total	14	20	41	29	46.5	68.5
9		Vaikkadu	Day	58	74	89	78	87	95
			Night	55	78	93	74	82	99
			Total	56.5	76	91	76	84.5	97
10		Sadayankuppam	Day	53	75	89	74	86	92
			Night	58	79	93	78	89	97
			Total	55.5	77	91	76	87.5	94.5
11		Thiruvottriyur	Day	53	78	89	72	72	98
			Night	56	82	92	75	76	95
			Total	54.5	80	91.5	73	74	96.5

I Industrial zone
R Residential zone
S Sensitive zone

Table 13 Ambient air samples exceeding TCPET limits for chlorine and ammonia: summer

S. No.	Season/months	Location	Samples during	% of samples exceeding TCPET limits					
				Cl_2			NH_3		
				I	R	S	I	R	S
1	Summer March–May	Chinnasekkadu	Day	9	25	42	14	38	51
			Night	5	29	48	18	34	55
			Total	7	27	45	16	36	53
2		Periyasekkadu	Day	14	35	44	25	38	50
			Night	18	31	48	21	34	53
			Total	16	33	46	23	36	51.5
3		Manali School	Day	63	73	85	74	85	99
			Night	67	79	89	78	81	95
			Total	65	76	87	76	83	97
4		Manali Fire Station	Day	68	74	84	71	81	93
			Night	64	78	88	75	85	97
			Total	66	76	86	73	83	95
5		**TNHB**	Day	60	79	89	68	83	95
			Night	64	75	85	72	89	99
			Total	62	77	87	70	86	97
6		Chinnamathur	Day	62	75	94	73	83	95
			Night	66	79	90	76	87	99
			Total	64	77	92	74.5	85	97
7		Amulavoyal	Day	62	78	91	71	85	91
			Night	66	75	95	75	81	95
			Total	64	76.5	93	73	83	93
8		Madhavaram	Day	20	43	56	30	52	60
			Night	24	40	52	33	56	63
			Total	22	41.5	54	31.5	54	61.5
9		Vaikkadu	Day	62	73	92	78	89	95
			Night	66	76	96	74	85	92
			Total	64	74.5	94	76	87	93.5
10		Sadayankuppam	Day	61	78	96	74	87	98
			Night	58	74	92	70	83	94
			Total	59.5	76	94	72	85	96
11		Thiruvottriyur	Day	12	21	40	12	30	52
			Night	8	25	45	16	34	56
			Total	10	23	42.5	14	32	54

I Industrial zone
R Residential zone
S Sensitive zone

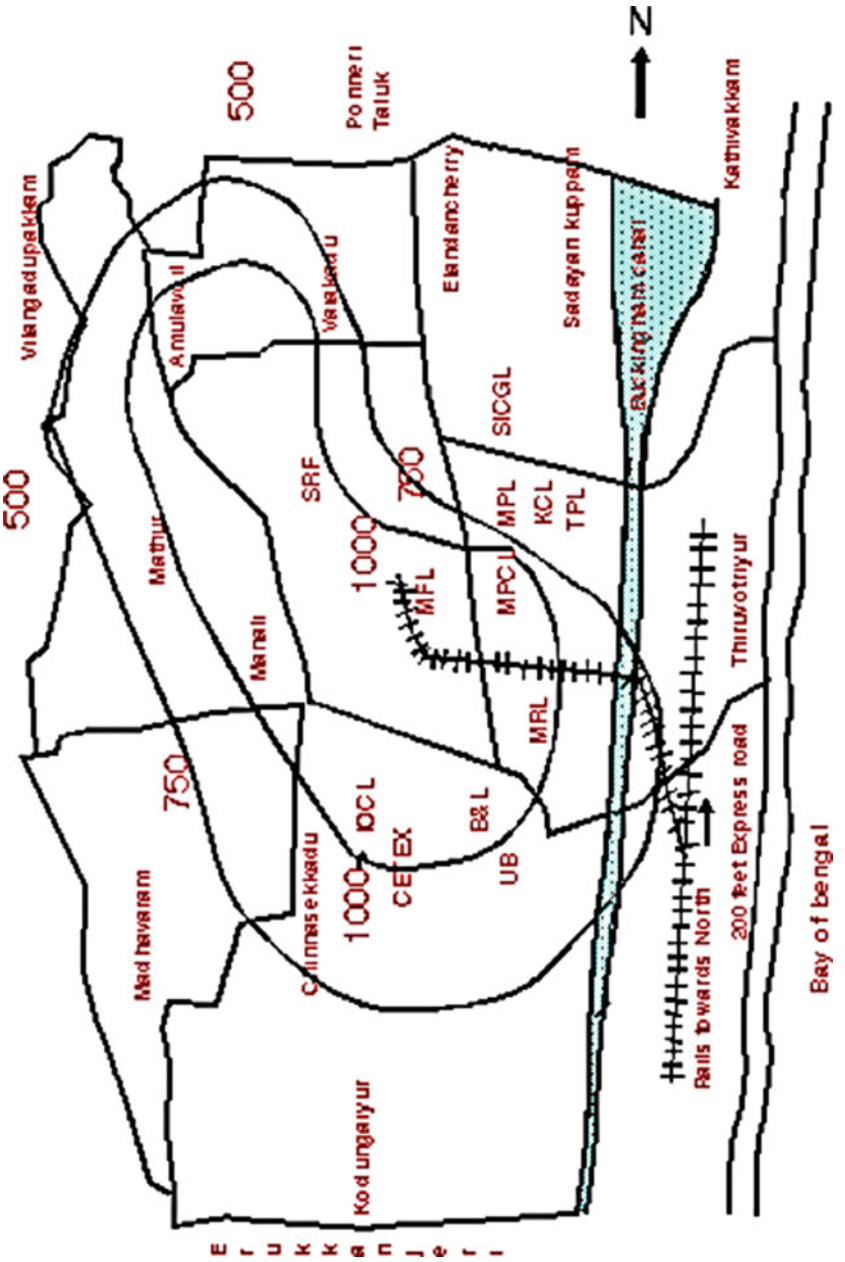

Fig. 12 Isopleths of NH_3 ($\mu g/m^3$) during monsoon

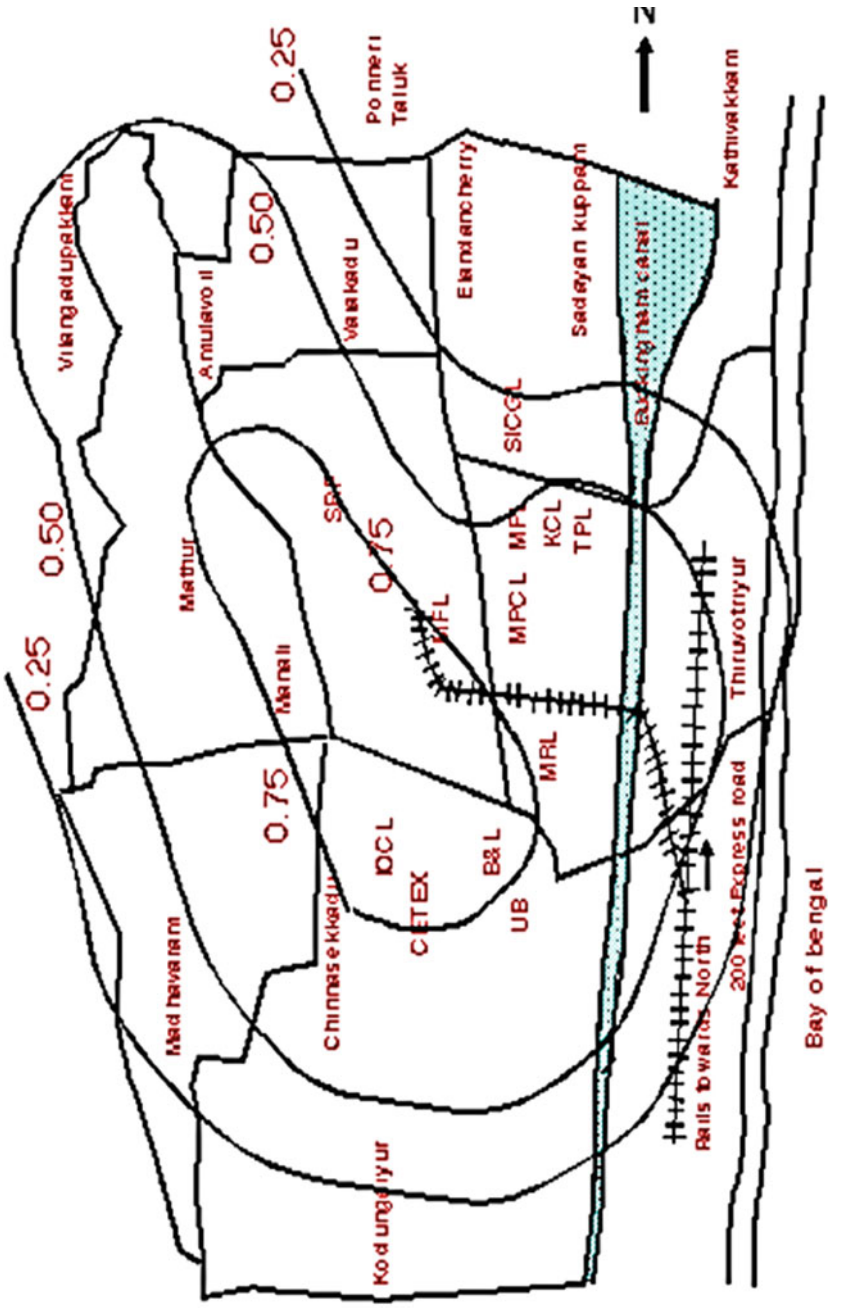

Fig. 13 Isopleths of Cl_2 (ppm) during monsoon

Plate 1 At times dense-gas plumes fall on the ground, posing serious health hazard

(3) During all four seasons (throughout the year), the air of MIC and the surrounding areas (14 km radius) is severely polluted when assessed on the basis of prevailing CPCB norms. It is not uncommon to final dense-gas plumes very close to the ground (Plate 1); one can be literally walking through or driving through such very unhealthy plumes.
(4) The hazardous industries in the region pose serious risk of air pollution, besides risk of major accidents (Abbasi and Abbasi 2011; Khan and Abbasi 1998, 1999).

8 Summary and Conclusion

Systematic studies based on proper reconnaissance, a representative sampling network, extensive sampling and meticulously done analysis reveal that the airshed of the study area—Manali Industrial Complex—is grossly polluted for most times in a year. The database created by the authors is expected to provide a frame of reference for future air quality assessments in the study area. It would, in turn, be helpful in monitoring the impacts of mitigative strategies.

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Inherent Safety in Offshore Oil and Gas Activities

Mahadevan Shankaren, Surendar Varadharajan, Akshi K. Singh and Abhishek Nandan

Abstract Natural health is a proactive methodology for hazard administration and process industry outline, activity. It is demonstrated that the consideration of the lifetime expenses of the task and procedure is a naturally more secure methodology which is a cost-ideal choice. Natural health can be combined at any phase of plan and activity; be that as it may, its application at the most punctual conceivable phases of being used in phases of process outline. In spite of the fact that it is big way to deal with danger/hazard administration, natural wellbeing has not been utilized as broadly as different strategies, for example, hazard and operability study and quantifiable hazard appraisal. The various reasons that are responsible are absence of concentration and lack of accessibility (Khan and Amyotte 2002). Hence, personal health is one of the most preferred choices in case of hazard administration in such industry exercises. Before, it has been connected to a few parts of offshore process outline and activity. Be that as it may, its utilization is as yet restricted. The paper focusses on the application of characteristic security in these sectors. This disks the utilization of accessible innovation for use of inherent security standards in different offshore exercises, both flow and made arrangements for what's to come.

Keywords Inherent safety · Process safety · Risk assessment · Oil and gas

1 Introduction

In the common method to manage plan, various initiatives are build up close to the layout methodology, leaving additional precautions. The cost concentrated system is supported by organization which generally considers welfare and wealth activities related to environment as a requirement. Likewise, neglecting such usage of key guidelines is related to science in taking out the practical security mitigation

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techniques. When it comes to a methodology or a framework, analysts and modelers are combining welfare control related to advancement adventure of compound methods, design. These aims have driven the cost reduction culture called natural security. It is to observe that a trademark security culture routinely achieves the most decreased overall costs through that of unit mass throughout its lifetime. There have been various undertakings by associations and individuals to make initial wealth. Kletz, Hendershot, Englund, Abbasi, and Harstadhas kept an eye on various issues with respect to safety, HAZOP, and risk evaluation techniques. This paper demonstrates a point-by-point picture of the potential for unavoidable wealth thoughts toward the ocean oil and gas activities. Our objective is to give an application oriented frameworks and advancements for the safe and secure operation of oil and gas industry. Mandatory portions in this paper have been acquired through the open composition which is acknowledged. The creation organized is not the ending of the intrinsic prosperity process; this is proved by analysis. Natural security uses key blueprint measures to achieve threat transfer, slip, and reduction. This may be by the advantage of: (i) the protection of used materials, (ii) the storage of hazardous tools which are lacking without any negative effect, (iii) the substances that are secured to reduce their harmful effect at certain condition, and (iv) this technique excludes essentialness of structures that are exceeding certain limit, for instance, weight, vacuum, or quick rotation. The main reason of an approach will empower fashioners to achieve a predominant acceptance between expectation, easing, mitigation, and removing hazards.

2 Intrinsically Safety Scheme in Offshore Activities

The basic goal in accomplishing inherent health is to wipe out hazards completely. Removal of risks away from shoreline is difficult that most of the hazards are identified with the organizations' capacity. Reaching the root of the hazard is achieved by higher command in the key principles of the Inherent health safety principles. The fundamental dangers on offshore establishments are the procedure liquids and preparing tasks, the ocean condition, and the procedure connection between the storage areas and different establishments.

To distribute, there should be minimal quantity of natural hazards, apart from developing the foundation and utilizing flat point to achieve the storage areas. Wide chances of application prevail in liquid storage handling. Standards of characteristic security are well suited to offshore establishment design. Advances in innovation can also leads to the decrease of risks factors.

Bringing the cost into consideration, complications of mass, space, support offshore, and naturally more secure outlines might be in offshore business than to the process parts. Late controls are currently empowering a characteristically more secure methodology, with lower inventories and less dependence on dynamic health systems. This has brought about a drive toward littler 'least offices' stages. With

everything taken into account, the standards of characteristic security are well suited to offshore establishment plan.

The accessibility of innovative choices for intrinsic security at different offices in offshore sector exercises is talked about in the accompanying minor segments.

2.1 Wellhead Areas with Respect to Stage Area

Wellhead 'dangers are huge supporters of the offshore offices' general hazard profile. The pattern toward subsea wellheads that are fixed back to offices has favorable circumstances which clearly lead critical advantages in administering hazards. The stage is to be sufficiently far from the wellheads so the hazards related to them can't undergo the platform (Khan and Amyotte 2002). Maintaining a separation among wellhead and stage is an inherent security which includes that offers impressive advantages concerning serious danger to the stage by disposing of the hazard.

2.2 Subsea Augmentation

Wellheads present a requirement for adaptable risers to be utilized to pass on the well liquids (and perhaps gas blend/gas lift) between the subsea streamlines and the stage. Like wellheads, risers have for the most part been an essential supporter of the hazard profile for toward the sea working environments. Subsea wellheads present the requirement for adaptable risers to be utilized to pass on the well liquids (and perhaps gas blend/gas lift) between the subsea streamlines and the stage. Like wellheads, risers have generally been a supporter of the hazard profile toward the sea workplaces. Like creation streamlines, on the off chance that gas lift/gas reinjection is a need, by then past what many would consider possible single risers to be used.

2.3 Convenience Module Area

The territory of comfort modules needs thought of: (i) hazards related with, (ii) craft exercises, (iii) clearing workplaces, with precise idea of dispatch capacities, and (iv) correspondence inconveniences under mechanical assembly space and settlement module. The naturally safe zone for the settlement measurement across object on a FPSO with a leading tower is at the stem. This is examined as disengagement of surge chance. For settled stages, ordered amount of various possible events has to be coordinated before picking the region of the comfort module.

3 Seaward Development

The significant risks in offshore preparing are the schedule of combustible substances, slug contactors, and warm exchangers like reinjection pumps, blowers, trade pumps, and turbines. For instance, the disposal or decrease in size may precise the application of minimal complex, maximum minimal gear which offers assurance for lessened hazard, lower mass, space necessities, and lower maintenance. Presented beneath are models of inborn security procedures regarding some parts away from shore.

3.1 Process Office Design

Expanding the separation between the most elevated hazard segments of the handling offices and the faculty is one of the most intrinsically safe methods for monitoring the hazard to the workforce associated with process offices (Khan and Abbasi 1998). Gas pressure offices are leading risk occurrence contributor due to the high weights included, and due to immediate release, gas lighting occurs. The framework for fuel gas (moderately less mass) is located near the offices of pressure, while maintaining a partition with offices and the structure. It is therefore important that the course of departure is intended to limit these dangers of impedance.

There are two major categories connected to the arrangement of break courses: (i) completely encased passages and (ii) previous investigations which demonstrate about the two theories which can be connected effectively. In any case, in specific situations a completely encased pressurized passage might be a more fitting option.

3.2 Detachment Forms

The usage of static hydro-winds is by a recognized advancement for the treatment of smooth water. They are extraordinarily essential equipment, maximum distance of pipe from separator; they require small upkeep and are in like manner far less slanted to spills than increasingly settled style lightness units (Mohd Shariff et al. 2006). In addition, power fluids were used to build up eddies smother valve for controlling steam from the valve, to reduce breakdown and disintegration problems, and to reduce maintenance needs.

3.3 Warmth Exchangers

Facilitating increase by centralized unit activities could also be acceptable. Various fluidic apparatus may produce exceptional mixtures, giving great warmth transfer. In ongoing years, minimal warmth exchangers, particularly plate-blade exchangers, have been determined for offshore obligation (Kletz 1991). 'Printed circuit' heat exchangers (PCHEs) which are elective conservative plan are utilized to cool the blower, which results in decrease of size and weight.

3.4 Multiphase Draw Out and Metering

Multiphase transmitting and metering are two making types of progress that in mix could totally change the manner by which oil and gas holds are conveyed (Cozzani et al. 2009). Multiphase metering would enable cash-related necessities for metering to be met without requiring isolated section trains for each store. The mechanical inconveniences of multiphase transmitting and metering are stunning, yet the potential central focuses from both security- and money-related points of view are liberal. The hardware utilized is routinely exceptionally smaller, and such progression could in like way be utilized on surface establishment.

3.5 Blowers

An inspection of a blower structure in reinjection of gas away from seashore line was considering some choices using a rebuilding program. The ideal plan is consisted of gradual coolers and reuse coolers in a similar group for stages 1 and 2 and also led to a decrease in the quantity of valves needed for change and flooding (Lutz 1997). The outline wiped out the requirement for some valves and reduced the amount of coolers from 3 to 1, and most likely reduced capital and labor costs as well.

4 Subsea Establishments

Recently, 'remote-worked submerged vehicles' (ROVs) speak for themselves as one of the most critical safety propellers. The adaptable nature and ability in vehicles continues to expand, and they may distribute the requirement for one day to jump completely (MARS 1994). A late investigation demonstrated that the outline for simple examination can reduce the cost of life. These approaches expect

to limit activity and upkeep prerequisites and diminish hazards by excluding individuals from the establishments. Wave-controlled generators are convincing to be created later, destroying the diesel generators' demand.

5 Auxiliary Respectability

Auxiliary respectability is an important issue for the outline, activity of establishments, particularly critical for coasting formations. When considering the use of intrinsic standards of health, it may be more important to divide angles where disaster was anticipated or where positive results of disappointment will keep away or diminished by the structure's key plan. In order to avoid the utilization of offshore structures by boring from coastal utilizing near land boring is performed. Be that, such techniques are not appropriate for applications a long way from shore in thorough waters and are never liable to be financially stable (Palaniappan et al. 2002). The standards of natural security along these lines are combined inside to decide that if a type of harm could sensibly be predicted, at that point a proportion of opposition (excess) to be given. There might be a job for inborn security in the affectability thinks about that used to test the materials to differ outward, inward risks.

6 Current Scenario and Future Activities Needed

6.1 Present Status of Naturally More Secure Outline

The discoveries of the investigation demonstrate that the term natural health is understood in offshore business. There seems, by all accounts, to be a number of unobtrusive, however, huge contrasts of conclusion with respect to what intrinsic security is, including 'danger evasion,' 'danger counteractive action,' 'chance minimization,' and 'great designing' (Mearns and Flin 1995). A few organizations are attempting to bring issues to light of the outline group by guaranteeing that security experts are incorporated into the undertaking group at the most probable stage. These goals are completely perfect with more secure way to deal with configuration—decreasing stock, spill focuses and upkeep necessities, diminishing staff introduction dangers, etc. In the minimal types of standard detachment, gas drying and slug is taking care of—territories as of now with the biggest inventions of harmful substances.

6.2 Activities Required to Make Characteristic Wellbeing a Training

Fundamental obstacles which grip intrinsic health are: the absence of consciousness of the idea, particularly by architects and undertaking pioneers; an absence of comprehension of the standards of inborn security and how these can be connected; trouble in anchoring time at the beginning periods of activities to think about security perspectives; the way in which security is tended to in practicality examines; and the constrained thoughtfulness regarding inherent health in regulations (Gupta and Edwards 2002). As per the researchers, the manner in which the design phase is actualized could be adjusted to give a superior and timelier chance to support the examination of characteristically more secure choices and intrinsically more secure plan objectives. Similarly, more adaptable and customer/contractual worker connections can make the sort of condition that avoids past difficult practises and empowers advancements (Crawley 1999). Numerous establishment plans join a few models of inborn health; however, these have a tendency to emerge from 'smart thoughts' or particular activities as opposed to a purposeful use of intrinsic security and its standards amid the outline procedure.

The accompanying proposals are displayed as modes in which naturally more secure ways to deal with configuration can be promoted:

1. Regulatory offices must step up with regard to bringing issues to light and advancing talk of characteristically more secure ways to deal with outline.
2. Researchers ought to be urged to take a shot at the showing of inborn health applications, and these discoveries ought to be made accessible to every single interested industry.
3. Regulatory offices must empower the utilization of inborn security by giving different motivating forces or community-oriented research openings.
4. An organized exchange paper should be produced on the utilization of inherent security and its points of interest. This could be accomplished through cooperation among ventures, administrative organizations, and specialists.
5. Efforts must be made to create simpler to utilize techniques and apparatus for characteristic security application. The truth at present is that there are a couple of orderly strategies or devices accessible to assess inborn health.
6. Regulatory organizations and industry support the incorporation of basic security standards which is used in preparing solutions for health experts as well as planners, and that preparation would be fitting for senior directors and venture administrators.
7. Advancement projects ought to be supported to address or energize intrinsically more secure innovation, plan, and task. Perhaps progressively noticeable need could be given to joint tasks to make and test new ways that could give intrinsically increasingly secure alternatives.
8. Consideration to be given to functional methods for empowering development and the scan for characteristically more secure plan arrangements in ventures.

This may incorporate giving additional assets in beginning periods of tasks having more open and adaptable authoritative connections.

9. Institutions which urge to incorporate intrinsically secure outline of procedures and plant specifically, as a major aspect of the educational modules for their designing alumni.

7 Summary and Conclusion

The arrangement toward the ocean foundations mirrors various employments of natural security; efficient and undeniable usage of these norms could incite all the more dominant execution. In case security is tended to be as essential go/no go display toward the starting occasions of plan, various open entryways for a naturally progressively secure, and perhaps more affordable, foundation may be lost. Experience in like manner will in general help the view that to some degree additional time spent at a beginning period can manage the critical issues and brief a general minimization in length since future levels can run even more effectively. To move rapidly into a characteristic prosperity based development, progression, layout, and procedure plant subsidization behavior, every segments of the business aggregate should recognize the lifestyle move supporting inherent security reactions at each dimension on step with premise. To move rapidly into a characteristic security-based creation, improvement, plan, and procedure plant capitalization culture, all segments of the business must recognize the lifestyle move supporting the trademark prosperity process at each dimension on a procedure with reason.

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Ambient Quality Downwind Major Industrial Estates of Puducherry, India

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Abstract This chapter presents studies on the air quality as it occurred downwind seven major industrial estates of Puducherry, India. The survey has revealed that in most cases, the pollutant levels are exceeding the limits prescribed for 'sensitive' locations (schools, hospitals)—which are situated downwind these estates—by the Central Pollution Control Board (CPCB) of the Government of India. It was also seen that even as in several cases the pollutant levels are present within the limits prescribed for residential areas, (through exceeding the limits for sensitive areas), they are close to the more liberal limits for the residential areas and can begin to exceed those limits, too, if the air quality deteriorates a little further. We have compared the present findings with an earlier survey, reported in 2005. It also shows that the air quality now, in general, is inferior to what it was in 2005.

Keywords NO_x · SO_x · SPM · Air quality · Puducherry · Industrial estates

1 Introduction

The rate of industrialisation in the Union Territory of Puducherry, especially its capital—the city of Puducherry—has increased several folds since 1992. This is largely due to the incentives that the Government of Puducherry offers, such as income tax holiday, sales tax concession and lower power tariff compared to other regions. The location of Puducherry, about 114 km south of Chennai, its status as a tourist hub, its strong economy and the availability in it of most of the facilities that

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a big city offers yet without the drawbacks of the big cities—all contribute to words making Puducherry an attractive place to set up industries.

The present study has aimed to assess the stack emissions of major polluting industries as also the quality of air downwind the major industrial estates of Puducherry.

2 Status of Industries in Puducherry

2.1 Number and Type of Industries

Beginning with just three textile mills fifty years ago, Puducherry now has 77 large-scale industries (LSI), 190 medium-scale industries (MSI) and 7792 small-scale industries (SSI). From employing about 8000 persons in the early 1950s, the industries in Puducherry now employ over 9 lakh persons (Table 1).

The easy and inexpensive access to land, water and power; the added inducements by way of incentives, concessions and tax holidays; and the consistent improvements in infrastructure and other support systems that facilitate industrial growth, have spurred the growth of industries in Puducherry, especially from 2000 onwards (Fig. 1). These industries are mostly situated in one of the seven major industrial estates presently in existence (Table 2):

(1) The Thattanchavady industrial estate was established in 1962 over an area of 51 acres. There are 110 units functioning there in 60 sheds of different sizes. These have been sold to entrepreneurs under the schemes of Hire-Purchase and Conditional Assignment.
(2) The rural industrial estate, which is situated in 15.6 acres of land at Kattukuppam and Manapet, was set up in 1969. In the 13 sheds and 38 plots of this estate, 19 industrial units have been functioning.
(3) The 167-acre industrial estate at Mettupalayam came up in 1976. There are 257 units situated in 367 plots and 89 sheds of various sizes across this estate.
(4) The Sedarapet industrial estate was established in 1982. It has 191 plots of different sizes, consisting of 83 units, in an area of 62.2 acres.
(5) The 25-acre industrial estate at Kirumampakkam houses 19 units.

Table 1 Industries in Puducherry

Scale	Number of units	Investment (crores of rupees)	Persons employed
Large scale	77	1254.78	18,511
Medium scale	190	604.5	11,873
Small scale	7792	859.31	68,069
Micro scale	907	80.51	4618
Total	8966	2798.85	103,071

http://industry.puducherry.gov.in/html/iprofile0.htm

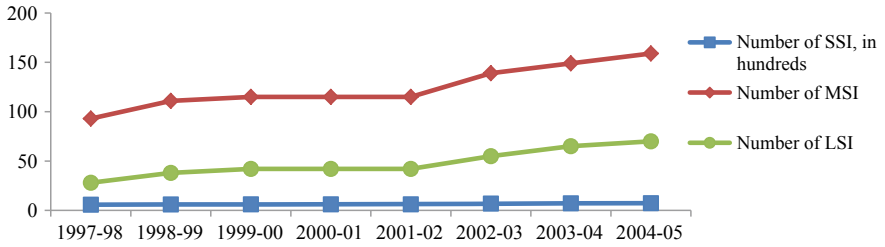

Fig. 1 Pattern of industrial growth in Puducherry (http://dste.puducherry.gov.in/industries%20details%20in%20puducherry.htm)

Table 2 Industrial estates in Puducherry

	Name of the estate	Area (acres)	Number of units/ plots
1	Thattanchavady	51	110
2	Mettupalayam	167	257
3	Sedarapet	62	83
4	Kattukuppam	16	27
5	Kirumampakkam	25	19
6	Thirubuvanai	50	123
7	Pillaichavady	13	23

Source Department of Industries and Commerce, GoP

(6) The Thirubuvanai industrial estate is exclusive for electronic industries. It is spread over 50 acres and consists of 123 sheds.

The location of these industrial estates is shown in Fig. 2.

Small-scale industries constitute 87% of all the Puducherry industries. The types of small-, medium- and large-scale industries in Puducherry are given in Table 3. Chemical and chemical product industries form the largest constituent, 20%, followed by leather, rubber and plastic, and metal products industries, 11% each. Amongst the LSI also, chemical and chemical products industries make up the bulk at 31%, followed by machinery and parts, and leather rubber and plastic, at 14% each.

The proportions of LSI and MSI amongst different types of industries are shown in Fig. 3.

2.2 *Pollution Potential of the Industries*

Based on the Prevention and Control of Pollution (Uniform Consent Procedure) Rule, 1999, industries in Pondicherry have been classified into three categories (http://dste.puducherry.gov.in/consentmechanismppcc.htm):

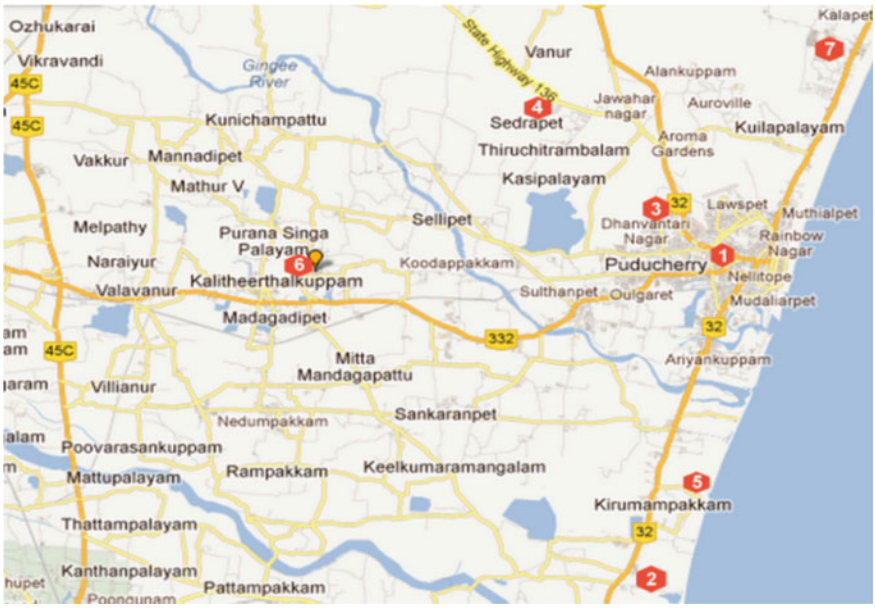

Fig. 2 Location of industrial estates

Table 3 Types of industries in Puducherry

Type	LSI	MSI	SSI	Micro	Total
Food products	6	13	920	34	973
Cotton and wool	7	10	883	285	1185
Wood products	0	0	478	20	498
Paper and printing	4	7	452	40	503
Leather, rubber and plastics	11	43	838	95	987
Chemical and chemical products	24	34	1635	62	1755
Non-metalic mineral products	8	5	314	22	349
Metal products	3	22	903	41	969
Machinery and parts	11	41	658	30	740
Miscellaneous	0	0	239	183	422
Personal services and hotel project	3	15	216	80	314
Repairing and services	0	0	256	15	271
Total	77	190	7792	907	8966

Red—highly polluting
Orange—moderately polluting
Green—lesser polluting

As can be seen in Fig. 1, there has been a marked and steady growth in the number of industries, with acceleration from the year 2000 onwards. The Union

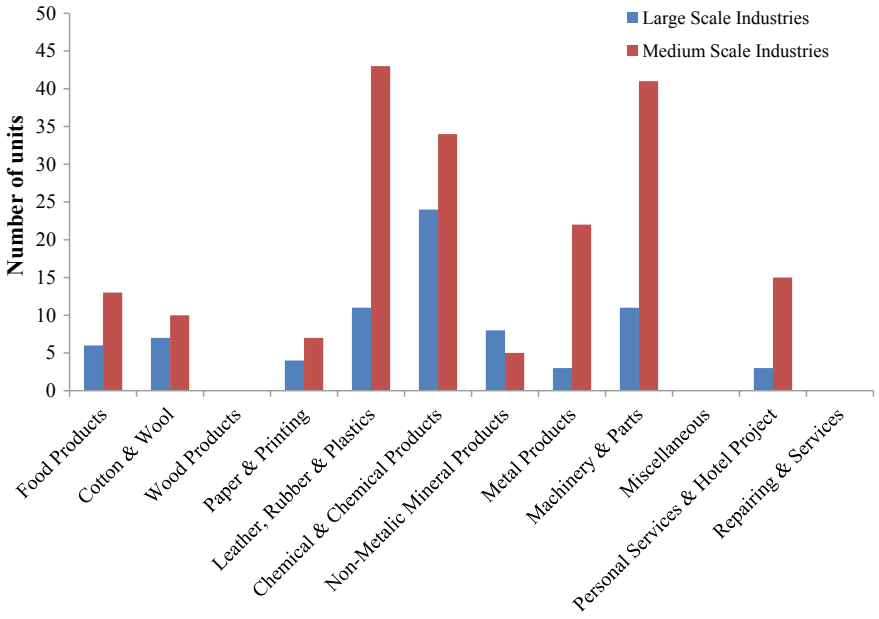

Fig. 3 Proportion of different types of large-scale and medium-scale industries in Puducherry

Territory now has 77 large-, 190 medium-, 7792 small-scale and 907 micro-scale units, totalling to 8966 industries in an area of 495 km^2. As stated earlier, majority of the industries are located in Puducherry and are concentrated in the five industrial estates—Sedarpet (16%), Mettupalayam (50%), Kattukuppam (5%), Thattanchavadi (21%) and Kirumampakkam (4%). These estates happen to lie close to residential localities. Hence, the pollution emanating from the estates affects the quality of life of the people residing close to the industries. Examples of this from Mettupalayam and Sedarapet estates are given below.

Mettupalayam is the biggest of the industrial estates of Puducherry. It houses medium- and small-scale industries which cover production of leather, electrical goods, chemicals, food, processed rubber and plastic. But it does not have effluent treatment facilities to cover its industries. As a result, the steam of untreated effluents emanating from this estate is let off into the sewage stream coming from the nearby residential areas. This causes the effluents to be carried along with sewage into open lands and residential areas during rains. It seriously affects the groundwater in the region. The industrial wastes of the factories are also dumped on open land (Abbasi and Vinithan 1997a).

In the Sedarapet industrial estate, also, proper waste treatment measures have not been put in place. Consequently, the effluents flow under gravity to low-lying areas and ultimately contaminate the ponds in the area. Since water from these ponds is used for agriculture by adjacent villages, this causes spread of pollution and serious contamination of the farm produce (Abbasi and Abbasi 2018; 2019). Flora and

fauna are adversely affected. Kalapet and Kirumambakkam are other areas beset with industrial pollution. Air pollution from several of these industrial areas is also becoming a cause of rising concern (Vinithan and Abbasi 1997b).

3 Materials and Method

3.1 General

The assessment of air pollution generated by those industries which have the potential to cause air pollution arising from their stack emissions was carried out by conducting sampling and analysis. Stack samplers and ambient air quality samplers of Vayubodhan make were employed. The sampling and analysis of all variables were done as per standard methods (APHA 1977; Abbasi 1998; Abbasi and Vinithan 1997b).

3.2 Ambient Air Quality Monitoring

The sampling sites were located downwind industrial estates. The concerned industrial estate, associated residential areas and the approximate downwind direction of the sampling sites are shown in Table 4.

The topographical location and meteorology of the sampling sites are given in Table 5.

4 Results and Discussion

4.1 Stack Emission

The quality of air coming through the stacks is presented in Table 6.

4.2 Ambiant Air Quality Monitoring to See the Effect of Different Industrial Estates

4.2.1 Thattanchavady

The land-use pattern of the study area and the location of the sampling station are shown in Fig. 4.

Table 4 Sampling locations and their downwind distance from industrial estates

Location number	Name of the industrial estate	Commune	Residential area/ institution downwind	Shortest downwind distance of sampling location from the industrial estate boundary[a] (m)
1	Thattanchavady industrial estate	Oulgaret municipality	Bharathi street	75
2	Kattukuppam Rural industrial estate	Bahour	Amman coil street	205
3	Mettupalayam PIPDIC industrial estate	Oulgaret municipality	Gandhi thirunallur street	163
4	Sedarapet PIPDIC industrial estate	Villianur	Pradap street	81
5	Kirumampakkam PIPDIC industrial estate	Bahour	PIPDIC street	107
6	Thirubuvanai Electronic park	Mannadipet	Mariamman coil street	131
7	Pillaichavady Software technological park	Oulgaret municipality	CPEE, Pondicherry University	502

[a]The distance was measured with the help of Wikimapia

The results of the ambient air quality monitoring in the Thattanchavady industrial estate (Table 7) along with the ambient air quality standards for residential and 'sensitive' locations, as set by Central Pollution Control Board (CPCB), India, are presented in Table 7. Schools and hospitals come under the 'sensitive' category and such units are present in the study area. The results reveal that the concentrations of pollutant NO_x, SO_x and SPM are within the limits set for permissible air quality for residential area as set by CPCB but exceed the limits for 'sensitive' locations (Fig. 5).

4.2.2 Kattukuppam

The land-use pattern at Kattukuppam and the location of the sampling station are shown in Fig. 6. Kattukuppam industrial estate is close to the sea. Due to this, the sea-to-land wind usually carries the pollutants not only to the residential areas situated close to, but also distant from, but also the industrial area.

The ambient air quality (Table 8, Fig. 7) reveals that even as the concentrations of NO_x and SO_x are within the permissible limits of CPCB for residential areas, the

Table 5 The topographical location and meteorology of the sampling sites

	Name of industrial estate	Topographical location of sampling point	Maximum and minimum temperature (° C)	Maximum and minimum wind velocity for the month of January (km/h)	Sky/ stability condition
1	Thattanchavady industrial estate	11° 56′ 41.7527″ N 79° 48′ 11.8732″ E	29°–19°	5–20	Clear/ unstable
2	Kattukuppam Rural industrial estate	11.804656N 79.7795E	30°–21°	5–20	Clear/ unstable
3	Mettupalayam PIPDIC industrial estate	11° 56′ 51.3697″ N 79° 47′ 2.756″E	30°–23°	5–20	Clear/ unstable
4	Sedarapet PIPDIC industrial estate	11° 59′ 49.9916″ N 79° 45′ 26.042″ E	29°–19°	5–20	Clear/ unstable
5	Kirumampakkam PIPDIC industrial estate	11° 8178N 79° 7939E	30°–21°	5–20	Clear/ unstable
6	Thirubuvanai Electronic park	11° 55′ 9″N 79° 38′ 53″E	31°–22°	5–20	Clear/ unstable
7	Pillaichavady Software technology park	12° 0′ 56″N 79° 51′ 13″E	30°–22°	5–20	Clear/ unstable

Table 6 Results of the stack emission studies

	Industry	Flue gas flow rate (NM^3/h)	Particulate matter (mg/m^3)	SO_2 (mg/m^3)	NO_x (mg/m^3)
1	AML Steel	20,342	85	2.1	*
2	Pushpit Steel	23,157	79	1.9	*
3	Kavery Alloys	19,417	113	4.7	*
4	Varadaha Steels	28,153	140	7.1	*
5	Athiyappa Chemicals	5346	63	6.7	*
6	Karthik Chemicals	*	143	0.8	*
7	Megna Chemicals	7483	65	4.5	2.7
9	EID Parrys	51,850	39	0.0	0.6
10	Hindustan Lever	150,000	161	0.2	0.5
11	Chemfab Alkalis	*	45	5.1	9

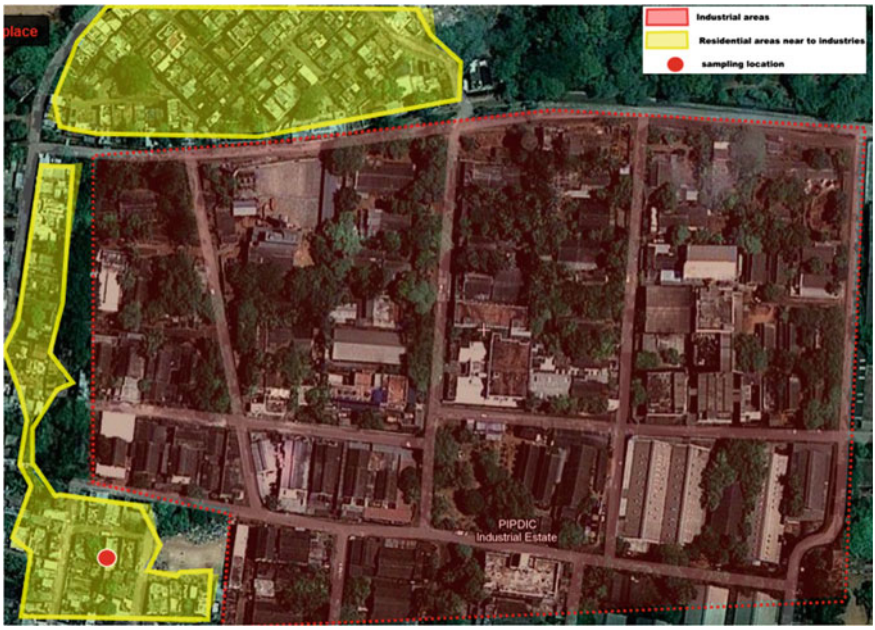

Fig. 4 Arial view of the Thattanchavady industrial estate (red shade), residential area (yellow shade) and the sampling location

Table 7 Ambient air quality at residential area near Thattanchavady industrial estate

Parameter	Observed value (µg/m^3)	CPCB standards, µg/m^3, for	
		Sensitive areas	Residential areas
SO_x	57.6	30	80
NO_x	42.8	30	80
SPM	105.8	100	200

SPM concentration is much higher from the maximum permissible level. This may be due to the emission of particulate matter from the rice mills. Further, all parameters exceed the limits for sensitive areas.

4.2.3 Mettupalayam

An aerial view of the sampling location at the Mettupalayam industrial estate is provided in Fig. 8. The estate has a densely populated residential area located downwind while it has barren land along two sides and commercial establishments on the other.

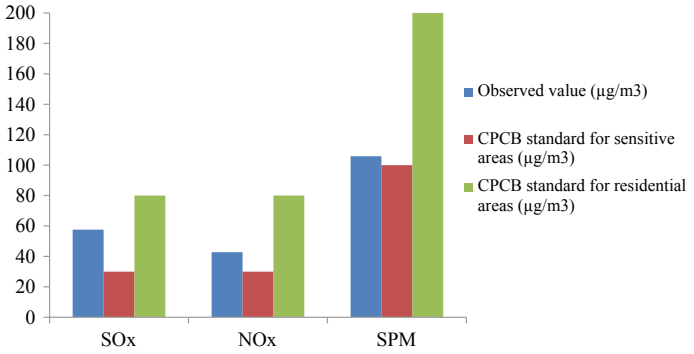

Fig. 5 Ambient air quality downwind the Thattanchavady industrial estate SOx

The sampling location at Gandhi Thirunallur Street was selected at 163 m downwind direction from the industrial estate boundary.

The ambient air quality (Table 9) shows that the concentrations of SO_x, NO_x and SPM are within the permissible limits prescribed by CPCB for residential areas but exceed the limits for sensitive areas. Also, all parameters are close to the limit for residential areas also (Fig. 9).

Table 8 Ambient air quality at residential area of Kattukuppam industrial estate

Parameter	Observed value (µg/m^3)	CPCB standards, µg/m^3, for	
		Sensitive areas	Residential areas
SO_x	49.8	30	80
NO_x	55.7	30	80
SPM	366.3	100	200

4.2.4 Sedarapet

The sampling location was set at Pradap Colony, about 81 m downwind from the industrial estate boundary. As seen in Fig. 10, the industrial estate has residential buildings close to one of its sides, which the other three sides have a mix of residential and commercial establishments.

The levels of all the assessed parameters (NO_x, SO_x and SPM) were within the prescribed limits of CPCB, for residential areas but the concentrations of NO_x and SPM were near to the upper limit of the CPCB standard, and so can exceed anytime (Table 10). All levels were well above permissible limits for sensitive areas.

The concentration of the pollutants in the context of the CPCB standards is shown in Fig. 11.

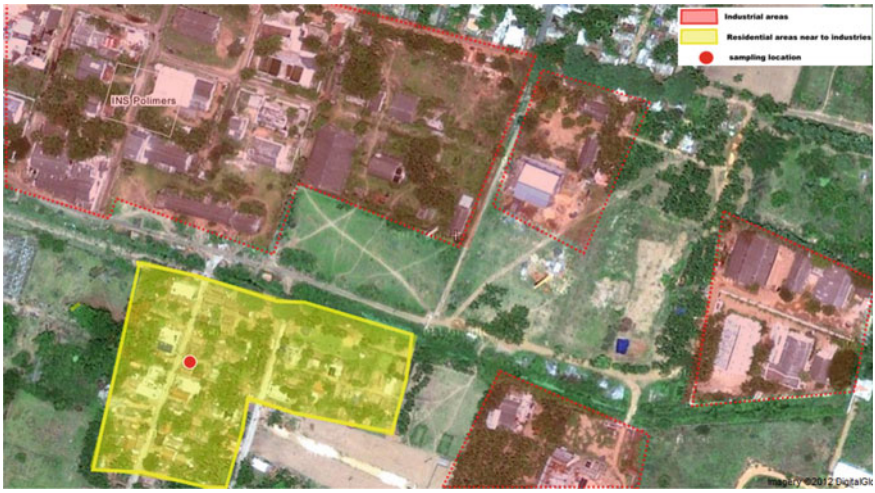

Fig. 6 Arial view of the Kattukuppam industrial estate (red shade), residential area (yellow shade) and the sampling location (red spot)

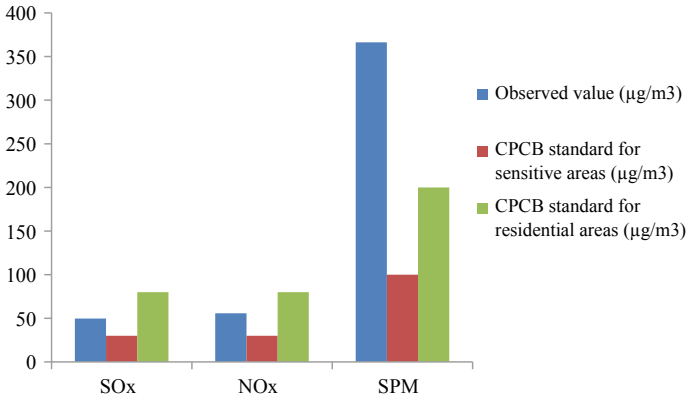

Fig. 7 Ambient air quality at residential area of Kattukuppam industrial estate in relation to the CPCB standard

Table 9 Ambient air quality at residential area of Mettupalayam industrial estate

Parameter	Observed value (µg/m^3)	CPCB standards, µg/m^3, for	
		Sensitive areas	Residential areas
SO_x	65.37	30	80
NO_x	65.54	30	80
SPM	173.61	100	200

Fig. 8 Ariel view of Mettupalayam industrial estate (red shade), residential area (yellow shade) and the sampling location (red spot)

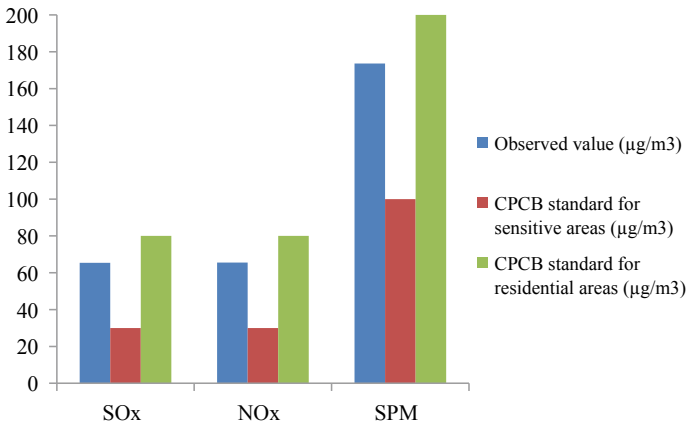

Fig. 9 Ambient air quality at the residential area downwind Mettupalayam industrial estate

Table 10 Ambient air quality at residential area of Sedarapet industrial estate

Parameter	Observed value (µg/m^3)	CPCB standards, µg/m^3, for	
		Sensitive areas	Residential areas
SO_x	41.94	30	80
NO_x	57.16	30	80
SPM	195.41	100	200

Fig. 10 The Sedarapet industrial estate (red shade), residential area (yellow shade) and the sampling location (red spot)

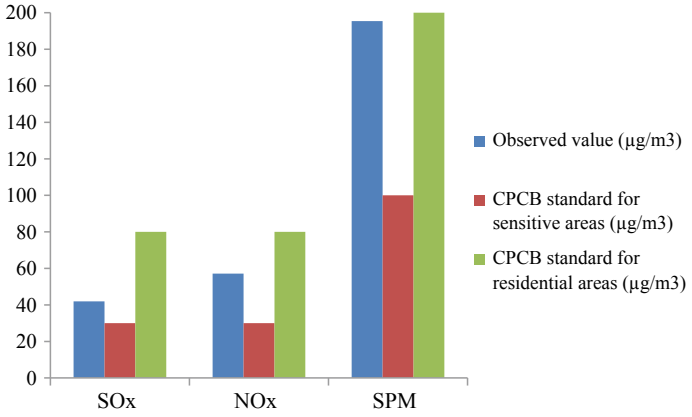

Fig. 11 Ambient air quality at the residential area downwind Sedarapet industrial estate in the context of the CPCB standards

4.2.5 Kirumampakkam

The ambient air quality monitoring near Kirumampakkam industrial estate (Fig. 12) revealed that only NO_x is under permissible limits for residential areas while SO_x and SPM exceed the limits (Table 11). All parameters exceeded limits for sensitive locations by over 200%. In the context of the CPCB norms, the pattern is as shown in Fig. 13.

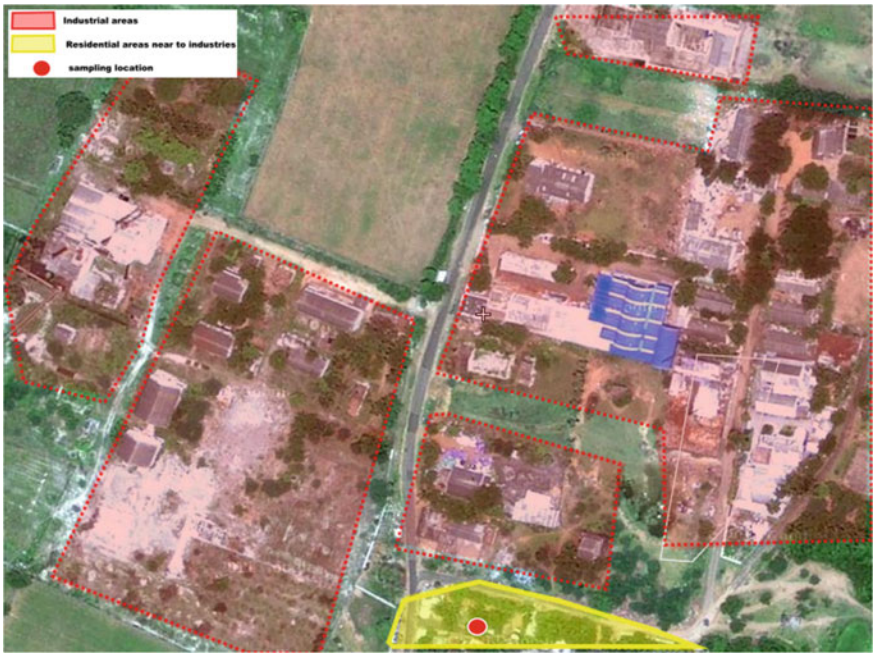

Fig. 12 The Kirumampakkam industrial estate (red shade), residential area (yellow shade) and the sampling point (red spot)

Table 11 Ambient air quality at residential area of Kirumampakkam industrial estate

Parameter	Observed value (μg/m^3)	CPCB standards, μg/m^3, for	
		Sensitive areas	Residential areas
SO_x	84.25	30	80
NO_x	61.28	30	80
SPM	218.78	100	200

4.2.6 Thirubuvanai

The sampling location was set at Mariamman Coil Street which is about 131 metres downwind of the Thirubuvanai industrial estate. An aerial view of the sampling location near the Thirubuvanai industrial estate is given in Fig. 14.

Given the essentially non-polluting nature of the processes used at Thirubuvanai, the ambient air quality (Table 12) expectedly had all pollutants (NO_x, SO_x and SPM) within the permissible limits of CPCB for not only residential but sensitive areas as well. The air quality results in the context of CPCB standards are shown in Fig. 15.

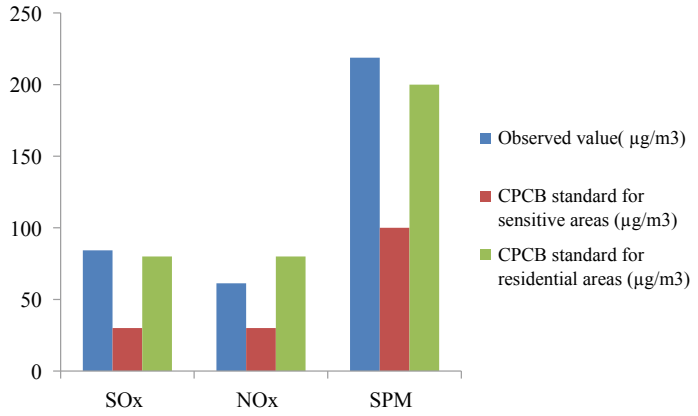

Fig. 13 Ambient air quality at residential area of Kirumampakkam industrial estate in relation to the CPCB standard

Fig. 14 The Thirubuvanai industrial estate (red shade), residential area (yellow shade) and the sampling location (red spot)

Table 12 Ambient air quality at Mariamman coil residential area of Thirubuvanai

Parameter	Observed value (µg/m^3)	CPCB standards, µg/m^3, for	
		Sensitive areas	Residential areas
SO_x	8.68	30	80
NO_x	16.31	30	80
SPM	93.19	100	200

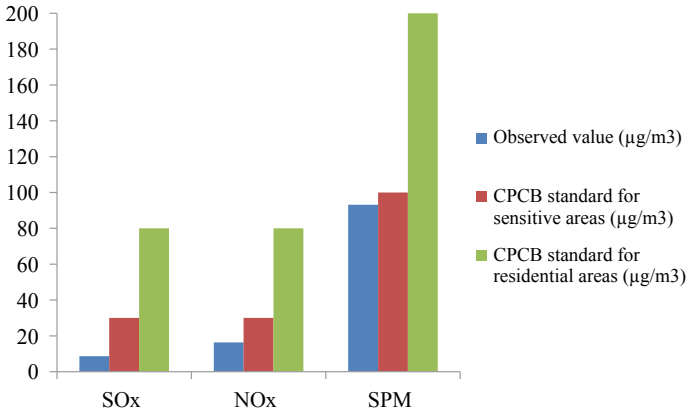

Fig. 15 Ambient air quality at Mariamman kovil residential area of Thirubuvanai

4.2.7 Pillaichavady

The sampling station was located about 505 m downwind the Pillaichavady estate, at the centre for pollution control and environmental engineering (CPEE), Pondicherry University.

The results of the ambient air monitoring (Table 13) show that similar to the case with Thirubuvanai, the SPM, NO_x and SO_x concentrations were all within the CPCB limits for not only residential areas but sensitive areas as well; SPM being on the threshold (Fig. 16).

4.3 Comparison with Past Studies

Abbasi and Vinithan (1997a, b) had carried out very extensive year-round ambient air quality monitoring of Pillaiyarkuppam and Kirumampakkam industrial estates during the late 1990s. They had found the air quality to be bad most of the time. Subsequently, pollution control measures enforced by the Government of Puducherry appear to have had positive effect as the pollutant levels found by Dr. N. Ramesh of the Department of Science Technology, and Environment,

Table 13 Ambient air quality at Pillaichavady

Parameter	Observed value (µg/m^3)	CPCB standards, µg/m^3, for	
		Sensitive areas	Residential areas
SO_x	19.2	30	80
NO_x	15.9	30	80
SPM	100.1	100	200

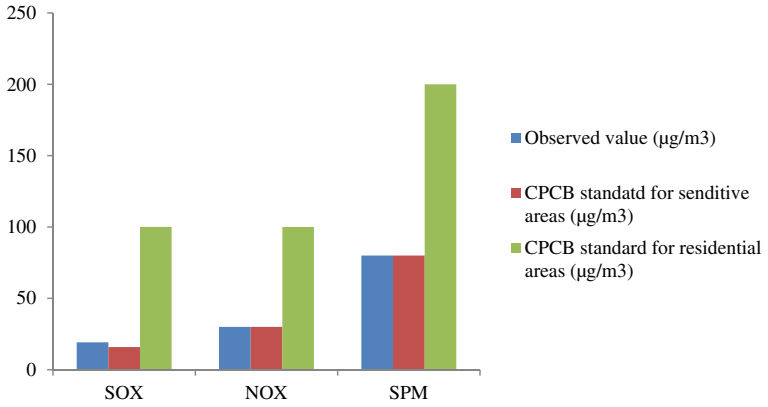

Fig. 16 Ambient air quality downwind Pillaichavady industrial estate

Government of Puducherry, and presented in his 2005 (Ramesh 2019), report were lower than found by Abbasi and Vinithan (1997a, b). But, as can be seen in Tables 14, 15 and 16, which present the gist of the present findings in comparison with the previous report, the air quality has, in general, deteriorated again. In most cases, the pollutant levels are higher than permissible for sensitive areas. Even with respect to residential areas, the levels are often seen to be close to the cut-off limit,

Table 14 The concentrations of NO_x downwind different industrial estates found by us as compared to the levels reported by Dr. N. Ramesh in 2005

Location	Concentration, µg/m^3 found in	
	Present study	The 2005 study
Thattanchavady	42.8	–
Kattukuppam	55.7	–
Mettupalayam	65.5	38.3
Sedarapet	57.2	17.9
Kirumampakkam	61.3	18.6
Thirubuvanai	16.3	13.9
Pillaichavady	15.9	–

Table 15 The concentrations of SO_x downwind different industrial estates found by us as compared to the levels reported by Dr. N. Ramesh in 2005

Location	Concentration, µg/m^3 found in	
	Present study	The 2005 study
Thattanchavady	57.6	–
Kattukuppam	49.8	–
Mettupalayam	65.4	29.4
Sedarapet	41.9	14.4
Kirumampakkam	84.3	8.6
Thirubuvanai	8.7	6.4
Pillaichavady	19.2	–

Table 16 The concentrations of SPM downwind different industrial estates found by us as compared to the levels reported by Dr. N. Ramesh in 2005

Location	Concentration, μg/m^3 found in	
	Present study	The 2005 study
Thattanchavady	105.83	–
Kattukuppam	366.25	–
Mettupalayam	173.61	254.14
Sedarapet	195.41	151.41
Kirumampakkam	218.78	140.04
Thirubuvanai	93.19	143.26
Pillaichavady	100.13	–

when not exceeding the limit. Moreover, with exponential increase in the use of fossil fuels, emission of CO_2 and other global warming and ozone depleting gases has also risen to add to the pollution caused by SOx, NOx, and SPM (Khan and Abbasi 1998, 1999; Abbasi and Abbasi 2010, 2011, 2017).

5 Summary and Conclusion

Studies on the air quality downwind all seven major industrial estates of Puducherry, India, are presented. It is shown that in most cases, the pollutant levels exceed the limits prescribed for 'sensitive' locations (schools, hospitals) as set by India's Central Pollution Control Board (CPCB). Also, even as in several cases, the pollutant levels are present within the limits prescribed for residential areas, they are close to the limits and can begin to exceed if the air quality deteriorates a little more. A comparison with an earlier survey, reported in 2005, also shows that the air quality now, in general, is inferior to what it was in 2005.

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Solid Waste Problem Due to Packaging Material and Its Management Options

Amit Kumar Singh, Somya Gandhi, Nihal Anwar Siddiqui, Prasenjit Mondal, Abhishek Nandan and Ehkamul Haq

Abstract A conceptual study has been performed on significance of packaging material in solid waste generation and its mitigation method. The theme of the paper says that after substantial progress in Iron Age and Bronze Age and civilization has reached the age of garbage. As we know exponential growth of garbage generates rates cannot be matched by the growth rates of municipal infrastructures. On another account "Study of all types of garbage (Bin drowned in garbage, drains choked with solid waste, public places littered with garbage) and ever lump of industrial garbage characterize the era of garbage". Talking about the development of other advanced countries the figure ranges depending upon the population. As the impact of solid waste/garbage transmit different disease contributing waste stagnation in choked up drains, evacuating damages also include pollution one should take appropriate measures to cut down the growth of MSW (Municipal Solid Waste) and following different norms and applying on large scale and limit the use.

Keywords Solid waste management · Municipal solid waste · Packaging material

1 Introduction

While assessment about garbage, the ruling ecological concern in the progressing past have been material utilize and reusing possible results. Packaging is regularly still thought to be just as a weight on the earth as irritating dissipation, which ample our garbage and landfills. We should look previously redirecting and somewhat false suppositions and remind ourselves over the central endeavor in responsibility of bundling material in solid waste age (Grönman et al. 2013). The need for bundling and advancement of bundling was brought about by the way that the creation and utilization occurred at independent places and times, and the delivered

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merchandise must be circulated and transported. It is estimated that by 2025, two-third of the population will live in city. This indicates that the additional people residing in cities rather occupied the whole planet in the 1980s (Pongrácz 2007).

Packaging has absolute and adverse effects on the condition. The adverse effects incorporate assets apply and the impacts of bundling linked squanders and emanations. The absolute effect is that bundling buyer merchandise encourages their dispersion, and hence makes it conceivable to acquire products generally not open. Ecologically cognizant bundling empowers fulfilling human needs in a compelling manner (Pongrácz 2007). Discussing the occupants abiding in US currently creates an expected 180 million tons of MSW every year, and per capita MSW generation is ascending in an event by 0.5% every annum. Secondly, Expansion wellbeing, ecological, and another untie concerns related among parts of included strong waste administration land filling, burning, and reusing have guaranteed that the per-ton expenses of MSW transfer choices are additionally expanding (Rousakis and Weintraub 1994).

Albeit present day bundling enables items to stay unblemished and pure for any longer than it was conceivable even in the ongoing past, bundling additionally speaks to the single biggest segment of the MSW stream. Currently, 90% of all bundling is disposed of, as a rule quickly after purchase (Rousakis and Weintraub 1994). As packaging administration gives a strong case of inconspicuous issues of ecological administration, and on the grounds that it mirrors the association between a standout among the most ordinary of human exercises (delivering MSW) and the natural outcomes of that activity, the administration of item packaging is a productive concentration for a talk of the natural effects, monetary substances, and human measurement of solid waste (Fig. 1).

This piece of writing talks about the test of MSW the board and path back leaving an awful effect, so to stay away from one should take legitimate measures. The development of a nation can be measured in terms of the per capita generation of garbage. The figure ranges from 0.5 kg per head per day in the developing countries to 2.5 kg in advanced countries. Seeing the figure range of India, will soon catch up in per capita garbage generation if not pollution control. Industries assume the significant fault for waste pills. Selection of assets and assembling forms

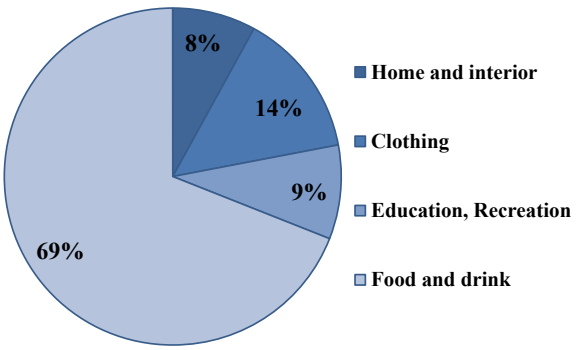

Fig. 1 Packaging use by type of goods

is regularly obliged by the benefit thought for the industrialist, while strong waste size with its natural expense is only here and there a parameter. Development flotsam and jetsam and continuous pulverization of structures to be supplanted by more industrial beneficial ones likewise indicate the civil strong squanders.

A short exchange of summed-up life cycle will delineate this bookkeeping insufficiency. This commonplace item span starts with the extraction of the characteristics assets utilized as crude materials (Rousakis and Weintraub 1994). The crude resources might be the premise of the last time (Instance, Trees are a crude resource for cardboard boxes), or they might be important conclusions to the generation procedure (e.g., coal is a crude substance expected to give vitality to delivering the steel utilized in metal holders).

2 Product's Life cycle

The crude material should be developed into an express which could later be framed into the item (Case in point: Wood mash is changed into sheet cardboard). This stage is eluded for material assembling. Next, the essential resources are framed into the completed items (e.g., pressing crate is produced using slab cardboard). The item is disseminated to the last consumer (Rousakis and Weintraub 1994).

At this phase, customer utilization of the item decreases its value. Eventually, the item has so little an incentive to the buyer that it is less expensive to dispose of it than to hold it. The last phase of existence cycle is squander management.

In this step, the item is disposed of or discarded (e.g., through cremation or land filling) otherwise reused. In market economy, the expense of creating a thing decides its cost. Every one of the initial four phases of an item's life cycle can correct expense of land, work, capital, and vitality utilization.

3 System Exterior Indication (Solid Waste Management)

The shopper value neglects to disguise somewhere around three classes of expense related with item life cycle.

The first indicator occurs because ecological regulation does not diminish every instance of environmental degradation. Contamination, notwithstanding when beneath the edge of control guidelines, debases the personal satisfaction of individuals dwelling adjacent the dirtied territory.

The second order of outside cost related to item's life cycle is the arrangement of financial externalities of the waste administration framework.

In general, the products are disposed of through one of the listed method:

- Land filling: Land filling is the most prevalent process of MSW disposal. It releases methane gas, a by-product of the disintegration of organic material (Rousakis and Weintraub 1994; Christensen et al. 1994).
- Incineration: Incineration decreases the amount of MSW that must be landfilled, as incineration has become an increasingly popular waste disposal method. It may also include dangerous heavy metals (Rousakis and Weintraub 1994; Pichat 1993).
- Recycled: It is very familiar term nowadays, on referring the technique for recovering materials that generally would be discarded and utilizing those materials as a hotspot for the manufacture of new items (Rousakis and Weintraub 1994).

There are ecological externalities of the waste administration system. The procedure of waste administration itself has related expenses because of environmental effect, regular asset exhaustion, and consequences for human wellbeing and welfare (Rousakis and Weintraub 1994).

4 Function of Packaging

According to Geiger, packaging is listed for the following function (Pongrácz 2007):

- Safety plays a vital role in packaging as it helps in protection.
- Circulation is the step which demarks about the distribution.
- Domestic and household.
- Intermediate act as intermediary between two. It acts as a role in between.
- Commercial/Advertisement
- Image-Component
- Value-Forming Function.

5 Consumption of Packaging Material

Ongoing Assessment, The normal family unit purchases merchandise pressed in 190 kg of bundling resulting in solid waste generation on using 7GJ energy every year. Bundling is fundamentally 9% of the stuffed item's general weight, are paper, plastics or composites.

The efficiency lies in the packaging materials used only 1–10% of the packed material. 11–20%, the comparatively valuable packages consist of plastics and aluminium packages. 21–40%, the fewer valuable packages.

Table 1 Indicates the details of availability of packaging raw material

S. No.	Binding material	Unprocessed material	Relic resource	Renewable resource	In general resources
1	Paper/ Board	Wood, natural fibres	Nil	All	Very abundant
		Auxiliary chemical	All	Nil	–
2	Metals				
a	Iron	Iron ore, scrap ore	About half	About half[a]	Limited
b	Tin chromium	Tin and chrome ores	Nearly all	Insignificant[a]	Severely limited
c	Aluminium	Aluminium ore scrap	Majority (but plentiful)	Minority[a] but growing	Moderately limited
d	Glass	Sand, soda	Majority (but abundant)	Minority[a] but growing	Abundant
e	Plastic	Crude oil (now)	Almost all	Little	Moderately limited
		Biomass (wood, sugar)	Nil	All	Very abundant
		Auxiliary materials, example—N, Cl, S, O	Some, but abundant	Some	Very small factor, no limitation

[a]Recycling

From 40% up, the unproductive packages take in glass and little-specific-mass-goods, such as deodorant portioned in small as well as light quantity (Pongrácz 2007) (Table 1).

6 Indicators for Quantification of the Impacts and Challenges

Suitable indicators were recognized in order to consider the environmental implication of wrapping plastic recycling activities. It is discovered that a wide range of reusing exercises are related to a lot of fossil vitality utilization as diesel fuel, framework power, and warm vitality. This adds to ozone harming substance (GHG) emanations just as fossil asset consumption. Conversely, the materials recouped because of reusing empower to increase natural advantages from the stayed away from virgin generation of such materials and related GHG discharges. So as to measure the, generally speaking, ecological ramifications of reusing exercises, net GHG outflows potential and net petroleum product utilization potential were in this manner distinguished as the most important natural markers.

So as to gauge the atmosphere sway, all the GHGs were considered, for example, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Menikpura et al.).

According to a recent study, the adverse environmental impacts of the initial production stages of packaging are more severe than the impact of packaging disposal.

Packaging production life cycle poses utmost environmental intimidation mostly at two stages:

- The raw material extraction stage
- The manufacturing stage.

The natural effects of packaging creation are gathered in the beginning periods of item life cycle, material accumulation for reusing has its very own expense. Recycling involves technology that pollutes and consumes energy (Pongrácz 2007).

7 Role of Packaging in Pollution

7.1 Litter

Litter establishes just a minor piece of complete squanders, yet it is of far-reaching concern. It is an unsavory sight, comprises a peril to numerous creatures, and is a conceivable wellbeing danger to people. Litter is regularly compared with bundling. Bundling materials (glass and plastic containers, jars, paper mugs, paper, and plastic wrappings) are surely the principle constituents of litter. Barring informal dumps, the extent of bundling is generally a quarter to half by weight, but since of the low mass thickness, bundling is frequently the dominant part by volume. The impact of plastics litter on the marine condition is additionally of specific concern. It begins from both land and ocean sources, and the trash is of three kinds: angling gear, for example, nylon lines, floats, and nets; bundling groups, lashes, and manufactured ropes; and general litter, for example, packs, jugs, and plastic sheeting (Pongrácz 2007).

7.2 Water Pollution

Contamination emerges from wastewater release of some bundling material assembling or related exercises. One of the essential water-dirtying exercises is paper creation, discharging organic oxygen request (BOD), substance oxygen request (COD), unpredictable suspended solids (VSS), and absolute suspended solids (TSS). Moreover, the assembling of various materials utilized in bundling, for example, cements, coatings, and inks are a wellspring of hydrocarbon contamination. The release of cooling water from power age thusly causes warm

contamination. Subjects of concern are additionally incidental outflows amid generation or preparing of bundling materials, particularly the seepage of putting out fires exercises amid unintentional flames (Pongrácz 2007).

7.3 Air Pollution

The primary wellspring of air contamination is the bundling material assembling process. A portion of the discharges, for example, vinyl chloride, CFC, and hexane can emerge from incidental flames or waste-cremation exercises. Direct bundling related outflows emerge from landfill locales, as an outcome of deterioration of wood and paper, discharging CO_2, and methane (Pongrácz 2007).

7.4 Solid Wastes

Bundling related strong squanders emerge as of now at extraction and preparing of crude materials. These squanders frequently end up in landfill destinations. Further pre buyer and post purchaser squanders must be recognized. The overall population is thinking about just the post purchaser strong squanders, despite the fact that that is just a piece of all bundling related squanders. The greater part of the pre purchaser bundling misuse of pack-maturing material, or bundle make is, be that as it may, reused in house. The nonrecyclable piece of pre shopper bundling squanders is arranged. A circuitous bundling related strong waste source is slag for delivering the power that was devoured by bundling action (Pongrácz 2007).

8 Framework for the Assessment

Measuring the natural effects, the Life Cycle Assessment (LCA) system was structured considering every one of the periods of the life cycle, specifically; accumulation of source isolated plastic, transportation to the baling office, baling, long separation transportation, and generation of plastic granules through the reusing procedure. Moreover, framework development was utilized to represent the impacts of material recuperation. Therefore, credits were given to record to the maintained a strategic distance from virgin generation of materials which had been recouped because of reusing (Menikpura et al.; Berglund and Börjesson 2006).

Life cycle appraisal is a technique for examination that illuminates the different instruments, which joins the quality of customary monetary model with present-day thoughts of full cost bookkeeping. LCA has its underlying foundations as far back as the mid-1960s. That time, asset and environmental profile investigations (REPA) were done, with the objective to foresee how changes in populace would influence

the world's absolute mineral and vitality assets. The investigation demonstrated that from a natural perspective, it is beneficial to utilize refill bundles contrasted with ace bundles (Rousakis and Weintraub 1994).

9 Past To Present Scenario (Literature Review)

At the point when mankind started to store sustenance or different things for the following day utilize, bundling in its crude shape rose. Earlier, leaves and brambles were utilized. By utilizing top of the line lightweight, tough, and less expensive material, the present pressing industry has advanced exponentially. The business is persistently scanning for bundling arrangements that have better quality, are less demanding to deal with, are clean, are lightweight, and, above all, are maintainable. The significant bundling materials are plastic, polystyrene, cardboard, and so on. These materials are low in cost, light in weight, and sturdy. The world's developing populace has prompted extensive measure of bundling waste, which additionally adds to the issue of its transfer and other natural issues.

High-vitality utilization (encapsulated) and ecological issues are related to bundling materials, which underscores the need to respect the best possible utilization of bundling materials from a situation perspective.

To dissect and evaluate the natural effects related to different bundling materials, a powerful philosophy is required. Life cycle appraisal (LCA) is a successful device that can be used to assess different natural effects of bundling materials (Berglund and Börjesson 2006).

This section talks about the natural effects related to bundling materials and the utilization of LCA to assess these effects so they can be decreased extensively.

On the other hand, one must start to consider activities that will decrease the negative natural effects delivered by the present bundling frameworks.

Spectators are, for instance, starting as far as possible to the accessibility of crude materials expected to make some bundling materials. Second is the quick exhaustion of the vitality sources required for the generation of packaging.

Notwithstanding the characteristic asset issue, it is vital to perceive the potential decrease in contamination that would come about because of reusing and reusing holders. Another framework is required in which utilization is diminished, and materials are reused and reused.

10 Conclusion

The concern about the impact of packaging on the earth gets from their moderately high rate in the family unit squander. This, nonetheless, demonstrates preferably the dimension of utilization over inordinate bundling. Bundles are made to convey the item to the buyer; consequently, they can't be seen independently, either from the

item or from utilization. Expanding measures of bundles in the waste stream just demonstrates expanding utilization. Bundling is emphatically impacted by social wants, political inclinations, and administrative and practical impacts. What's more, bundling isn't just a push act. A bundle yet a framework and the package itself can't be isolated from its substance. Thus, an ecological appraisal can't mean just eco-sensible effect investigation; neither can the judgment of natural amicability be founded exclusively on the sort of bundling material. Plastics have maybe the most negative picture, yet of being lightweight and solid, in this way giving high insurance esteem with low natural effect. It is particularly valid for composites, which join a few materials for better insurance while utilizing insignificant measure of the individual materials.

The utilization and reuse of glass bundling is a state-explicit inquiry. The crude material is in ample supply and there are no specialized boundaries to its reuse or racy-stick. On the off chance that there is a well-working arrangement of glass reuse, transforming it might include noteworthy consumptions, just as ecological effects.

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Atmospheric Aerosols (PM_{10} and $PM_{2.5}$) and their Influence on Air Quality in Visakhapatnam City, Andhra Pradesh, India

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Abstract The ambient air quality of Visakhapatnam with respect to particulates showed remarkable variation between industrial and residential areas. Both PM_{10} and $PM_{2.5}$ reported moderate level in industrial area as per the AQI and Exceedance Factor. From the results of both $PM_{2.5}$ and $PM_{10,}$ it is observed that PM has recorded above permissible limits in commercial and industrial areas whereas, in residential area, both PMs were within the limits of NAAQ standard. In Industrial area, Zn is found to be dominated with 27% of the total elements analyzed followed by aluminum, respectively. When metals exist beyond the permissible limits, they are potential to produce Reactive Oxygen Species (ROS) in humans and cause various health problems. From the study, it is concluded that PM has emerged as the most critical pollutant. The existence of $PM_{2.5}$ above the permissible limit in industrial and commercial areas is a serious concern and immediate steps are to be initiated to identify the sources and the extent of their taking part in ambient air pollution.

Keywords Aerosols · Air pollution · Air quality · Particulate matter

1 Introduction

The population growth along with industrialization has resulted in the entry of pollutants into the atmosphere. In India, the total population is expected to rise to 1.6 billion by 2050, as rural people are migrating to urban areas in search of lively-hood. This will results in significant pressure on infrastructure and natural environment, specifically air environment. The affecting air quality in India is

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mainly because of particulate matter emitting from mobile sources (vehicles) and industries along with solid waste burning, agricultural activities, wood dust, secondary aerosols, indoor air pollution, etc.

Urbanization and rise of population trends in cities have resulted in large number of vehicular populations contributing to gaseous pollutants such as SO_2, NO_x, CO, O_3, C_6H_6, and HC (Bhanarkar et al. 2005). According to Statistical yearbook (2016) of Ministry of Statistics and Programme Implementation (MOSPI), the registered total number of vehicles has increased from 54 million to 159 million in 2012. Among the category of vehicles, two-wheelers are dominant. The increase in number of vehicles is a serious concern because of pollutants being emitted at ground level.

The other major sector responsible for air emissions in ambient air is the industrial sector. Over the past ten years, major industries like I.T, textiles, thermal power, and electronics have shown impressive growth of 7.4%. Majority of these industries fall under "red category" as per the regulations of CPCB and having potential to cause environmental impacts.

2 Air Quality Trends in India

The increase in air pollution in cities, particularly Respirable Suspended Particulate Matter (RSPM) has caused severe economic loss to public health. It is estimated that RSPM in 50 cities has a population of more than 110 million which can cause a loss of Rs. 15,000 crores, equivalent to three billion US dollars (MOEf 2005).

The studies related to population growth and vehicular traffic in many cities in India, revealed that traffic is a chief source of air pollution and its retention in ambient air depends on several important parameters such as mixing, diffusion, dispersion of pollutants, etc. (Lakshmana Rao and Satish 2014).

In India, air pollution has emerged as one of the major public health hazards. Earlier studies reported that air pollution regularly reaches high levels in Indian cities, causing acute threat to the health of citizens within a short span and causes major health risks on long-term basis. The monitoring data showed that high levels of air pollution were recorded in most Indian cities. According to the report of WHO, 13 Indian cities out of 20 reported as most polluted cities of the world. The major pollutant responsible for health disorder is particulate matter (SPM, PM_{10}, and $PM_{2.5}$). The annual average of $PM_{2.5}$ among the polluted cities varied from 88 to 153 $\mu g/m^3$. Allahabad and Agra have reported least and whereas Raipur, Gwalior, Patna, Delhi reported more than 134 $\mu g/m^3$. The main reason for production of Particulate matter is industries and vehicles. To overcome this problem, identification of sources and implementation of corrective measures to reduce pollution levels and to protect human health hazards is the need of the hour.

According to the studies of Gurjar et al. (2016), there is a need to focus on controlling non-existing emissions such as burning of Municipal Solid Waste (MSW) and biomass in cities. According to them a decrease in the trends of SO_2

was observed in Delhi, Mumbai, and Kolkata, due to reduction of sulphur content in coal and diesel. Whereas an increase in the trend of NO_x was observed because, increasing number of vehicles in terms of SPM and PM_{10} have reported higher levels in all in the three cities with Delhi recording the highest ambient concentration of $PM_{10,}$ Whereas Mumbai and Kolkata reported fluctuation in trends of SPM.

The existing air quality scenario in India needs a comprehensive deed plan for improving the air quality. The deed plan should be realistic, technically feasible and economically viable to get the desirable results. Enhancement in technical, industrial and agricultural progress has improved the economy and at the same time, triggered deterioration of environmental quality due to lack of sustainable approach towards environmental protection. Ambient air in urban areas is a result of emissions from municipal services, fossil fuel consumption, and industrial operations causing serious health problems.

3 Sources of Ambient Air Pollution

Urban atmospheric pollution is the product of emissions from an array of sources, mainly stationary, industrial and domestic fossil fuel consumption, vehicle emissions by petrol and diesel (Brulfert et al. 2005; Parra et al. 2005). Sources of air pollutants in urban environment are classified into mobile (cars, buses, trucks, etc.); stationary (industries, power generators at commercial complexes); area (solid waste open burning, agriculture activities, etc.) and natural sources (windblown dust, forest fires, etc.). Among the sources, mobile sources particularly automobiles account more than 50% of the total air pollution in many cities. In addition, stationary or point source emissions from thermal power plants, pharma industry, and chemical industries contribute in significant amount. Area and natural source pollutants do not usually create air pollution problems like the other sources, but sometimes cause significant impact on the environment. In India, atmospheric aerosols are one of the major concerns today. Pollution over the last decades its shown of explosive growth rate of 0.3 billion in the year 1950 to 1.04 billion in the year 2002 accompanied by improper planning of urban infrastructure and urbanization. A rapid growth of population is the main reason for environmental concern in the country. The total population of India may reach up to 1.6 billion by the year 2050. The continuous increase in population along with urban development, laid pressure on land use patterns and natural resources, particularly the air environment.

4 Meteorological Influence in Urban Air Pollution

Meteorological parameters play a crucial role in air pollution studies. Air pollutants are emitted into the atmosphere, meteorological parameters of wind speed, wind direction, temperature, etc., are playing significant role in understanding the behavior of pollutants, i.e., either to absorb or disperse. The occurrence pollution concentration in a particular area depends primarily on wind speed, function of mixing depth and physical state of an area. Among the pollutants, the concentration dust particulates are higher in winter compared to other seasons. This is because of dust particles in ambient air during winter due to low wind speed and mixing height.

Local meteorology which is often called micrometeorology has a major role in air pollution. A relation between micrometeorology and dispersion of air pollutants essentially involves wind in the broader sense. Wind fluctuations over time and space take a crucial role in the dispersion of air pollutants. Wind flow in horizontal way is a key parameter in transport of pollutants. A high wind speed always has a high dilution capacity. On the contrary, low or mild wind may favor accumulation of pollutants. Wind direction also largely influences the pollutant dispersion. Direction and speed of wind for a given time in particular space is known as wind rose which helps to understand the prevailing wind speed to predict the dispersion of pollutants from a point to air source. Turbulence and atmospheric stability are also very important parameters in dispersion of air pollutants. The urban surface pattern and temperature or solar isolation is the key parameter to determine these two. Thermal turbulence and unstable atmospheric condition always favor the dilution of the emitted air pollutants, whereas mechanical turbulence and stable atmospheric condition do the reverse. Relative humidity often entertains the formation procedure of some secondary pollutants but washed out effect of rain scavenges the air pollutants from the atmosphere.

5 Particulate Matter (PM)

PM-Particulate Matter pollution is a complex mixture of substances suspended in air and exists in various forms, i.e., dust, aerosol, smoke, soil, pollen, and soot (Viana et al. 2006). PM originates as both natural and anthropogenic sources. The natural sources contribute PM in the ambient air are dust storms, forest fires, and sea spray. The anthropogenic sources are burning of fossil fuels in industrial operations and use in vehicles. In developing countries, the significant amount of particulates contributed from coal combustion used for heating the houses and generation of electricity. The presence of PM in ambient air and inhalation causes various health diseases that include asthma, lung cancer, respiratory and cardiovascular diseases, etc. According to the report of WHO (2001), particulate matter causes approximately 3 million deaths per year in the world. Particulates deposition in skin and nasal

passes could cause various types of chronic and sub-chronic allergies to skin and respiratory tract. However, the most serious health risk associated with the fine ambient particles is fibrogenesis of lung tissue. This is due to accumulation of fine ambient particulates in the lung tissue (Omidvarborna et al. 2015).

6 Trace Metals

Trace metals enter into the ambient air in the form of fine suspended particulate matter which emits as a result of emissions from industries, urban activities, burning of fossil fuels in the form of vehicular emissions, excessive use of fertilizers and pesticides in agriculture. The presence of excessive trace metals in air particulate matter indicates the deterioration of the quality of ambient air of a particular area and possible health risks to the population (Pope et al. 2009). Trace metals generally cause toxicity present in suspended particulate matter; besides, few trace metals act as nutrients in plants, animals, and humans, but if they occur beyond the permissible limits they may cause toxicity. The trace elements such as Cadmium (Cd), Mercury (Hg), and Lead (Pb) are toxic and have very low concentrations; and they do not play any role in metabolism of living cells (Duruibe et al. 2007).

7 Objectives of the Work

(1) To determine the concentration of ambient air Particulate Matter (PM), i.e., $PM_{2.5}$ and PM_{10} in different environmental backdrops of Visakhapatnam.
(2) To calculate the Air Quality Index (AQI) and Exceedance Factor, to assess the level of pollution and air quality in the study area.

8 Methodology

8.1 Study Area

Visakhapatnam (82° 57′ 37″–83° 28′ 12″ E longitude and 17° 30′ 15″–18° 11′ 15″ N latitude) is positioned on the north coast of Andhra Pradesh and is commonly known as Vizag. Named after the lord “Visakha”, Vizag was once a small fisherman village known to be a part of the Vijayanagar kingdom during the fifteenth century, and during the British command, it was transformed to a port town and made the district headquarters under Madras Presidency. Presently, one of the second largest cities of Andhra Pradesh, and considered as the industrial capital of the state.

Initially, industrial development was seen in and around port area until 1970 after it was dispersed along the sea coast with establishment of various industries like steel, fertilizer, petroleum refinery, and development of SEZs. Now, Vishakhapatnam, and its port is one of the largest ports in the country. Popularly called as the "City of Destiny", Vizag is considered as one of the fast-growing cities in India.

The city has a typical tropical climate among three distinct seasons, summer (March–June), Rainy (June–October) and winter (November–February). The monthly means of Maximum and Minimum temperatures gradually turn down from summer to winter, while the diurnal variations in the temperature increase from summer to winter. The hottest month is May when the daily temperatures reach 41 °C and the lowest daily temperatures occur during the month of January with a daily mean of 23 °C. The annual normal rainfall is at 780 mm, 70% of which occurs during the rainy season and is a contribution of the Southwest Monsoon.

The present study is carried out in residential, commercial and industrial areas. Five sampling areas were selected and monitoring was done as per NAAQMS frequency for eight months for 24 h. A total of 32 samples were collected. Sampling duration is maximum 24 h and minimum 8 h.

As per the objective of the project and work schedule, meteorological data has been collected from the local weather monitoring station to prepare the wind roses to fix the study areas from November 2015 to June 2016.

Based on the weather data and wind directions, the study areas were selected for ambient air quality monitoring at different environmental backdrops of Visakhapatnam (Table 1).

8.2 Ambient Air Quality Monitoring

A standard methods were employed for sampling and analysis of particulate matter ($PM_{2.5}$ and PM_{10}) in ambient air (CPCB 2011a, b). The fine particulate sampler was kept above 3 m above the ground level. "Whatman GF/A grade Glass Fiber filter/ PTFE" paper was used for collection of particulate matter.

PM_{10} [Ecotech-AAS 127] monitors were installed in the period of sampling. The monitoring stations were well equipped with temperature, wind, and relative humidity monitors.

8.3 Determination of PM_{10} and $PM_{2.5}$

To estimate PM_{10} and $PM_{2.5,}$ gravimetric method was employed using GF/A and PTFE filter papers. The particle retention efficiency was more than 98% for both PM_{10} and $PM_{2.5}$ particulates. Each filter paper was thoroughly inspected visually and was kept in a desiccator for 24 h before initiation of monitoring. The

Table 1 Description, latitude, and longitude of monitoring stations

S. No.	Name of the monitoring station	Zone	Latitude	Longitude	Description of the locality
1.	Akkayyapalem	Residential	17° 44′ 18.08″ N	83° 18′ 5.54″ E	Residential colonies
2.	Jagadamba	Commercial	17° 42′ 26.22″ N	83° 18′ 0.34″ E	Commercial areas with number of shopping malls, Vegetable markets, Institutions and Hotels. It is a centre point for shopping and commercial activities
3.	Reading Room	Residential and commercial	17° 42′ 02.01″ N	83° 17′ 45.66″ E	
4.	Parawada	Industrial	17° 31′ 18.16″ N	83° 04′ 54.34″ E	Several major and minor industries located within these areas
5.	Auto Nagar	Industrial	17° 41′ 45.00″ N	83° 11′ 22.93″ E	

instrument verified for any leaks and greased. Before turning on instrument, Dry Gas Monitor (DGM) reading was noted and sampling was continued for 24 h (Table 2).

Calculation:

W_1 g = Initial Weight of filter paper
W_2 g = Final Weight of filter paper
W_2 g − W_1 g = Net Weight of Filter paper
V_1 m^3 = Initial volume of Air
V_2 m^3 = Final volume of Air

$$PM_{10}(\mu g/m^3) = \sqrt{\frac{(W_2 - W_1)}{(V_2 - V_1)}} \times 10^6$$

8.4 Trace Metals

To measure trace metals in air filters, advanced instrument technique such as EDXRF and IC-PMS was employed by following standard operating protocols and analysed 13 elements (Na, Mg, Al, Si, S, Cl, K, Ca, Ti, Mn, Fe, Cu and Zn) in each filter paper.

8.5 Air Quality Index

"Air Quality Index (AQI) is defined as a single number for reporting, in general scheme that transforms the weight value of individual pollution-related parameters into a single number or set of numbers and its respect to human health and it combines many pollutants concentrations in some mathematical expression to arrive at single number for quality of air" (Tables 3 and 4).

Table 2 Instruments used for collection of aerosols

S. No.	Parameter	Instrument used	Sensitivity
1.	PM_{10}	Ecotech AAS-127	2.5–10 μm particle size
2.	$PM_{2.5}$	Ecotech AAS-127	2.5–10 μm particle size

Table 3 Category and range of Indian Air Quality Index

AQI category	AQI range
0–50	Good
51–100	Satisfactory
101–200	Moderate
201–300	Poor
301–400	Very poor
401–500	Severe

Table 4 Breakpoint concentration of PM_{10} and $PM_{2.5}$

S. No.	India (24 h) for PM_{10}		India (24 h) for $PM_{2.5}$	
	AQI category	Break point concentration	AQI category	Break point concentration
1	Good	50	Good	30
2	Satisfactory	100	Satisfactory	60
3	Moderate	250	Moderate	90
4	Poor	350	Poor	120
5	Very poor	430	Very poor	250
6	Severe	430+	Severe	250+

Table 5 Four air quality categories for EF

Category	Range
Critical pollution—C	When EF is more than 1.5
High pollution—H	When EF is between 1.0 and 1.5
Moderate pollution—M	With an EF between 0.5 and 1.0
Low pollution—L	With an EF less than 0.5

8.6 Exceedance Factor

"Air quality can be categorized into four broad categories based on Exceedance Factor (EF). EF EF is ratio between the observed annual mean concentration of criteria pollutants and annual standard for the respective pollutant and area class". EF category and ranges are given in Table 5.

$$\text{Exceedance Factor} = \frac{\text{Observed annual mean concentration of criteria pollutant}}{\text{Annual Standard for the respective pollutant and area class}}$$

9 Results and Discussions

9.1 Introduction

The results of $PM_{2.5}$, $PM_{10,}$ and trace metals were obtained by making an average of eight months data, i.e., from November-2015 to June-2016. The data related to PM_{10}, $PM_{2.5}$ and trace metals in particulate matter were presented in Tables 4.2 to 4.4. The meteorological data of study sites are presented in Table 6.

Table 6 Average values of meteorological parameters

S. No.	Month	Temperature (°C)		Wind speed (m/s)		Relative humidity (%)		Rain fall (mm)
		Max	Min	Max	Min	Max	Min	
1.	Nov-15	32	18	17	0	82.7	51.9	172.6
2.	Dec-15	32	20	17	0	90	37.6	0
3.	Jan-16	30	13	14.6	0	90.6	22.9	0
4.	Feb-16	30	14	12.8	0	91.8	17.7	0
5.	Mar-16	38	21	18	1	97%	45%	2
6.	Apr-16	39	25	21	5	97%	33%	0.2
7.	May-16	43	26	26	1	100%	36%	6.1
8.	Jun-16	37	26	17	0	90%	62%	9.6
9.	Jul-16	37	25	20	1	89%	56%	11.7
10.	Aug-16	38	25	17	2	90%	60%	10.2

9.2 Meteorological Parameters

Meteorological parameters influence the air pollution concentration of a particular site. Even though the total discharge of contaminants into the atmosphere in a given area remains constant from day to day, the degree of air pollution may vary because of differences in meteorological conditions. Meteorological conditions in the study area will have a critical impact on air quality. Hence, study of meteorological conditions with the following parameters is an important aspect, Temperature; Relative Humidity; Rainfall; Wind Speed; and Wind direction.

9.3 Meteorological Scenario in the Study Area

Meteorological data has been collected by using **weather watchdog** and the collected data is presented in Table 6.

9.4 Temperature

During the study period, the average temperature is varied from 28 to 32 °C. The recorded maximum temperature is 43 °C and minimum temperature is 21 °C.

9.5 Relative Humidity

Relative humidity varied from 70 to 74%. The minimum humidity is 32% and maximum humidity is 93%.

9.6 Wind Speed and Wind Direction

The average wind speed is varied from 2.2 to 4.4 m/s. It is observed that during the study period, the predominant wind direction is SW–NE. The details of wind pattern and wind rose are shown in Fig. 1. Map showing study sites and monitoring of air particulates at sites are shown in Figs. 2 and 3.

The monthly means of $PM_{2.5}$ and PM_{10} concentrations showed variation with the sampling site and the results are presented in Tables 7 and 8 and Figs. 4, 5, 6, 7 and 8.

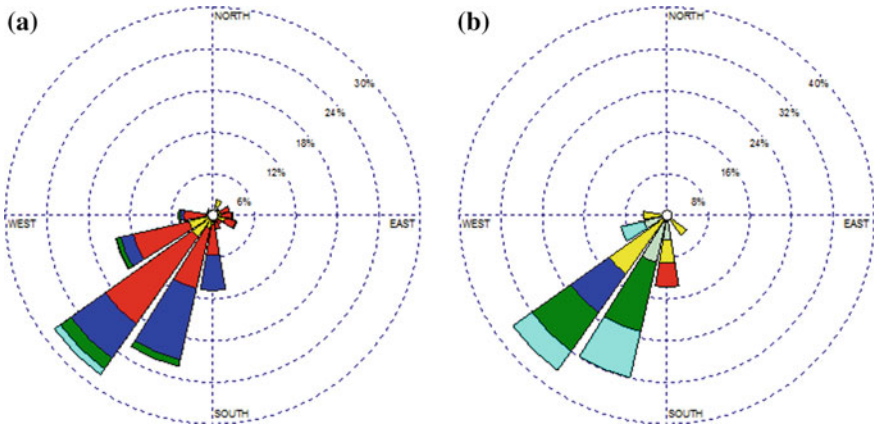

Fig. 1 **a** Wind rose in the month of summer. **b** Wind rose in the month of winter

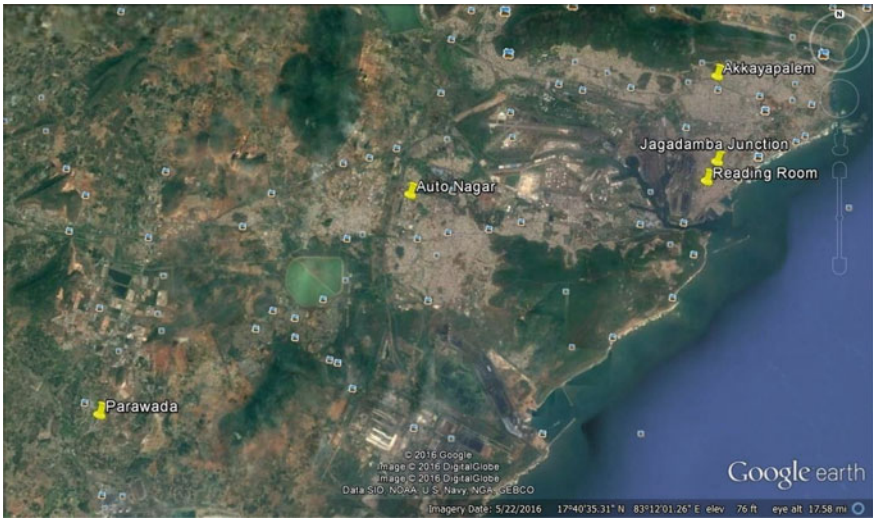

Fig. 2 Map showing study sites at Visakhapatnam city

9.7 Particulate Matter (PM)

9.7.1 Residential Area—Akkayapalem

At the residential area, the concentration of $PM_{2.5}$ and PM_{10} showed diverse responses. The concentration of $PM_{2.5}$ ranged from 13.08 to 41.15 $\mu g/m^3$. The maximum concentration was observed during summer months, i.e., from March to

Fig. 3 Instruments of fine particulate samplers at monitoring stations

June. While the lowest concentrations were recorded in winter months. The mean concentration was found to be 27.11 μg/m^3 for the entire study period and value was within the permissible limits as per NAAQ standards.

9.7.2 Commercial Area—Jagadamba

At commercial area of Jagadamba, the concentration of $PM_{2.5}$ ranged from 23.57 to 46.77 μg/m^3. Maximum concentration was observed during summer, i.e., from March to June. While the lowest concentration was noticed in the month of February. The mean concentration was found to be 46.95 μg/m^3 for the entire study period and values have exceeded the permissible limits as per NAAQ standards. During winter, the concentration of $PM_{2.5}$ is within permissible limits whereas, in summer, high PM values were recorded.

9.7.3 Commercial Area—Reading Room

At the commercial area of Reading Room, the concentration of $PM_{2.5}$ ranged from 29.92 to 59.17 μg/m^3. Maximum concentration was observed during summer, i.e., from March to June. While the lowest concentration was noticed in the month of January. The mean concentration was found to be 44.54 μg/m^3 for the entire study period and values have exceeded the permissible limits as per NAAQ standards.

9.7.4 Industrial Area—Parawada

At Industrial area of Parawada, the concentration of $PM_{2.5}$ ranged from 40.62 to 69.76 μg/m^3. Maximum concentration was observed during summer, i.e., from March to June. While the lowest concentration was noticed in the month of January.

Table 7 Annual average conc. (μg/m^3) at different environmental backdrops in urban areas of Visakhapatnam (μg/m^3)

Study sites	Nov-15		Dec-15		Jan-16		Feb-16		Mar-16		Apr-16		May-16		Jun-16	
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
Akkayapalem	27.57	48.67	13.08	25.97	19.84	34.77	18.37	29.42	41.15	78.89	38.45	70.89	37.98	81.89	27.89	71.58
Jagadamba	33.57	61.03	38.57	79.53	25.56	38.15	23.57	59.03	33.57	69.03	46.77	85.29	44.67	69.56	36.87	71.51
Reading Room	51.47	59.44	59.17	61.29	29.92	52.31	31.47	69.34	51.47	79.44	51.46	61.45	38.29	61.74	33.69	62.31
Parawada	69.76	85.95	59.88	85.95	40.62	71.15	49.86	75.59	49.86	85.95	60.3	75.9	51.26	76.25	43.57	69.03
Auto Nagar	59.26	73.45	42.27	83.73	31.98	64.58	39.26	63.54	39.26	73.45	56.23	78.96	46.11	82.92	41.39	73.56

Table 8 Minimum and maximum concentrations of $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)

Station	$PM_{2.5}$		PM_{10}		$PM_{2.5}$	PM_{10}
	Min	Max	Min	Max	NAAQ standard	
Akkayapalem	13.08	41.15	25.97	81.89	Annual **40** ($\mu g/m^3$) 24 h **60** ($\mu g/m^3$)	Annual **60** ($\mu g/m^3$) 24 h **100** ($\mu g/m^3$)
Jagadamba	23.57	46.77	38.15	85.29		
Reading Room	29.92	59.17	52.31	79.44		
Parawada	40.62	69.76	69.03	85.95		
Auto Nagar	31.98	59.26	63.54	83.73		

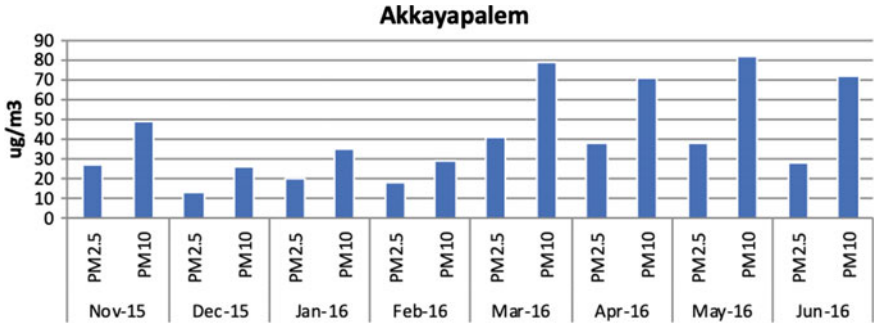

Fig. 4 Annual mean concentration of $PM_{2.5}$ and PM_{10} ($\mu g/m^3$) at Akkayapalem

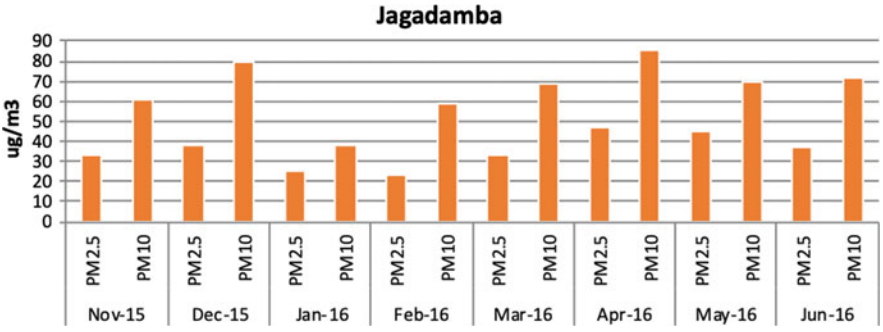

Fig. 5 Annual mean concentration of $PM_{2.5}$ and PM_{10} ($\mu g/m^3$) at Jagadamba

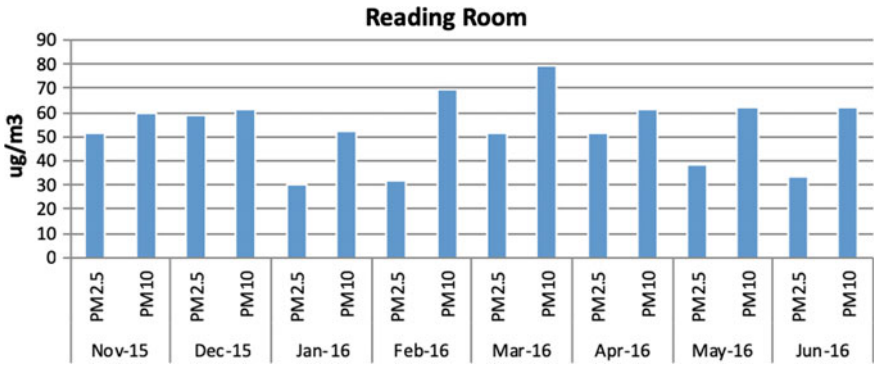

Fig. 6 Annual mean concentrations of $PM_{2.5}$ and PM_{10} ($\mu g/m^3$) at Reading Room

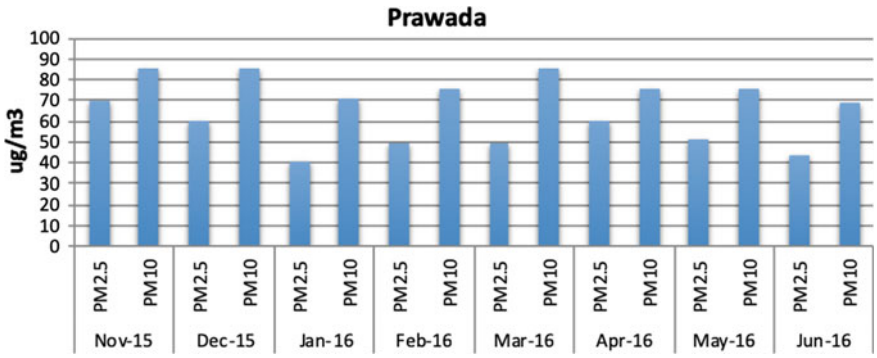

Fig. 7 Annual mean concentration of $PM_{2.5}$ and PM_{10} ($\mu g/m^3$) at Parawada

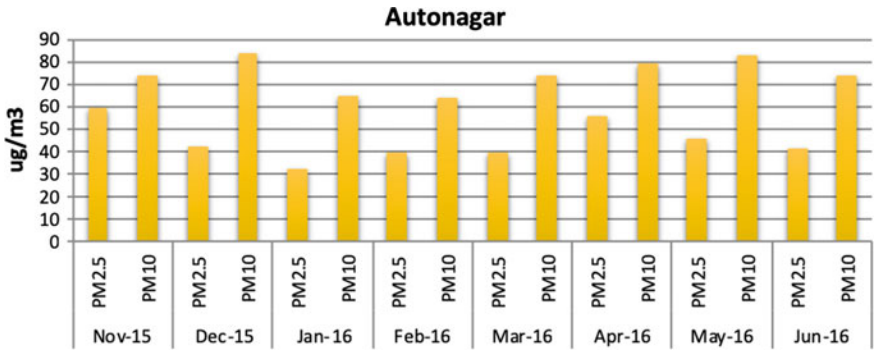

Fig. 8 Annual mean concentration of $PM_{2.5}$ and PM_{10} ($\mu g/m^3$) at Auto Nagar

The mean concentration was found to be 55.19 μg/m^3 for the entire study period and values have exceeded the permissible limits as per NAAQ standards.

9.7.5 Industrial Area—Auto Nagar

At Industrial area of Auto Nagar, the concentration of $PM_{2.5}$ ranged from 31.98 to 59.26 μg/m^3. Maximum concentration was observed during summer, i.e., from April to June. While the lowest concentration was noticed in the month of January. The mean concentration was found to be 45.62 μg/m^3 for the entire study period and values have exceeded the permissible limits as per NAAQ standards.

9.8 Particulate Matter PM_{10}

9.8.1 Residential Area—Akkayapalem

At Residential area of Akkayapalem, the concentration of PM_{10} ranged from 25.97 to 81.89 μg/m^3. Maximum concentration was observed during summer, i.e., from March to June. While the lowest concentration was noticed in the month of December. The mean concentration was found to be 53.93 μg/m^3 for the entire study period and values ware within the permissible limits as per NAAQ standards.

9.8.2 Commercial Area—Jagadamba

At Commercial area of Jagadamba, the concentration of PM_{10} ranged from 38.15 to 85.89 μg/m^3. Maximum concentration was observed during summer, i.e., from April to June. While the lowest concentration was noticed in the month of January. The mean concentration was found to be 61.72 μg/m^3 for the entire study period and values have slightly exceeded the permissible limits as per NAAQ standards.

9.8.3 Commercial Area—Reading Room

At Commercial area of Reading Room, the concentration of PM_{10} ranged from 52.31 to 79.44 μg/m^3. Maximum concentration was observed during summer, i.e., of March. While the lowest concentration was noticed in the month of January. The mean concentration was found to be 65.87 μg/m^3 for the entire study period and values have exceeded the permissible limits as per NAAQ standards.

9.8.4 Industrial Area—Parawada

At Industrial area of Parawada, the concentration of PM_{10} ranged from 69.03 to 85.95 μg/m^3. Maximum concentration was observed during summer, i.e., of March. While the lowest concentration was noticed in the month of January. The mean concentration was found to be 77.49 μg/m^3 for the entire study period and values have exceeded the permissible limits as per NAAQ standards.

9.8.5 Industrial Area—Auto Nagar

At Industrial area of Auto Nagar, the concentration of PM_{10} ranged from 63.54 to 85.95 μg/m^3. Maximum concentration was observed during summer, i.e., of March. While the lowest concentration was noticed in the month of February. The mean concentration was found to be 77.49 μg/m^3 for the entire study period and values have exceeded the permissible limits as per NAAQ standards.

The results of both $PM_{2.5}$ and PM_{10} have recorded above permissible limits in commercial and industrial areas. Whereas in the residential area both $PM_{2.5}$ and PM_{10} were well within the limits of NAAQ standards.

9.9 Elemental Composition

The average concentration of analysed elements in PM_{10} showed diverse responses among all the sampling sites during the study period. The average concentration of all the analysed elements during the study is given in Table 9.

9.9.1 Akkayapalem

In Akkayapalem (residential) area Si is reported in maximum concentration (0.0420 μg/m^3) followed by Al (0.0294 μg/m^3), Cl (0.0265 μg/m^3) and Na (0.0189 μg/m^3) respectively. The other elements are reported in trace quantities.

9.9.2 Jagadamba

In Jagadamba (commercial) area Sulphur (S) reported in maximum concentration (0.4945 μg/m^3) followed by Na (0.2778 μg/m^3) and Ca (0.1838 μg/m^3) respectively.

Table 9 Mean concentration of elements in PM_{10} (μg/m^3) at different monitoring stations

S. No.	Elements	Akkayapalem	Jagadamba	Reading Room	Parawada	Auto Nagar
1.	Na	0.0189	0.2778	0.0784	1.6983	0.0368
2.	Mg	0.0143	0.0379	0.0147	0.1163	BDL
3.	Al	0.0294	BDL	0.0569	1.4074	0.0285
4.	Si	0.0420	0.0259 (mg)	0.0898	0.0090 (mg)	0.0447
5.	S	0.0366	0.4945	0.0474	0.2833	0.0333
6.	Cl	0.0265	0.0181	0.0844	0.2009	0.0595
7.	K	0.0030	0.0527	0.0064	0.8065	0.0037
8.	Ca	0.0113	0.1838	0.0294	0.4569	0.0167
9.	Ti	0.0004	0.0038	0.0011	0.0289	ND
10.	Mn	0.0003	0.0030	0.0021	0.0233	0.0013
11.	Fe	0.0056	0.0506	0.0138	0.0583	0.0070
12.	Cu	0.0010	0.0027	0.0026	BDL	0.0009
13.	Zn	0.0007	BDL	BDL	1.8885	BDL

BDL below detectable level

9.9.3 Reading Room

In Reading Room area, Si (0.0898 μg/m^3) reported maximum followed by Cl (0.0844 μg/m^3), Na (0.0784 μg/m^3), Al (0.0569 μg/m^3), S (0.0474 μg/m^3) and Ca (0.0294 μg/m^3).

9.9.4 Parawada

In Parawada industrial area Zn (1.8885 μg/m^3) reported in maximum concentration followed by Na (1.9683 μg/m^3), Al (1.4074 μg/m^3) and K (0.8605 μg/m^3).

9.9.5 Auto Nagar

In Auto Nagar area, Cl (0.0595 μg/m^3) reported in maximum concentration followed by Si (0.0447 μg/m^3), Na (0.0368 μg/m^3), S (0.0333 μg/m^3), Al (0.0285 μg/m^3) and Ca (0.0167 μg/m^3). From the study it was observed that soil dust, resuspension of dust, industrial and road traffic emissions are the main drivers for causing variability in elemental composition with respect to local meteorological conditions at each sampling station. From the results it is observed that Na, Ca, Al, Si and K presence is an indication that crustal elements (soil) contributed significantly to particulate matter mass in all the sampling stations. In addition to above elements,

sulphur contributed largely in commercial areas, indicating vehicular emissions significantly contributing to particulate mass concentrations. The presence of Cl and Na in all the sampling locations is an indication that sea salt is also influencing the particulate mass concentration. This condition is generally high in summer season, because of meteorological conditions and close proximity of all the areas to sea. In industrial area the presence of trace elements such as Zn, Al, Mn, Fe, Cu, Ti are indication of industrial emissions to particulate mass concentrations.

9.10 Percentage Distribution of Analysed Elements in PM_{10} at Different Sampling Locations

The percentage distribution of thirteen metal and non-metal elements were presented in the forms of Pie charts as Figs. 9, 10, 11, 12 and 13.

In residential areas (Akkayapalem), silica was dominated by 22% followed by Sulphur and Aluminium (15%). In commercial area (Jagadamba), sulphur was dominated by 43%, followed by sodium (24%) and calcium (16%). In reading room area, silica was dominated by 21% followed by chloride 20%, sodium 18%, aluminum (13%), and sulphur (11%), respectively.

In Industrial area (Parawada) Zinc was dominated with (27%) followed by silica, sodium, sulphur, and Aluminium, respectively. Similarly, in Auto Nagar—industrial area chloride was dominated by 26% followed by silica (19%), sodium (16%), sulphur (14%), and aluminium (12%), respectively. From the results, it may be observed that silica is one of the major components of soil dust, is dominated in residential areas followed by industrial areas. It is also observed the prevalence of sulphur in commercial and industrial areas indicates the source of origin is from automobile emissions.

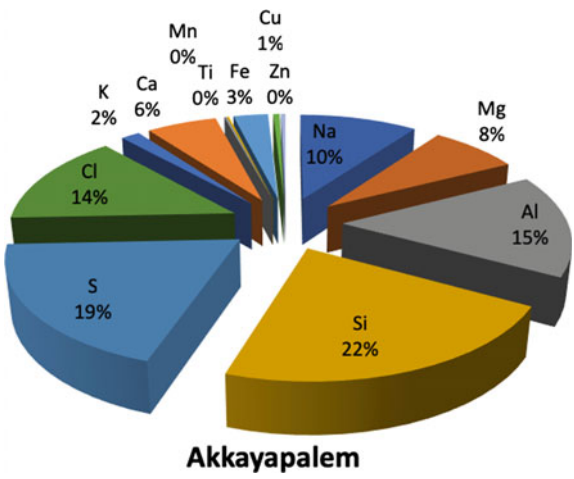

Fig. 9 The percentage distribution of analysed elements in PM_{10} at Akkayapalem

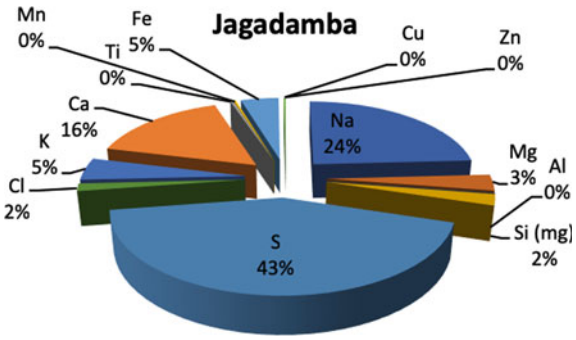

Fig. 10 The percentage distribution of analysed elements in PM_{10} at Jagadamba

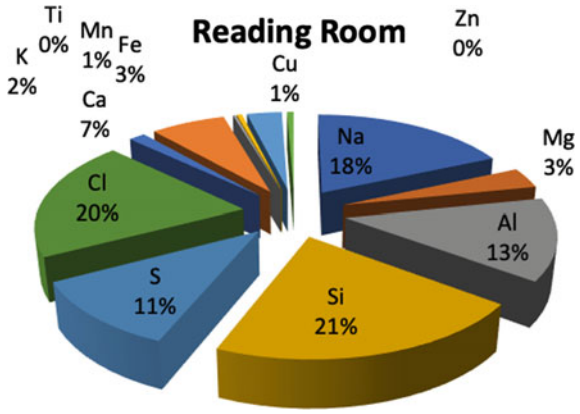

Fig. 11 The percentage distribution of analysed elements in PM_{10} at Reading room

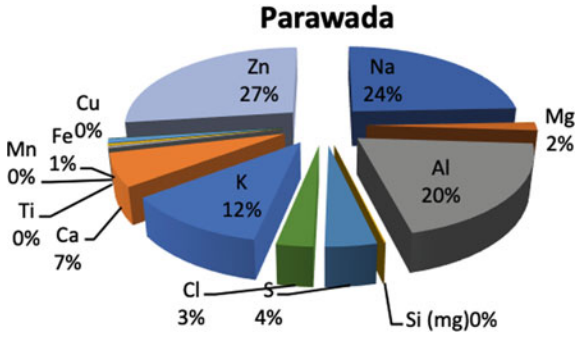

Fig. 12 The percentage distribution of analysed elements in PM_{10} at Parawada

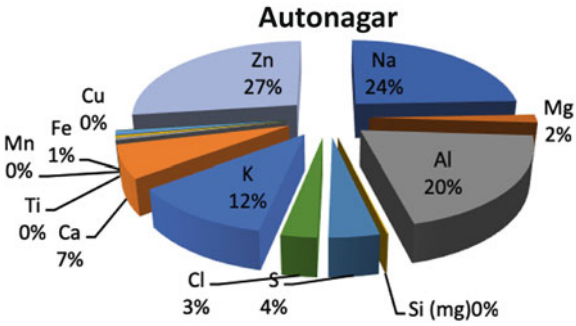

Fig. 13 The percentage distribution of analysed elements in PM_{10} at Auto Nagar

9.11 Air Quality Index

Tables 3 and 5 represent the air quality index and air quality category corresponding to the index calculated on the basis of criteria pollutants viz. $PM_{2.5}$ and PM_{10}. A seasonal variation of AQI for each site in each zone is achieved to reflect the town's status in winter and summer.

AQI results show that according to $PM_{2.5}$ in Akkayapalem, Air Quality Index is 44.65, which comes under a satisfactory category with minor breathing discomfort to sensitive people. The remaining four sites, i.e., Jagadamba (56.49), Reading room (72.28), Parawada (88.56), and Auto Nagar (74.12), come under moderate category with largely breathing discomfort to the people with lung problem, heart disease, children and older people. Values obtained by method of IND-AQI. PM_{10} in all study sites, AQI grade has fallen under satisfactory, i.e., Akkayapalem (55.26), Jagadamba (65.39), Reading room (63.42), Parawada (78.22), and Auto Nagar (74.27), where minor breathing discomfort has been reported to sensitive people. The impact of pollution due to mobile vehicles, construction activities, traffic congestion increases vehicle emissions and degrades ambient air quality; aerosols are converted due to huge amount of large vehicles which move on roads continuously, the particles become fine particulates due to re-suspension and it impacts on breathing minorly for sensitive people and impact largely to the people suffering from lung problems, heart disease, children, and older people (Tables 10 and 11).

9.12 Exceedance Factor Analyses

Based on the data, $PM_{2.5}$ and PM_{10} for winter and summer seasons, the exceedance factors are calculated as shown in Table 12. It is evident from the table that, in

Table 10 AQI grade of different study sites in Visakhapatnam city for the year 2015–16

Study sites	$PM_{2.5}\mu g/m^3$			$PM_{10}\mu g/m^3$		
	AQI Conc.	Break Point	Grade	AQI Conc.	Break Point	Grade
Akkayapalem	44.65	31–60	S	55.26	51–100	S
Jagadamba	56.49	61–90	M	65.39	51–100	S
Reading Room	72.28	61–90	M	63.42	51–100	S
Parawada	88.56	61–90	M	78.22	51–100	S
Auto Nagar	74.12	61–90	M	74.27	51–100	S

Table 11 Breakpoints for AQI scale (CPCB 2015)

Category $PM_{2.5}$	Category PM_{10}	Health Impacts
Good (0 – 30)	Good (0 - 50)	Minimal Impact
Satisfactory (31 – 60)	Satisfactory (51 – 100)	Minor breathing discomfort to sensitive people
Moderate (61–90)	Moderate (101–250)	Breathing discomfort to the people with lung, heart disease, children and older adults
Poor (91–120)	Poor (251–350)	Breathing discomfort to people on prolonged exposure
Very Poor (121–250)	Very Poor (351–430)	Respiratory illness to the people on prolonged exposure
Severe (>250)	Severe (>430)	Respiratory effects even on healthy people

winter, for $PM_{2.5}$ the EF range is 0.5, where the category comes under low (L) in Akkayapalem, whereas the remaining sites of Jagadamba 0.8, Reading room is 1.1 and Auto Nagar 1.1, EF category under Moderate (M), except in Parawada EF range is 1.4 and the category come under High (H). For PM_{10} in winter in Akkayapalem EF range is 0.6 and it comes under Moderate (M), except remaining all sites, i.e., Jagadamba, Reading room, Parawada, and Auto Nagar comes under High (H), respectively. In summer for $PM_{2.5}$ and PM_{10} in all sites, the category is High (H), except Akkayapalem is a residential area come under Moderate (M) level.

Table 12 EF for $PM_{2.5}$ and PM_{10} at different environmental backdrops in urban areas of Visakhapatnam in winter and summer

Study sites	Exceedance factor $PM_{2.5}$			Exceedance factor PM_{10}		
	Mean	EF Range	Category	Mean	EF range	Category
Winter EF						
Akkayapalem	19.72	0.5	L	34.71	0.6	M
Jagadamba	30.32	0.8	M	59.44	1.0	H
Reading Room	43.01	1.1	M	60.60	1.0	H
Paravada	55.03	1.4	H	79.66	1.3	H
Auto Nagar	43.19	1.1	M	71.33	1.2	H
Summer EF						
Akkayapalem	36.37	0.9	M	75.81	1.3	H
Jagadamba	40.47	1.0	H	73.85	1.2	H
Reading Room	43.73	1.1	H	66.24	1.1	H
Parawada	51.25	1.3	H	76.78	1.3	H
Auto Nagar	45.75	1.1	H	77.22	1.3	H

10 Conclusion and Suggestions

Based on the above observations, the ambient air quality of Visakhapatnam with respect to particulates showed remarkable variation between industrial and residential areas. Both PM_{10} and $PM_{2.5}$ reported moderate level in industrial area as per the AQI and Exceedance Factor. From the results of both $PM_{2.5}$ and PM_{10}, it is observed that PM has recorded above permissible limits in commercial and industrial areas. Whereas, in residential area, both PM were within the limits of NAAQ standard. The major contributors of Particulate matter include automobile emissions burning of urban refuse and diesel generators. In industrial areas Zn is found to be dominated with 27% of the total metals analyzed followed by sulphur and aluminium, respectively. When metals present in air beyond the permissible limits induse Reactive Oxygen Species (ROS) and cause impact on human health. From the study, it is concluded that PM has emerged as the most prominent pollutant. The existence of $PM_{2.5}$ above the permissible limit in industrial and commercial areas is a serious concern and immediate steps are to be initiated to identify the sources and the extent of their contribution to ambient air pollution.

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Dehradun City: Vehicular Pollution During 2008 to June 2018

Sharad Kumar Tripathi and Anupama Tripathi

Abstract The air pollution crisis in cities is mainly due to the emissions of various gases emitted from the vehicle. Due to the growing economic base, pressure on India's Uttarakhand state capital Dehradun is increasing rapidly. In the last 10 years, the number of vehicles has increased more than doubled in Dehradun, due to the narrowing of roads, jams and slow moving of vehicles are also an important cause of air pollution, by increasing the smoke emissions from the old vehicles. In this research paper, various harmful gases responsible for air pollution in Dehradun have been described and they have been taken into account on the harmful effects of their animal and vegetation life. The research paper has provided detailed information on vehicle numbers responsible for air pollution in Dehradun, their transport, road conditions, harmful emitted gas and smoke etc. and the difference between 2008 and 2018 has also been noticed.

1 Introduction

1.1 Need for Vehicular Pollution Investigation

The scientists and environmental scholars of the country have concentrated on the different cities of the country where the number of vehicles is high and has tried to get the information that due to which air pollution is being generated, the level of adverse effects on animals and plants. The number of vehicles playing in Indian cities, metropolitan cities, in particular, is still insignificant as compared to the same in the USA, Europe, and Japan. Even then, the inferior maintenance of vehicles in

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combination with lower combustion efficiency is making exhausts a menace to the city dwellers.

2 Pollutants Emitted by Vehicles

There are various pollutants emitted by vehicles:

(a) Gaseous Pollutant—CO_2, SO_2, CO
(b) Rubber & Plastics
(c) Road dust particles in air.

Most of the medium and low middle-class people in India use two-wheelers, and three-wheelers vehicles, which use mixed oil, which is the main source of the generation of harmful gases related to heavy air pollution.

In the four-stroke cycle petrol engine, the operating temperature and the air-fuel ratios are generally low. In contrast in a compression ignition diesel engine, operating temperature, pressure and air-fuel ratio are rather high and as such there is much less emission of unburnt hydrocarbons, intermediates as carbon monoxide. However, in this case NO_x and nitrated organic might be produced in much larger quantities than in the case of petrol engines. Diesel vehicles also emit relatively larger quantities of very fine particulate in their smoke because of large amounts of fuel of low vaporisability being consumed. The two-stroke cycle engines (two-wheelers and three-wheelers) may emit even larger quantities of particulate because of the lubricating oil having been mixed with the fuel.

3 Hazards of Vehicular Air Pollution

Different types of vehicles emitted very dangerous gases which are harmful for animals, plants and whole environment, and create disbalance the ratio of gases in whole world. These gas responsible for respiratory problems, lung and heart disease, eye disease and destroy blood cells ratio also. Smog leads asthma and poor visibility. Sulphur Dioxide (SO_2) is responsible for serious lung disease like bronchitis. These gaseous particles harmful for natural vegetation as well as disturb gaseous ratio of whole world. Carbon Monoxide (CO) is more responsible for low Hemoglobin in the animal blood. Low Hemoglobin means low respiratory capacity symptoms develop in animal body. The nitrated compounds are also involved in the generation of extremely fine particulate and enhance creation of photochemical smog.

Thus, from the health point of view, oxides of nitrogen and carbon monoxide are pollutants of serious concerns. From the aesthetic and nuisance considerations, particulate would be the most readily visible and could cause considerable public concern.

4 Types and Number of Vehicles in Dehradun

Dehradun exhibited phenomenal growth in population and per capita income along with spatial spread of the city. The number of commuters also grew phenomenally. To cope up with the movement of men and materials traffic volume in Dehradun has increased many folds during the past two decades and mainly in the last decade. The steady increase in registered number of all varieties of vehicles between Jan 2008 and Dec 2017 is tabulated in Table 1. Fold increase from 301,400 to 717,700 in a decade should cause concern about vehicular pollution.

5 Distribution of Vehicles of Different Types

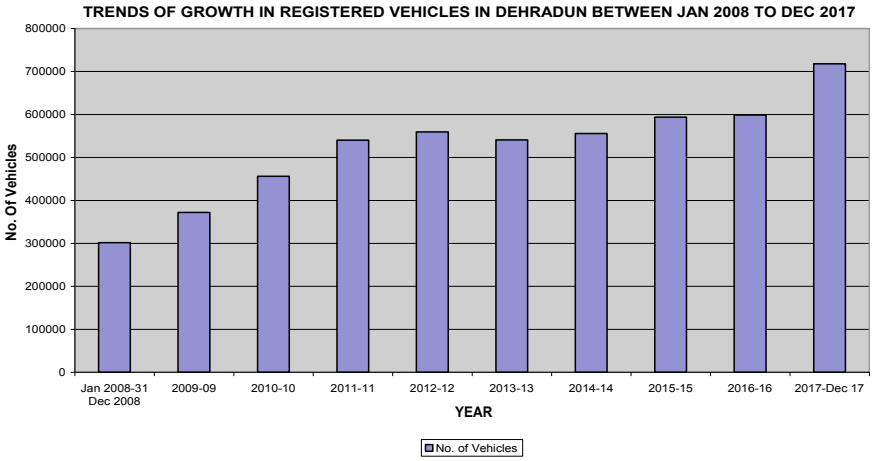
As one could expect, the largest fraction of the vehicles in Dehradun are scooters, the vehicles of the officegoers and status for the white-collared office employees. The next largest category is in private petrol and diesel-driven cars, jeep, and station wagons. These vehicles transport the senior officers, the affluent business persons, industrial magnets and a large number of staff of foreign mission and international agencies. The number of heavy goods vehicles or of public transport buses and taxis is relatively much smaller.

Table 1 Trend of growth in registered vehicles in Dehradun between January 2008 and 18 June 2018

Year	Total numbers of registered vehicles (round fig.)
Jan 2008-31 Dec 08	301,400
2009-09	371,800
2010-10	455,900
2011-11	539,900
2012-12	559,400
2013-13	540,600
2014-14	555,600
2015-15	593,800
2016-16	598,800
2017-Dec 17	717,700

Source https://parivahan.gov.in/vahan4dashboard/

The distribution of the registered vehicle as on Jan 2008 is shown on given below:



The total number of "on-road" vehicle in Dehradun in Dec 2017 was 717,700, the model composition of the vehicle population is presented in graph no. 1. In accord once with the national vehicle composition, the two-wheelers are the predominant vehicle type in Dehradun, accounting for 76% of the total vehicle population (Tables 2, 3 and 4).

In the four-stroke petrol engine, the operating temperature and the air-fuel ratios are generally low. As such, significant amounts of CO are emitted.

Two-wheelers and three-wheelers have two-stroke petrol engines. Due to the mixing of the lubricating oil and the fuel, large quantities of CO and unburned hydrocarbons are emitted. It was estimated that the two and three-wheelers contributed 74% of total vehicular unburned hydrocarbons during 1990 and 50% of the CO. In addition, the two-wheelers are high-level emitters of suspended particulate matter and have poor fuel efficiency.

Table 2 Standards of the pollution level classification and health

AQI	Possible health impacts
Good (0–50)	Minimal impact
Satisfactory (51–100)	Minor breathing discomfort to sensitive people
Moderate (101–200)	Breathing discomfort to the people with lung, heart disease, children and older adults
Poor (201–300)	Breathing discomfort to people on prolonged exposure
Very poor (301–400)	Respiratory illness to the people on prolonged exposure
Severe (>400)	Respiratory effects even on healthy people

Source Central Pollution Control Board (CPCB), New Delhi

Table 3 Estimated mass of pollutants emitted by different vehicle types in India

Categories	CO_2	CO	NO_x	SO_2	HC
Bus	28,748.16	207.26	673.93	79.24	51.72
Omni busses	8508.42	60.94	200.53	23.45	15.11
Two wheelers	8701.08	719.64	62.15	4.25	464.49
Light motor vehicles (passenger)	4378.10	370.29	92.23	2.11	1016
Cars and jeeps	23,901.22	212.30	22.14	5.67	28.01
Taxi	2367.08	10.23	5.68	117.05	1.48
Trucks and lorries	70,288.92	491.15	859.51	193.73	118.69
Light motor vehicles (goods)	44,654.58	442.04	110.94	123.73	12.13
Trailers and tractors	46,563.85	460.94	115.69	128.34	12.65
Others	5705.22	57.41	64.54	32.19	8.96

Source Emission from India's transport sector: statewise synthesis; T. V. Ramachandra a, b and Shwetmala

Table 4 The status of the AQI in Dehradun during Janaury 2016

S. No.	Name of station	City	Sampling date	AQI	Status
1.	B.S.N.L. BLDG, clock tower	Dehradun	06.01.2016	135	Moderate
			11.01.2016	135	Moderate
			14.01.2016	118	Moderate
			19.01.2016	171	Moderate
			22.01.2016	177	Moderate
			28.01.2016	163	Moderate
2.	Raipur road	Dehradun	07.01.2016	154	Moderate
			12.01.2016	139	Moderate
			15.01.2016	113	Moderate
			20.01.2016	122	Moderate
			23.01.2016	159	Moderate
			29.01.2016	153	Moderate
3.	Himalayan drugs (ISBT)	Dehradun	08.01.2016	203	Poor
			13.01.2016	220	Poor
			18.01.2016	219	Poor
			21.01.2016	222	Poor
			27.01.2016	266	Poor
			30.01.2016	189	Moderate

Source Central Pollution Control Board, New Delhi

Diesel-powered heavy goods vehicles and buses are by far the most important source of NO_x form the transport sector. It is estimated that goods vehicles and buses which constitute 7% of national total vehicle population contribute 85% of vehicular NO_x.

6 Control Measures

6.1 Vehicle Maintenance

Maintenance of any kind of traffic, etc. does not increase the air pollution in the atmosphere unnecessarily, due to which the major air-quality pollutant emissions of carbon monoxide, nitrogen oxides, burned with petrol, diesel, and alternative fuel engines. The atmosphere is safe and the work is affected by hydrocarbons and particle matter if vehicle maintenance in timely.

6.2 Vehicle Speed

The quantity of emission of different air pollutants depends upon the general operating conditions of the vehicle, specifically the speed of the vehicle, (Table 5). The highest rates of NO_x emission generally occur for vehicle traveling at high speeds. The converse is generally true for CO emissions, the maximum emissions of CO occur at slow driving speeds and as a result of the acceleration and deceleration in the stop–start driving condition characteristics of urban traffic.

The fuel demand for the road transport sector has increased considerably in the past decade, the consumption of gasoline and diesel by the road transport sector has increased from 1.5 to 7.2 million tones, respectively, in 1981 to 3.5 and 14.8 million tons in 1991. However, this still only accounts for approximately 1% of world fuel consumption.

If emissions from the vehicle are to be improved, it is essential that measures be introduced to upgrade the quality of the fuel, such as a reduction in the percentage of tetraethyl lead and aromatics and an increase in the octane rating.

Table 5 Typical sulphur content in fuel types

Fuel	Sulphur content (%)
Kerosene	0.25
Fuel oil	3.5–4.5
Gasoline	0.25
Diesel-HSD	1.0
Diesel-LDO	1.8

Source Imperial College of Science, Technology And Medicine, University of London, A Study of Ambient Air Quality in Dehradun 1985, India

Table 6 Dehradun city the approximate data of traffic flow (per hour) on different roads—2018

S. No	Main roads	Two-wheeler	Three-wheeler	Four-wheeler
1.	Saharanpur road	1526	203	2032
2.	Haridwar road	1845	169	2566
3.	Gandhi road	2133	176	3018
4.	Chakrata road	2203	116	3564
5.	Rajpur road	1468	112	3615
6.	Raipur road	2412	189	1987
7.	Sahastradhara road	2015	187	2689
8.	Kaulagarh road	879	93	1896
9	Prem nagar road	2521	174	2664
10.	E. C. road	1726	96	3698
11.	Kaonli road	2178	201	1478
12.	Gen. M. S. road	1104	76	2855
13.	New cantonment road	749	53	1785
14.	Darshan Lal Chowk	2897	316	3684
15.	Ring road	2757	354	3251

Source Self Observation

6.3 Traffic Condition

The pollution from mobile sources is further exacerbated by the insufficient urban road space. The wide mix of road users, including pedestrians, oxen pulled carts, bicycles and motor vehicles, in addition to the free-roaming cattle accentuates the congestion on the roads.

Transport NO_x emission has increased significantly over the past 20 years and projections indicate that NO_x emissions will continue to rise due to increased motor vehicle traffic. In terms of the urban ambient air quality, the level of NO_2 is therefore of particular importance (Table 6).

7 Conclusions and Recommendations

The transportation problems of Dehradun pertain mainly to the (a) mixed transporting system (b) increase in vehicles (c) lack of proper road network (d) lack of suitable parking places (e) insufficiency in public commuting services.

To the maximum possible extent, the missed mode of transportation should be avoided during the peak hours of traffic period.
To serve the commuter needs an improved public transporting system in Dehradun is necessary, in order to reduce the growing use of personal mode of transport.

A better co-ordination between the various authorities responsible for traffic management is essential in controlling the traffic flow in the Central Core Area. Stringent rules have to be imposed to check the illegal registration. Motorists should be checked for a valid license to use road that will reduce the unnecessary congestion and vulnerability of life.

Diesel spouting three-wheeled vehicles (locally called Vikrams) should be redesigned to run in battery-operated mode.

The reduction in personal mode of transport and converting the diesel spouting engines are the strong solutions to save this fragile region from the degrading environment.

Preventing entry of heavy vehicles inside the city providing terminal facilities for goods traffic at entry points along highways has to be explored.

Constructing bye-passes and new ring roads to divert by passable traffic without entering the city and already existing Mussoorie, bye-passes can be made all-weather to prevent tourist vehicles passing through the central part of the city.

After a detailed studies of traffic and its various aspects such as vehicular traffic (two-wheelers, three-wheelers and four-wheelers), condition of main roads, growth of traffic in Dehradun City, existing minimum parking facilities in the city, etc., it is evident that traffic congestion/jam occurs frequently on the main roads of the city as mentioned below.

1. Traffic jam/congestion in the Saharanpur Road from Darshan Lal Chowk to Prince Chowk to Bhoosa Store, on Haidwar Road from Prince Chowk to Mandakini Hotel (it sometimes extends to Araghar), Bridge also experience traffic congestion/jam. It has been observed that the main reasons for the traffic congestion/jam on different roads are commonly due to:

   (i) Narrowness of the roads.
   (ii) Encroachment of roads by the shopkeepers.
   (iii) Unauthorised parking of vehicles on both sides of the roads in front of shops and other establishments.

2. It has also been observed that the traffic congestion/jam in Dehradun City occurs due to inadequate parking facilities. Though Dehradun City is having such a big status, it has only a few parking sites and that too are with less covered area and capacity (Near Clock Tower, Gandhi Park, etc.). Absence of sufficient parking facilities results in unauthorized parking of vehicles on the main roads sides which creates ultimately the traffic congestion/jam.
3. I am noticed tremendous increase in number of various vehicles especially two-wheelers, cars, jeeps, and vikrams which are also responsible for increased flow of traffic while traffic facilities have not been developed accordingly, which result in traffic congestion/jam.
4. It has also been observed that the maintenance of the roads of the city is not up to mark and condition of most of the roads are also in poor condition. Some of the roads are so rough and uneven that the vehicles cannot be driven smoothly which result in traffic congestion due to low speed.

8 Suggestion

After the in-depth study of traffic congestion/jam on the main roads of Dehradun City, I am proposed following remedial measures for containing the same:

1. Administrative action to stop illegal parking on the roadsides and to maintain the traffic flow.
2. Strict action to check unauthorized encroachment on the roadsides by shopkeepers.
3. widening of Raipur road from Survey Chowk to Rispana Rao, whole Gandhi Road, Haridwar road until Araghar and Saharanpur Road until Bhoosa Store be taken up immediately in a time-bound development programme.
4. There should be timely maintenance of the roads of the city for a smooth flow of traffic.
5. New other parking facilities should be constructed on each and every suitable spots.
6. Two way traffic system should be strictly introduced.
7. Government should encourage use of bicycles for local conveyance, which will enable to control excessive use of scooter and to contain traffic congestion. The use of bicycle is not only reducing fuel consumption buy also good for health. This has already been experimented by other countries successfully.
8. By-pass roads on each and every road should be developed to divert the heavy vehicles.

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Effect of Vehicular Pollution in the Fastest Developing Cities of India: A Critical Review

Vivek Kumar, Rahul Silori and Raja

Abstract Urbanization and rapid growth in population in developing countries have contributed towards increasing vehicle density on roads while not having sufficient road capacity and crowded intersection in areas of congestion leading to air pollution. Air contamination is a standout among the most genuine natural worries in nations like India. Carbon monoxide, hydrocarbon, oxides of nitrogen and sulphur, ozone, lead, and suspended particulate matter are the major pollutants that vehicles emit. These pollutants have unhealthy effects on human's health and ecology. Larger parts of people are expected to be living in urban areas; hence, vehicular pollution and city air pollution become major concern. The study reviews the previously conducted research on vehicular pollution and its impact on the environment. This review, in addition, gives a collective study conducted in four fastest developing cities of India, viz. Mumbai, Amritsar, Kota, and Jalgaon City. This paper also suggests some measures to control vehicular pollution.

Keywords Urbanization · Vehicle density · Air pollution · Suspended particulate matter · Vehicular pollution

1 Introduction

The earth comprises of various communities that reside together and are dependent on each other for their survival. This is called an ecosystem. The ecosystem must be balanced so that organisms continue to exist and no particular species is overused or exploited. The ecosystem consists of various living and non-living communities. The non-living community of ecosystems such as air, water, and soil comes under the environment. Hence, environment too plays an important part in balancing our ecosystem. Air is an important component of the environment which is required for the survival of living beings, and problems could arise if it gets polluted.

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The emission of a large amount of carbon dioxide from industries, harmful gases from excess burning of fuels such as kerosene, cow dung, and coal in residences, uses of artificial fertilizers in agriculture, and deforestation are some of the factors contributing towards air pollution.

With urbanization in different parts of the country, there has been acceleration to air pollution and its harmful impacts on general population. The urbanization has also led to increase in the vehicles on road. These vehicles release harmful gases such as oxides of nitrogen, carbon monoxide, sulphur dioxide, hydrocarbons, SPM, and other gases which cause air pollution. This is termed as vehicular pollution. Vehicular pollution is a major concern in the country causing air pollution; this is because the rate at which the vehicular pollution is increasing is too high. According to statistics, 55% of the air pollution is caused due to the vehicular emission and about 19% is due to the industries (Centre of Science and Environment 1998).

Among all the gases that are released by the vehicle, SPM is most dangerous to health (***World health organization***, 1997). The major source for the emissions of the SPM is the sulphur content that is present in the diesel (Central Pollution Control Board 1999**)**. The emission rate of some pollutants also depends upon the speed of the vehicle. The emission rate of CO increases on decreasing the speed of the vehicle (Krawack 1993).

Vehicular pollution has bad effect on the health of an individual. A long exposure in the areas where vehicular pollution is high causes breathing problems, reduces the function of the lungs, and causes coughing and asthma problems too. Statistics shows that about 6–8% of people in the world die because of inhalation of polluted air (***World health organization***, 1997). Hence, effective measures must be taken to control the vehicular pollution so as to reduce its effect on the health of the people. The usage of vehicles running on natural gas could reduce the rate of emissions, but it also has some disadvantages like high cost, short travel range, and heavy tank of fuel. The direct instruments involved are emission fees, emission standards, and market permits, whereas environmental taxes, technology standards, etc., are indirect instruments (Blackman and Harrington 2000) that are used for controlling air pollution.

This review focuses on analyzing the vehicular pollution in four different cities of India, namely Kota (Rajasthan), Jalgaon (Maharashtra), Amritsar (Punjab), and Mumbai (Maharashtra) carried out previously by assorted researchers. The effects of pollutants on health caused by greater exposure were also observed. In addition to it, the variation in the release of the pollutants at the day and night was also noticed.

2 Background

2.1 *Vehicular Pollution Study in Mumbai (Bhalerao et al. 2014)*

A study was conducted to understand the scenario of vehicular pollution in Mumbai City. The vehicular pollution in the city mainly is comprised of carbon dioxide, carbon monoxide, nitrogen oxide, unburnt hydrocarbons including lead, particulate matter, etc. Carbon monoxide was found to be major pollutant emitted from vehicles, causing almost ninety per cent of the total emission. Tables 1 and 2 give heavy vehicles plying in the city and growing vehicular density in Mumbai.

The authors reported that the air pollution levels remain low in monsoon and turn out to be outrageous in the season of winter. The cyclic alteration is ascribed to conditions of meteorology, for example, downpours, prevalent wind directions, the inversion frequency, turbulence, etc. The city has witnessed a noteworthy positive change in minimum temperature during the winter season which has increased the city's humidness, and pollution has lead to low visibility. Insufficient road space, deficiency of infrastructure for non-motored vehicles, severe congestion, and inefficacious management of transportation are the major bottlenecks in Mumbai's transportation system. A measurement air pollution level in Mumbai was brought by Municipal Corporation of Greater Mumbai (MCGM) and MPCB (Maharashtra Pollution Control Board). It was discovered that the levels of SO_2 were in the desired limit and an increment in the levels of SO_2 and NO_2 was seen. Levels of CO_2 showed a marginal rise. Yearly levels of SO_2, NO_2, RSP, and CO at traffic junctions during 2003–2012 are given in Figs. 1, 2, and 3.

The levels of air quality were observed at fixed locations for the year of 2005–2012 for its conformation with ambient air quality standards for SO_2, NH_3, NO_2, SPM and lead covering all testing sites which are depicted in Tables 3, 4, 5, 6, and 7.

The following measures were taken in Mumbai to control air pollution:

- An arrangement for controlling vehicular pollution was formed under the 1988 Motor Vehicle Act.
- Across the Maharashtra border, 22 checkpoints and 61 flying squads were made to check vehicle documents, tax payments, and vehicles entering and leaving the state.
- Environmental tax is levied on old vehicles in Maharashtra State from 15 October 2010.

Table 1 Heavy vehicles commuting through the city (Bhalerao et al. 2014)

S. No.	Heavy vehicles plying in the city	No. of vehicles
1	Trucks and Lorries	7600
2	Tankers	371
3	Three-wheelers delivery vans	32,000
4	Four-wheelers delivery vans	20,000

Table 2 Vehicular populace and its development (Bhalerao et al. 2014)

Year	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010
Total number of vehicles	1,190,420	1,316,123	1,393,647	1,533,816	1,631,837	1,715,044	1,806,974
Percentage of increase in vehicles	0.055	0.0973	0.0805	0.1006	0.0639	0.051	0.0536
Total vehicles converted to CNG and LPG	126,841	151,128	209,577	153,158	154,704	157,266	1.63,548

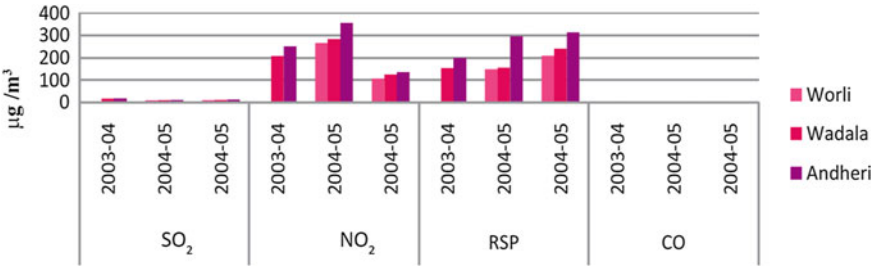

Fig. 1 Yearly levels of SO_2, NO_2, RSP (respiratory suspended particulate), and CO at traffic junctions, 2003–2005 (Bhalerao et al. 2014)

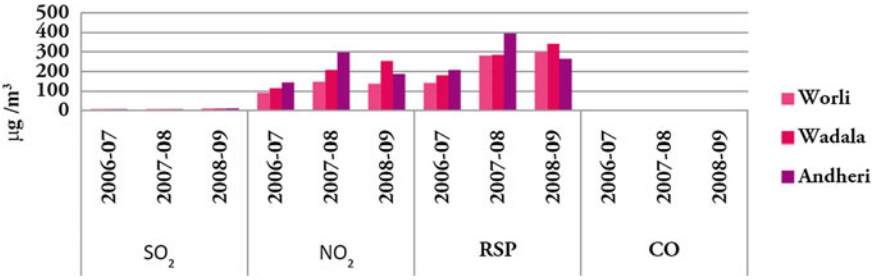

Fig. 2 Yearly levels of SO_2, NO_2, RSP (respiratory suspended particulate), and CO at traffic junctions, 2006–2009 (Bhalerao et al. 2014)

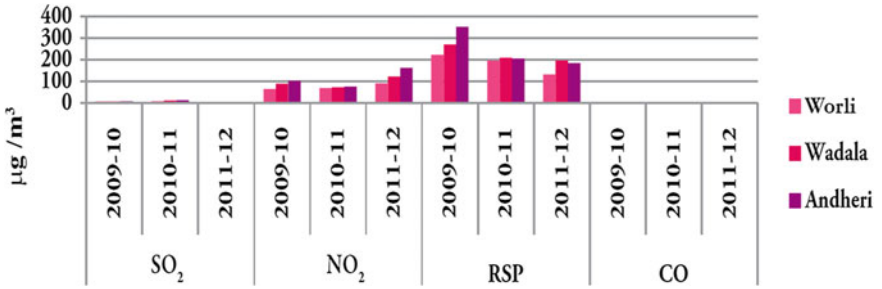

Fig. 3 Yearly levels of SO_2, NO_2, RSP (respiratory suspended particulate), and CO at traffic junctions, 2006–2009 (Bhalerao et al. 2014)

Table 3 Yearly average of SO_2, 2004–2012 (Bhalerao et al. 2014)

Site	SO_2 concentration-mg/m^3							
Year	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
Standard	NAAQ standard for SO_2 is 50 mg/m^3							
Worli	24	21	12	14	13	9	8	14
Khar	15	19	12	11	12	9	7	10
Andheri	23	16	10	11	13	12	8	11
Bhandup	28	24	12	14	18	14	10	12
Boriwali	17	14	10	8	8	7	7	9
Maravli	28	27	20	18	16	16	10	16

Table 4 Yearly average of NO_2, 2004–2012 (Bhalerao et al. 2014)

Site	NO_2 concentration-mg/m^3							
Year	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
Standard	NAAQ standard for NO_2 is 60 mg/m^3							
Worli	29	39	27	31	67	41	32	44
Khar	53	57	51	47	84	47	44	57
Andheri	47	51	46	47	86	53	40	56
Bhandup	38	49	33	34	67	29	34	40
Boriwali	20	25	17	19	31	22	14	20
Maravli	59	74	51	54	89	65	50	60

Table 5 Yearly average of NH_3, 2004–2012 (Bhalerao et al. 2014)

Site	NH_3 concentration-mg/m^3							
Year	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
Standard	NAAQ standard for NH_3 is 0.4 mg/m^3							
Worli	75	78	54	75	54	81	63	84
Khar	90	79	67	70	58	47	49	48
Andheri	85	79	61	71	66	82	51	52
Bhandup	77	73	59	62	59	46	47	52
Boriwali	85	75	54	50	39	49	37	38
Maravli	458	263	176	199	265	293	242	241

Table 6 Yearly average of SPM, 2004–2012 (Bhalerao et al. 2014)

Site	SPM concentration-mg/m^3							
Year	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010-11	2011–12
Standard	NAAQ standard for SPM is 140 mg/m^3							
Worli	145	185	150	185	183	201	197	205
Khar	235	278	266	258	252	250	221	219
Andheri	275	220	308	281	263	227	203	238
Bhandup	230	255	220	268	206	200	198	273
Boriwali	117	170	118	132	129	113	125	158
Maravli	316	401	392	439	389	603	642	760

Table 7 Yearly average of lead, 2004–2012 (Bhalerao et al. 2014)

Site	LEAD concentration-mg/m^3							
Year	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
Standard	NAAQ standard for LEAD is 0.76 mg/m^3							
Worli	0.1	0.2	0.19	1	0	1	0.16	0.14
Khar	0.1	0.2	0.24	5	0	0	0.18	0.15
Andheri	0.2	0.1	0.27	1	0	0	0.14	0.13
Bhandup	0.1	0.2	0.20	7	0	0	0.18	0.22
Boriwali	0.1	0.1	0.13	0	0	0	0.07	0.08
Maravli	0.2	0.3	0.48	24	1.30	2	0.37	0.34

- Mumbai Traffic Police introduced Pollution Under Control (PUC) Certificates for vehicles in accordance with the Central Motor Vehicle Regulations of 1989 and was mandatory for two-wheelers and four-wheelers.

Cleaner fuel specifications as laid by Bureau of Indian Standards for diesel and gasoline were made mandatory to be followed.

2.2 *Vehicular Pollution Study in Amritsar (Robin and Ashwani 2009)*

The author aimed to compare the pollution caused by the different categories of vehicles and estimated the total amount of pollutants released by them in the city of Amritsar. The data of the registered vehicles between the years 2004–05 and 2008–09 was collected from the district transport department, Amritsar, as shown in Table 8.

Vehicle was classified based on the space occupied/type of fuel used. The annual fuel consumption per vehicle was calculated using the following formula:

Annual fuel consumed (litres)/vehicle = Annual Mileage (km) ÷ Average Mileage/litre of fuel consumed (kms/litre).

This annual fuel consumption/vehicle was used for the calculation of annual emission of pollutants (tonnes/year).

The data for the amount of the released gases (NO_X, CO, and HC) by different categories of vehicle was collected, and the amount (g/l) was obtained as shown in Table 9.

Annual emission of the pollutants (tonnes/year) was obtained for each type of vehicle within the interval of 2004–2009 and was compared. From the results of CO emission by different categories of vehicles, it was found that the two-wheelers (scooters/motorcycles) contributed the most in CO emission in each year, while the four-wheelers using diesel as a fuel contributed least. These variations are represented in Fig. 4.

The results of HC emission depicted that two-wheelers' (scooters/motorcycles) contribution towards the emission of CO in each year was the most and the four-wheelers using diesel as a fuel along with cars/jeeps contributed least. These variations are shown in Fig. 5.

The maximum NO_X emission was by four-wheelers using diesel as a fuel, and the minimum emission was by three-wheelers and two-wheelers (scooters/motorcycles) as shown in Fig. 6.

Table 8 Registered vehicles from 2004–05 to 2008–09 (Robin and Ashwani 2009), (District Transport Office, Amritsar, 2009)

S. No.	Vehicles	2004–05	2005–06	2006–07	2007–08	2008–09
1	Cars/jeeps	5062	5308	6291	5989	6251
2	Scooter/motor cycle	26,401	28,945	26,092	24,215	21,252
3	Three-wheelers	633	958	951	930	918
4	Four-wheelers/diesel	1188	933	1592	1758	1660

Table 9 Amount of emission of different gases for each type of vehicle (Robin and Ashwani 2009)

S. No.	Type	CO (g/l)	HC (g/l)	NO_X (g/l)
1	Cars/jeeps	240	31	16
2	Scooter/motor cycle	304	215	1.8
3	Three-wheelers	257	161	1.8
4	Four-wheelers/diesel	19	8	37

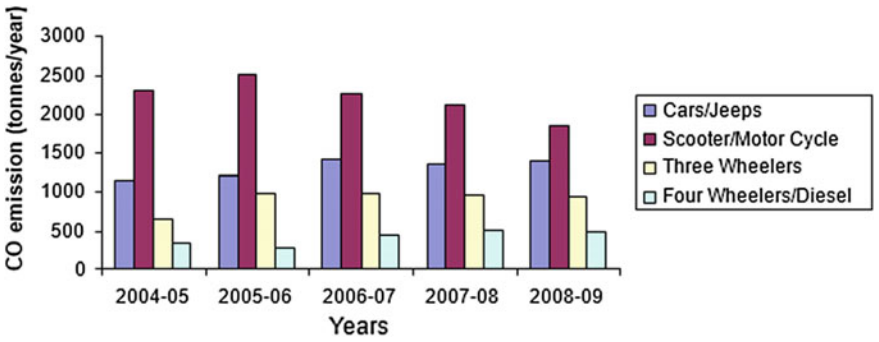

Fig. 4 Graphical representation of year-wise annual CO emission (Robin and Ashwani 2009)

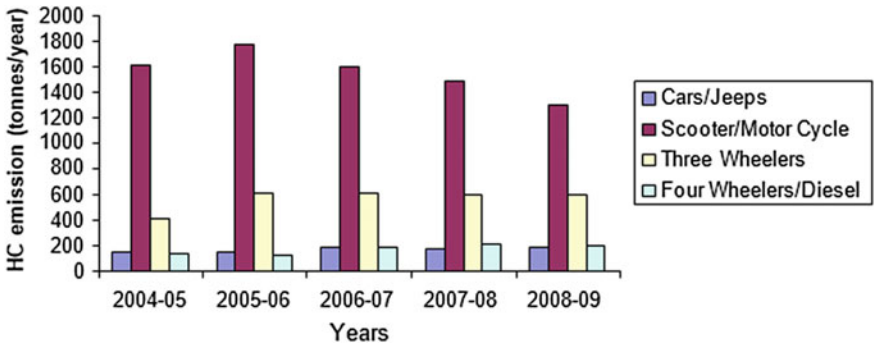

Fig. 5 Graphical representation of year-wise annual HC emission (Robin and Ashwani 2009)

From the data of annual emission of pollutants (tonnes/year) obtained for each type of vehicle shown in Fig. 7, it was concluded that scooters/motorcycles were the major sources for CO and HC emission, whereas cars/jeeps and four-wheeler using diesel as a fuel were the major source for NO_X emission.

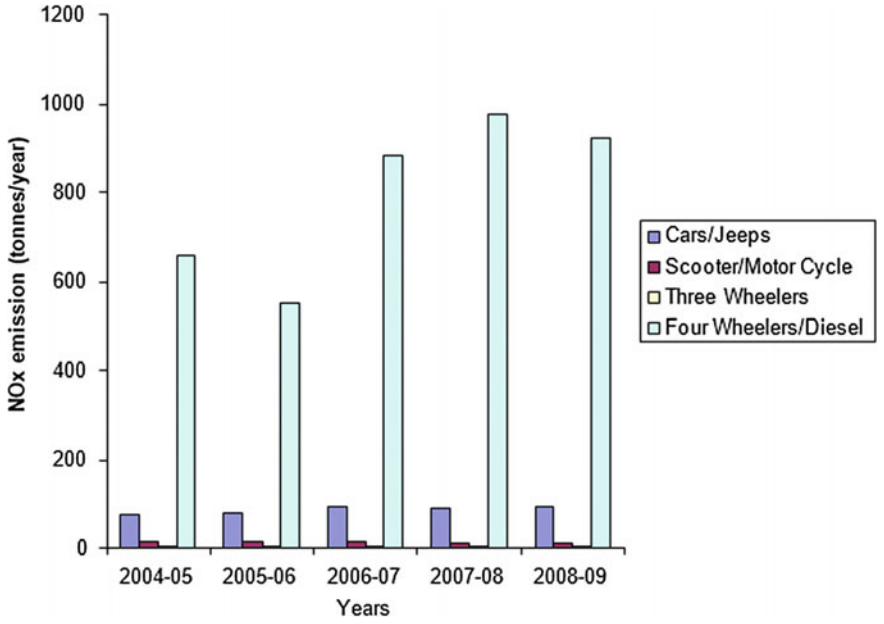

Fig. 6 Graphical representation of year-wise annual NO_X emission (Robin and Ashwani 2009)

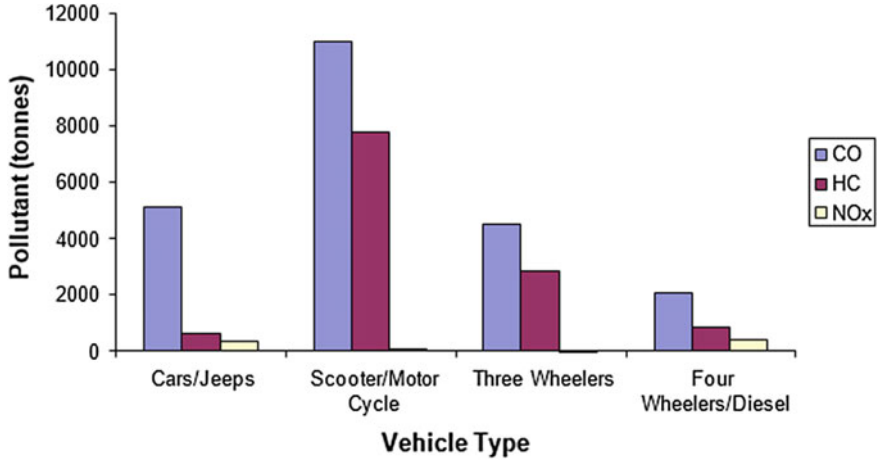

Fig. 7 Graphical representation of pollutants' impact during 2004–2009 (Robin and Ashwani 2009)

2.3 *Vehicular Pollution Study in Kota (Choudhary and Gupta 2016)*

This research study was conducted in the Kota City situated in the state of Rajasthan. In this study, the author mainly focused on estimating the amount of pollutants released by the vehicle in day and night time and later compared these two. Ten major road regions of Kota were selected, namely Rawatbhata road, Chambal Garden road, CAD. road, Mahaveer Nagar road, Jhalawar road, Bhamashah Mandi road, Gumanpura (Kotri) road, D.C.M. road, Kishore Sagar Talav road, and Nayapura road. A high volume of air sample was collected during the day and night time at each of the selected locations for assessment of pollutants released by vehicles. The major focus was on suspended particulate matter (SPM), SO_2, and NO_X. After analyzing the quantity of SPM, it was found that in most of the selected regions, the concentration of SPM in day was higher than that of night time. The variations of concentration of SPM during day and night time are shown in Fig. 8.

After the estimation of the amount of CO_2 released in day and night time, it was found that the graph (Fig. 9) did not have same pattern as, at some locations, the SO_2 released during night was found to be higher than the day time. This was because of the emission of SO_2 by the heavy vehicles that are only allowed to run in nights.

Similarly, the estimation of the amount of NO_X was done and the variations were obtained as shown in Fig. 10.

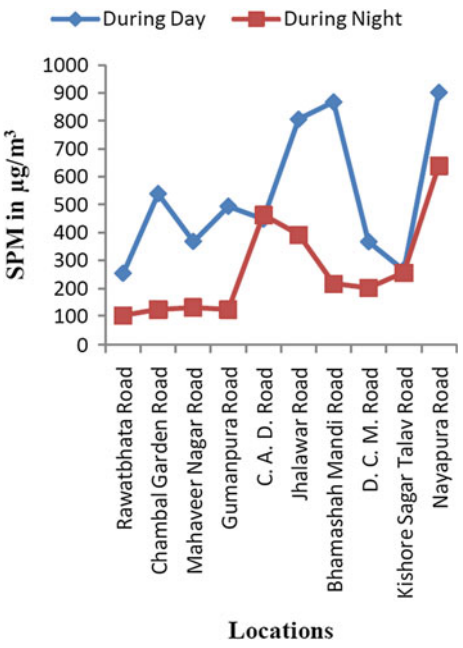

Fig. 8 Levels of SPM (microgram/m^3) at various locations during day and night (Choudhary and Gupta 2016)

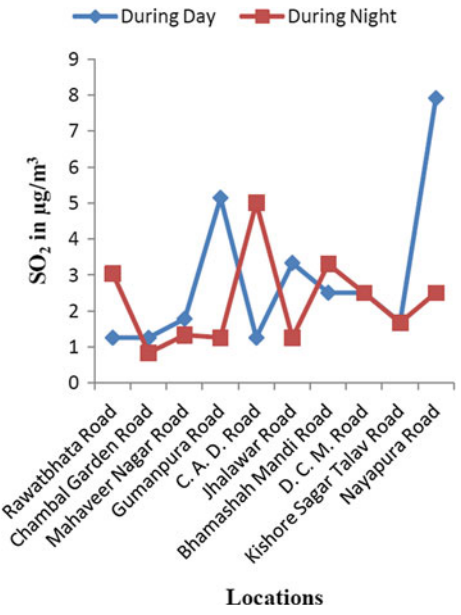

Fig. 9 Levels of SO_2 (microgram/m^3) at various selected locations during day and night time (Choudhary and Gupta 2016)

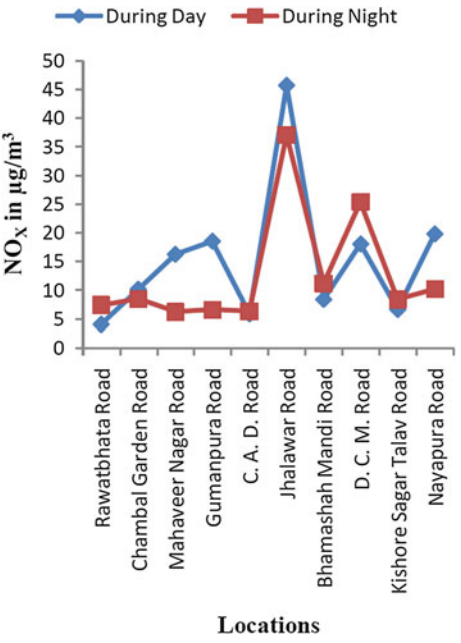

Fig. 10 Levels of NO_X (microgram/m^3) at various selected locations during day and night time (Choudhary and Gupta 2016)

After a detailed inspection performed in all the ten selected locations, it was observed that the concentration of SPM, SO_2, and NO_X was much higher during the day and night time as compared to the standard values given, Central Pollution Control Board of India (CPCB). Hence, it was concluded that the air quality was not good for the residents of Kota City.

2.4 *Vehicular Pollution Study in Jalgaon City (Ingle et al. 2005)*

The ambient air quality monitoring was carried out through the city of Jalgaon (NH-6) in the state of Maharashtra, representing the main road crossings in the study area. The study focused on estimating the pollutants released by the vehicles and the need for personal protective equipments by traffic policemen during the working hours. For this study, 60 traffic policemen with no smoking habit from the different parts of Jalgaon were examined along with 60 healthy young adult natives of Jalgaon City who were the control samples. Control samples were chosen based on the factor that lifestyle of both traffic policemen and control samples should be nearly same. The control samples were generally used for the comparison of results of traffic policemen. The whole year was divided into four different parts based on the four different seasons, and air quality index at different locations for each season was calculated. The results obtained are shown in Table 10.

The evaluation of the respiratory system of all the policemen and the control samples was done by the pulmonary function test. Pulmonary function test helped in analyzing the health of each traffic policemen. The relation between the air quality index and the health of the traffic policemen was established. It was seen that in each season, the health of the traffic policemen became poorer as the air quality index increased. This study also showed that the performance of lungs of traffic policemen was depleting because of their exposure to the vehicular pollution. The pulmonary function test concluded that most of the traffic policemen were vulnerable to asthma and it was suggested that traffic police officers use personal protective nose equipment obligatorily during duty hours to help them prevent vehicular pollution.

Table 10 Monitored air at various selected places from May 2003 to April 2004 in Jalgaon City (Ingke et al. 2005)

Sampling Locations												
S. No.	Season			Prabhat		Ajanta				Icchdevi			
		SO_2	NO_X	RSPM	SPM	SO_2	NO_X	RSPM	SPM	SO_2	NO_X	RSPM	SPM
1	Pre-monsoon	49 ± 6	53 ± 3	224 ± 44	437 ± 64	104 ± 50	94 ± 32	264 ± 104	917 ± 337	151 ± 37	121 ± 28	197 ± 54	957 ± 380
2	Post-monsoon	58 ± 15	48 ± 8	182 ± 15	410 ± 62	134 ± 40	122 ± 23	299 ± 198	848 ± 164	119 ± 15	98 ± 12	246 ± 112	730 ± 145
3	Winter	94 ± 7	83 ± 8	239 ± 6	613 ± 96	139 ± 18	121 ± 9	213 ± 37	886 ± 95	114 ± 7	96 ± 9	222 ± 7	879 ± 29
4	Summer	57 ± 18	53 ± 8	255 ± 116	597 ± 284	78 ± 6	67 ± 20	302 ± 92	819 ± 338	63 ± 19	73 ± 19	251 ± 173	857 ± 509
5	Annual average	64 ± 17	58 ± 16	224 ± 27	515 ± 105	113 ± 28	101 ± 26	269 ± 4I	867 ± 43	112 ± 36	97 ± 19	229 ± 24	855 ± 94

*The values are in $\mu g/m^3$. *The values are average ± SD of three estimations. The annual average is of 12 estimations

3 Conclusion

Further understanding of vehicular pollution will require a background of previous research studies. In this review, we have conferred studies conducted in four different cities of India on vehicular pollution and its impact on the environment in order to that an idea can be developed concerning the quantitative estimation of pollution and its impact on the environment. This review is often thought about as a useful base to the researcher for further study on vehicular pollution and city air pollution in various parts of the country. It can be concluded that vehicular pollution has harmful effects on the atmosphere, viz. temperature changes and problems like asthma in humans. Constant increase in the quantity of pollution due to vehicles in the environment is due to urbanization and increase in population.

Name of the cities	Conclusion/key points
Mumbai (Maharashtra)	Growth in the population and vehicular density has led to rise in the level of pollutants in the city. Level of air pollution is down in monsoon and high in winter. Unpredictable weather, temperature change, and depletion in air quality are major concerns of air pollution in the city
Amritsar (Punjab)	Among all the categories of vehicles that are classified, two-wheelers are the major source of the vehicular pollution. It was also seen that the effect of increase in population has led to increase in no of vehicles resulting in more vehicular pollution
Kota (Rajasthan)	Level of pollution during day time is higher than the pollution level at night. Hence, the harm to the health due to vehicular pollution is more probable during the day time. So, one needs to be extra precautious against continuous exposure to the traffic. The major sufferers of the vehicular pollution are the local residents as they are continuously exposed to the polluted air
Jalgaon (Maharashtra)	Higher earnings, motility, and faster development of the city have contributed towards the growth of motorized vehicles. Due to higher exposure of the traffic police officers to vehicular pollution, a reduction in the lung efficiency was seen. Personal protective nose equipment for traffic police officers is suggested during their working hours

Understanding the importance of clean environment and harmful impacts of vehicular pollution on human health, the following suggestions might facilitate to reduce the same:

- Emphasis must be given on electrical running vehicles.
- Odd–even must be implemented strictly in cities with heavy population.
- Fixed volume of cars must be released per year from manufacturers.
- Carpooling must be encouraged in workplaces.
- Vehicles of more than 20 years life must be banned.

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Repercussion of Electromagnetic Radiation from Cell Towers/Mobiles and Their Impact on Migratory Birds

Nair Shravan Surendran, Nihal Anwar Siddiqui, Prasenjit Mondal and Abhishek Nandan

Abstract Electromagnetic Radiation (EMR) are the radiations where the electric and magnetic field vary simultaneously and which generally comprises of x-rays, gamma rays and visible light. They are generally emitted from electrically charged particles and are a major source of radiation from mobile phones and cell tower antennas. EMR poses as a prominent health hazards on birds, humans, other animals, plants and environment. Sparrows, pigeons, parrots and swans are some of the birds highly affected by these radiations. These impending effects are not lesser than any form of environmental pollution. When birds come in contact with radio frequency waves they clutter and fly every which way, which hurt their regular navigational capacities. Various outcomes of these radiations lead to neural damage, locomotory defects, endangering reproductive capacities in birds. Identification of the recurrence, span of non-ionizing electromagnetic fields causing harm on environment would develop procedures for relief and would empower the best possible utilization of wireless devices to appreciate its monstrous advantages, while assuring one's well-being and that of the earth. Hence, it is crucial that stricter radiation standards must be authorized by the legislators. A couple of investigations on negative outcomes of such radiations on birds, human well-being, and environment have been examined and inventive proposals for remediation proposed.

Keywords EMR · Neural · Non-ionizing · Legislators

1 Introduction

Cell phones are presently a vital piece of modern life. The across the board utilization of mobiles has been followed by setting up an expanding number of base station antenna on poles and buildings. There is huge increase in the amount of cell

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towers without thinking about its drawbacks. Everywhere throughout the world, individuals have been discussing related impacts on health because of radio waves from mobiles and cell towers. There has been an exponential growth of mobile towers, i.e. TVs, radio and microwaves over the last 10 years. Such towers have negative impact on people, however, also poses higher impact on migratory birds, out of which about 4 to 5 million are approximated to die due to collision from towers (Everaert and Bauwens 2007).

Recently, birds have been constantly prone to EMR and Radiofrequency waves from different sources like UMTS, GSM, 3G remote telephones. Wireless Local Area Network, Wireless Personal Area Network and Digital Enhanced, Cordless Telecommunications that are raised unpredictably prior no investigations regarding natural effect estimating vast haul impacts (Balmori 2009). Further their impact is portrayed in terms of signal variations, intensities, and prolonged durations. The most prominent segment of this exposure starts from portable media telecommunications. Additionally, EMR pollution being a generally new ecological problem, there is an absence of built-up standard methods and conventions to eradicate the EMR effects particularly among birds, which frequently make the assessments between studies troublesome (Bhattacharya and Roy 2014; Mind the Gap 2019).

Here the classification of EMR into its further components is discussed in Fig. 1.

From various studies, it was observed that migratory birds and basically aves are influenced by electromagnetic fields. Their probability to cope with the exposure is disturbed and their immune system is harmed due to it. Microwave radiation, or, in other words radiofrequency radiation (RFR), is transmitted by cell phone towers. The nervous system and immune system of small insects and birds are considerably affected by long term introduction to low-level frequency waves. Since

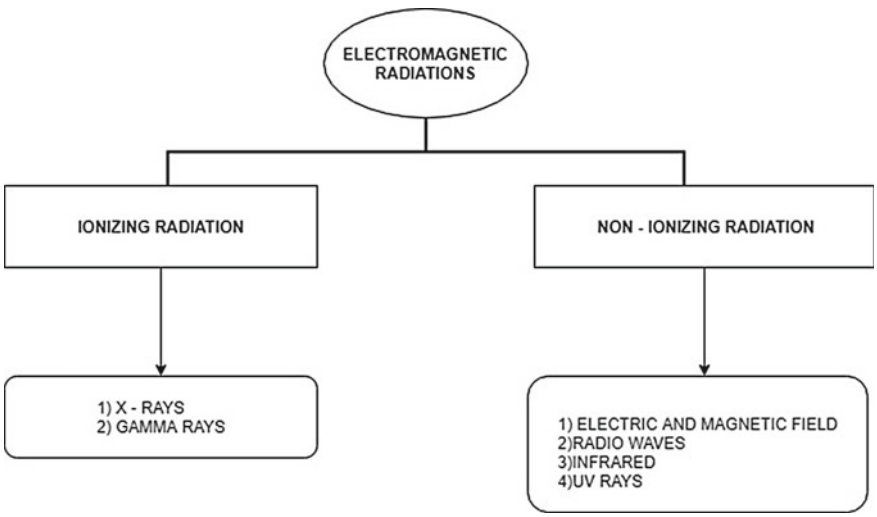

Fig. 1 Electromagnetic radiation classification

electromagnetic radiations, otherwise called electrosmog can't be felt, seen or smelt one would not understand their potential damage over extensive stretches of introduction until the point that they show as biotic complication. Over-presentation of non-ionizing radiations induces health risks in spite it being viewed has less impactful than ionizing radiation (Advisors 2015; Biology et al. 2019).

2 Mobile Tower Radiation Pattern

The frequency range of antennas in mobile towers range from 869 to 890 MHz for CDMA, 935 to 960 MHz for GSM900, 1805 to 1880 MHz for GSM1800 and 2110 to 2170 MHz for 3G (Everaert and Bauwens 2007; Us et al. 2016). The RF-EMF waves range from 10 MH to 300 GHz. Mobile device innovation employs frequency range from 800 MHz to 3 GHz what's more, these tower utilizes a recurrence of 900 or then again 1800 MHz, for the most part, known as microwaves. (Biology et al. 2019).

The different exposure range of radiofrequency waves from a standard cell tower is shown in Fig. 2.

There are two types of microwave radiation, namely,

1) Thermal—depends on the temperature and the material of the body (e.g. blackbody radiation)
2) Non-thermal—depends mainly on the temperature of the body (e.g. synchrotron radiation).

The present presentation safety norms are chiefly dependent on the thermal impacts, which are deficient. Non-thermal impacts are a few times more unsafe than thermal impacts. Rate at which human body absorbs this radiation is termed as

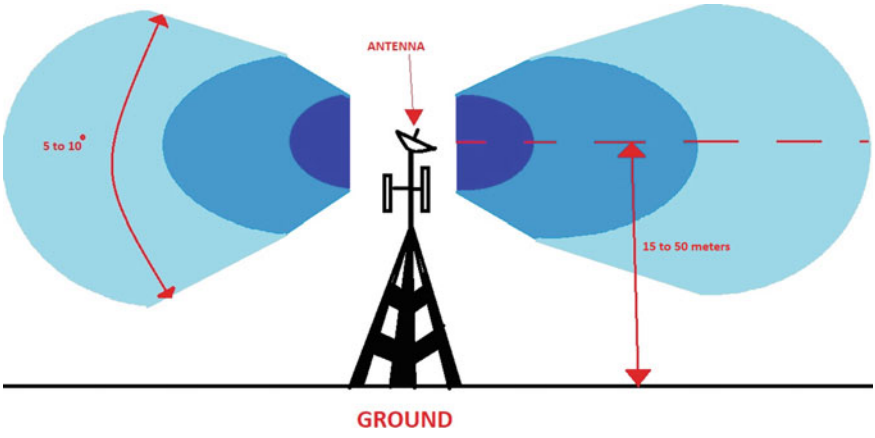

Fig. 2 Cell tower antenna—radiation pattern

Table 1 SAR value for different mobiles according to 2019 report (Rate 2019)

S. No.	Model	SAR (w/kg)
1	Mi A1	1.75
2	One plus 6T	1.54
3	Oppo F9 pro	1.312
4	iPhone Xs	1.17
5	Vivo Nex	1.06
6	Honor view 20	1.03
7	Redmi Note 7 pro	0.996
8	Nokia 8.1	0.711

Specific Absorption Rate (SAR). It basically specifies the radiation from cell phone. Its unit is watts per kg (W/kg) (Rate 2019). The biological impacts rely upon the amount of the energy a living organism absorbs in its body and not what is already present in space. Recurrence of transmission, distance between the radiating source and the organism's size, water content are the factors that influence the induction of RF-EMF radiations. Introduction will always be lesser from towers at extreme conditions than from phones.

The values of SAR with respect to different mobiles are given in the table as follows;

Table 1 indicates the different mobile phones available in the market according to 2019 reports arranged in descending order of their SAR values whereas the acceptable value of SAR is 1.6 W/Kg.

3 Comparative Study of EMR on Birds

- Everaert and Bauwens (2007), developed a model to study the long term exposure pattern on house sparrows in six different districts in Belgium. They sampled around 150 pin locations in those six areas to identify the strength of radiofrequency waves and variation in their habitat. For this study they opted for Chi^2-tests, $P < 0.001$ and AIC-criteria. Minimum and maximum value of electric field strength were determined for GSM 900 MHz and GSM 1800 MHz (Everaert and Bauwens 2007). Later these areas were taken as a straight out factors in all models and believed it to be an intermediary for unknown obscure variable. S-PLUS v. 6.2 software was used for the analysis of this statistical data. This experiment led to the observation that the amount of house sparrows seen in those locations is inversely proportional to the electric field values of GSM base stations and thus implies that the behaviour of House Sparrows is negatively impacted because of the continuous exposure of high levels of radiation (Everaert and Bauwens 2007).

- Rafiqi et al. (2016), studied the nature of radiofrequency waves and how they affect the DNA and cause genetic disassociation. Further, it was identified that these radiations have an adverse effect on birds neural, behavioural, locomotive and reproductive capabilities. Later they classified their research into impending impacts on humans, animals, birds, insects and came into conclusion that the electromagnetic relation of was done to determine the distance radiation with the biosystems needs to evaluated to determine its extent of damage (Rafiqi et al. 2016).
- Stephanie et al. (2009), studied possible impacts of mobile towers on migratory birds and bats in Rock Creek Park, Washington, D.C. for 3 continuous years (2006, 2007 and 2008). He used double sampling method for his study consisting of ground sampling and net sampling. The tower search grids consisted of 21 N–S transect lines 100 m in length cantered on the tower, accompanying a 10 000 m^2 area. In addition to ground sampling, two to three 25 ft × 25 ft nylon nets were placed at each tower site with an aim to safeguard the birds that might collide with the towers and fall. Search for carcass was done on daily basis. Further Monte Carlo Simulation was done to determine the distance of carcass with respect to the tower. Whereas determination of difference in mortality among the different plots was done by Pearson's Chi^2-test. They came into conclusion that towers with a height greater than 61 m pose a higher risk for the migrating birds also from their data it was clear that the monopole towers were not a majorly endangering the migratory birds in those locations (Ferebee et al. 2009).
- Durgam et al. (2017), conducted a 6-month survey in Bijapur district to identify the impact of mobile tower radiation on birds. This survey focused on the different types of birds in the vicinity before and after mobile tower. 9 towers were selected in specific and the radiations emitted by those towers along with the bird count were estimated. These data were then tabulated by using SPSS. The results obtained signified that over half the population of birds (i.e. from 475 to 245 birds) in the area have been reduced after the instalment of the tower within a span of 6 months (Singh 2017).
- Balmori (2009), studied the radiofrequency radiation and its ill effects from wireless telecommunications on wildlife. He explored different aspects affecting the birds, insects, amphibians, plants, and trees. Also investigated various physical mechanism adherence, alarm, and aversion behaviour, reproductive capability and impact on nervous system because of these radiations. He came into conclusion that the microwave radiation damages the nervous system by altering electroencephalogram, causes problems in building and functioning capability, embryonic development, locomotion, genetic, and developmental growth of birds and that certain ban on mobile towers should be imposed where endangered species are present (Balmori 1088).
- Ghildiyal et al. (2014), compared the current scenario of mobile radiation in India with that of the world. They focussed on the standards and laws in India regarding various factors of cell tower and how they lack with respect to other nations. Studies suggest that strict radiation norms should be incorporated

wherein the prescribed guidelines should be limited inside for residential or office buildings, schools, hospitals (Us et al. 2016). Also to increase the frequency of towers but with lesser power transmission (Ghildiyal et al. 2014).

- Bhattacharya and Roy (2013), conducted a study to determine the interrelation between avian occurrences, nesting and electromagnetic radiation emitted from the towers at Kalyani, West Bengal. Determination of number of birds and their nest also recording the respective power density in different locations was done by point count method. Further nest survey for all common birds along with measurement of the extent of exposure to cell phone radiation was done. It recorded 19 species of bird with only 2 active nests in the vicinity from the active nest survey that too situated 80 m away from the tower. Hence concluded that areas having lower radiation impact generally those away from towers have higher count of birds than those near the tower (Bhattacharya and Roy 2013).
- Sivani and Sudarsanam (2012) studied the factors related to EMR which affects the birds and other living beings. These factors are RF-EMF Radiation, specific absorption rate, cell tower standards in India and related them to a different scope of study to determine its ill effects on birds, humans, biosystem and ecosystem, insects, plants, mammals, amphibians and reptiles. They found that long-term exposure of these radiation causes Electrohypersensitivity and EFI Syndrome which are one of the major problems faced by countries like United Kingdom and Sweden these days (Biology et al. 2019).
- Bhattacharya and Roy (2018), stated that only 3% of total electromagnetic radiations are on birds. These exposures biologically affect the birds. It was seen that birds are severely affected during breeding season. They found that microwaves effects the nervous system of birds which is directly dependant on the penetration depth whereas electromagnetic radiations affect the flying and caging birds by constricting the stabilizing period in birds. It was also for egg production seen that microwaves affect the avian dominance behaviour and productivity of white storks whereas Short term exposures led to 50–60% decline in insect productivity that is one of the many reasons for the disappearance of sparrows in urban areas (Bhattacharya and Roy 2014).
- Kalel et al. (2012), practically determined the correlation of birds with increasing urbanization in Amravati city, Maharashtra for one month. 61 different species of birds were considered for this study where it was observed that many birds were seen in the urbanized areas rather than industrial area. This survey was done by line count method. They came to the conclusion that increasing mobile towers due to globalization has negative impact on the bird population which results into reduction of number of species in the urban environment although populations of fewer bird species were increasing at the same time, number of species is greatly reduced in urban environments (Ramesh et al. 2014).

4 Impact of Radiation on Birds

It was seen that radiofrequency waves destroy the earth's magnetic field which the birds utilize for their navigation. While short-time exposure to electromagnetic fields causes them to disorient and fly in different directions. Millions of birds die every year due to the harmful radiation from cell tower. It can be never seen that sparrows, bats, pigeons and any other birds flying around a cell tower, it is because surface area of birds are moderately bigger than their weight with respect to human beings. Hence they are more exposed to the radiation. Fundamental research on migratory birds showed solid negative relationships between extent of radiation from the tower and birds activity such as breeding, locomotion, and reproduction in the vicinity of the EMR waves (Bhattacharya and Roy 2013). Impacted immune systems will always expand the chances of a bird to have diseases, infections, parasites. Plumage weakening is one of the first symptoms related to weakening or ailment in birds which cause damage to the feathers due to stress (Balmori 2005). Microwaves can influence regenerative growth in birds. Its presentation influences regenerative accomplishment of kestrels, expanding fertility, egg size and embryonic improvement yet diminishing hatching capacity. Higher exposures to these radiations can cause genotoxic effects. Exposure to EMR field is appeared to summon differing reactions changing from aversive conduct reactions to formative abnormalities and mortality in avian. Non-thermal levels of non-ionizing radiation can influence a bird's capacity to recuperate from intense physiological stressors, other than potential physiological and behavioural repercussions (Mind the Gap 2019). Mainly accidents occur during night, fogs, rough climate as during that time they use the earth's magnetic field for their navigation purpose which leads to disorientation of path by the microwave radiation from telecommunication masts. Electromagnetic pollution is one of the main causes for decrease in bird population (Rodgers and Hore 2009).

Table 2 gives information about the number of birds before and after 3 months of installation of cell phone tower in Bijapur district.

Table 2 Bird count in bijapur district (Singh 2017)

S. No.	Birds	Before	After 3 months
1	Peacock	50	10
2	Wild Duck	25	10
3	Crow	150	100
4	Parrot	55	20
5	Cuckoo	25	15
6	Sparrow	25	10
7	Wild Pigeon	75	50
8	Eagle	50	25
9	Woodpecker	20	5
	Total	475	245

4.1 Effect on Sparrows

There has been a drastic decline of sparrows in the past decade. Generally in the vicinity of cell towers it has been seen that sparrows affected due to exposure have behavioural changes causing frequent fighting, young one mortality and abandoned nests. Their quality of being so responsive towards the changes occurring in environment makes them a prominent favoured indicator species present in the environment. A healthy ecosystem for human beings with respect to air and water quality, vegetation and other parameters indicates a stable sparrow population (Us et al. 2016). There has been a vast reduction in population of house sparrows indicating that because of these environmental changes the modern livelihood is experiencing conditions that are not suitable for human health (Us et al. 2016). In London, since 1994, there has been fall of 75% House Sparrow population (Mind the Gap 2019) that was experienced after the growth of cell towers (Release 2009). It has been observed that the microwave radiations are dangerous for House Sparrows also that the increasing concentration of microwaves has caused a decline in their population. Punjab university once carried a study where they exposed 50 eggs of House Sparrow for a duration of 5–30 min to the electromagnetic radiation as a result of which all 50 embryos were found damaged (Mind the Gap 2019).

4.2 Effect on White Storks

White storks are very sensitive to electromagnetic radiations that influence their environment via electrical impulses. This exposure causes deterioration of health, changes in behaviour and reproductive activity in storks. They usually live in those areas where there is a higher exposure of electromagnetic radiation which indicates a difference in total productivity but not in partial productivity between the near nests and those far from the antennae. Microwaves possess higher potential to induce adverse reactions on their behaviour whereas chronic exposures have long-term effects on their health and other vital areas.

4.3 Effect on Honey Bees

Bees use internal ‘clocks’ for navigation (Balmori 2005). These biological clocks are affected by the radiations from cell tower because of which they are unable to make up for the changing position of the sun throughout the day resulting in navigational error. There has been a large reduction in the population of bees due to the disorientation caused due to microwaves. The stressful condition created by these radiations tends bees to stimulate the body’s mechanism to fight against it leading to Colony Collapse Disorder or Vanishing Bee Syndrome. The steady

decline in bees can cause more calamities in future than global warming. Electromagnetic radiation on honey bees affects its navigation, reproduction, honey production ability and misbalance in biological clocks (Farrell et al. 1997).

5 Conclusion

It has been observed that EMR poses a high threat to migratory birds. Microwave and radiofrequency are the major reason for the decline of bird's population. Study shows that long term exposure of non-thermal radiations have caused genetic, neural, reproductive, locomotory problems in birds. EMR is thus a growing environmental issue. They can be stated as an invisible enemy that no one can sense or see but destroying one's life. No longer will mobiles be known as cigarettes of 21st century, essentially being much more dangerous than cigarettes on long term exposure. Thus, there is an urgent need to look at this issue of increasing ill effects of cell tower radiations. Electromagnetic radiations should be considered as a pollutant and strict norms should come into action. So the solution for this can be termed as to have increased amount of cell towers with lesser transmitted power also to provide with boosters where the power is less. This does not mean that all cell towers should be destroyed rather solutions should be found to reduce the emission. Moreover, there are lesser data available about EMR effects on birds and hence there is an urgent need to look into this issue by initiating scientific studies on it. Unfortunately ignorance by the mobile companies and unaware people add to this disaster and the birds are suffering from it silently.

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Sources of Heavy Metal in Indoor Air Quality

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Abstract Indoor air quality is based on physical, chemical, and biological attributes of air in the indoor environment of any building facility. Lack of proper ventilation system employed is another main source of the indoor air pollutants (Utell 2000). The lack of ventilation system and more use of different types of products like batteries, cell phone, lights, etc., deteriorate the indoor air quality by reducing the dilution of the indoor air pollutants. Heavy metals named are mercury, lead, cadmium, chromium, arsenic, iron, etc. Heavy metals are highly dangerous to human, especially for children.

1 Introduction

In this paper, an attempt has been made to review the sources of heavy metal degrading the indoor air quality. It is a major concern in the developed and developing countries, for making the houses energy-efficient and relatively airtight, reducing ventilation and increasing pollutant concentrations. They can be indistinct and do not always generate easily recognized effect on health (Al-Khashman 2004). Indoor air quality has a major effect on rural area, where some 3.6 billion people use traditional fuel sources for domestic activity such as firewood, charcoal, and cow dung. We use different products inside the building, and most of the products generate many types of heavy metals like mercury, lead, zinc, etc., and all cause indoor air quality (Wu 1995). Some general causes that degrade the indoor air quality are indoor electronic equipments, cooking, smoking, temperature control, insecticides and pest control and perfumes deodorants and cleaning agents (Nandan et al. 2019).

As per WHO, 4.3 million people who die annually from exposure to household air pollutants, most perish from stroke (34%), ischemic heart disease (26%) and chronic obstructive pulmonary disease (22%). Pneumonia and lung cancer account for 12% and 6% of deaths, respectively.

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1.1 Source of Heavy Metals

Figure 1: Represents the sources of heavy metals along with permissible limit which is basically the allowable concentration of these heavy metal; the acute exposure is not much harmful but the long-time exposure is chronic.

1.1.1 Volatile Organic Compound Sources in Indoor Air

Domestic products include:

- Paints, varnishes, and other solvents,
- Cleansers and disinfectants,
- Energy storage and automobile products,
- Dry cleaning of clothes,
- Components used in buildings and furnishings,
- Xerox and other printing devices,
- Craft materials including glues and permanent markers.

1.1.2 Health Effects of VOC's

- Irritation in respiratory tract and eye,
- Headaches, loss of dexterity, and nausea are the symptoms occurred due to VOC's,

Pollutants	Major sources	Effect on human health	Permissible level (mg/l)
Arsenic	Pesticides, fungicides, metal smelters	Bronchitis, dermatitis, poisoning	0.02
Cadmium	Welding, electroplating, pesticide fertilizer, Cd and Ni batteries, nuclear fission plant	Renal dysfunction, Lung disease, Lung cancer, Bone defects (Osteomalacia, Osteoporosis), increased blood pressure , kidney damage, bronchitis, gastrointestinal disorder, bone marrow, cancer	0.06
Lead	Paint, pesticide, smoking, automobile emission, mining, burning of coal	Mental retardation in children, developmental delay, fatal infant encephalopathy, congenital paralysis, sensor neural deafness and, acute or chronic damage to the nervous system, epilepticus, liver, kidney, gastrointestinal damage	0.1
Manganese	Welding, fuel addition, ferromanganese production	Inhalation or contact causes damage to central nervous system	0.26
Mercury	Pesticides, batteries, paper industry	Tremors, gingivitis, minor psychological changes, acrodynia characterized by pink hands and feet, spontaneous abortion, damage to nervous system, protoplasm Poisoning	0.01
Zinc	Refineries, brass manufacture, metal Plating, plumbing	Zinc fumes have corrosive effect on skin, cause damage to nervous membrane	15
Chromium	Mines, mineral sources	Damage to the nervous system, fatigue, irritability	0.05
Copper	Mining, pesticide production, chemical industry, metal piping	Anemia, liver and kidney damage, stomach and intestinal irritation	0.1

Fig. 1 Sources of heavy metal its effects and permissible limits. *Source* http://www.ijp-online.com/article.asp?issn=0253-7613;year=2011;volume=43;issue=3;spage=246;epage=253;aulast=Singh

- Damages to liver, kidney, and CNS,
- Eyesight disorders and memory destruction.

1.2 Lead Sources in Indoor Air and its Health Effect

Mining, manufacturing, and burning of fossil fuel are termed as anthropogenic activities which have increased the amount of lead and its compounds in immediate surroundings. Industries like batteries making, beauty products, ammunitions, solder, and pipe use lead as the sources material which is a common source of lead in environment (Martin 2009). Lead is too lethal in nature, and it is used in different products such as paints, varnishes, and gasoline. The major sources of Pb contact are lead-based paints, petroleum products, beauty products, toys, household dust, infected soil, and industrialized emission (Martin 2009). Poisoning occurred due to lead which leads to various distinctive diseases, and their symptoms are easily seen in children's and adults, which include CNS and the gastrointestinal tract (Matschullat 2000). Water-carrying pipes may be made of Pb which can degrade the quality of water (Brochin 2008). As per EPA, it is considered as cancer-causing compound. Deposition in the body depends on the flow of blood into various tissues, and almost, 93% of lead is deposited in bones as unsolvable phosphate (Papanikolaou and Hatzidaki 2005).

Pb toxicity effects can be either acute or chronic immediate effect which includes lead poisoning. Symptoms like loss of appetite, headache, hypertension, lower and upper abdominal pain, dysfunction of renal, exertion, sleeplessness, arthritis, and hallucinations are effects of acute toxicity, and it occurs in an industry which uses lead. Symptoms of chronic exposure like mental retardation, birth defects, autism, various allergies, dyslexia, weight loss, hyperactivity, paralysis, weakness of muscles, and brain and kidney damage, and even death are effects of chronic toxicity (Martin 2009; Taylor and Winder 2012). Environmental and domestic uses of lead are reasons for lead diseases, but we can eliminate the risk associated with lead exposure by taking proper preventive (Brochin 2008).

1.3 Arsenic Sources in Indoor Air and its Health Effect

Both natural and anthropogenic activities have resulted in arsenic contaminations. Mining and processing of ores are the major sources of arsenic which is termed as anthropogenic activities. The presence of arsenic in air and land is due to the smelting process. Sedimentary and meta-sedimentary bedrocks (Smedley 2002) are the sources of arsenic. Paints, varnishes, dyes, soaps, metals, and semiconductors are the industries that contain arsenic. Pesticide and fertilizer industries and animal feeding operation are the sources of arsenic which release large amount of arsenic in the environment. Arsenite and arsenate are more harmful to human health as they

are carcinogen (cancer-causing compound) and may lead to liver, lungs, urinary bladder, and skin cancers.

Arsenic exposure to humans is via air, food, and water. Arsenic toxicity is mainly due to contaminated drinking water worldwide (Chowdhury and Biswas 2000). Range of arsenic in groundwater is 10–100 times as per WHO guideline for drinking water (10 μg/L) (Hoque and Burgess 2011). Water might get polluted due to improper disposing of chemicals, pesticides containing arsenic, or natural mineral deposit. Toxicity of arsenic may have acute or chronic effects, and arsenicosis is effect of chronic exposure. Pigmentation and keratosis are the exact skin lesion and the result of chronic arsenic exposure (Martin 2009).

1.4 Mercury Sources in Indoor Air and its Health Effect

Indoor surroundings consist of heavy metal mercury which is highly toxic in nature. Poisoning caused by mercury is also known as acrodynia or pink disease. Pharmaceutical industry, paper and pulp industry, preservative manufacturer, agriculture industry, and chlorine and caustic soda manufacture are sources of mercury (Morais 2012). Mercury is capable of combining elements to form organic and inorganic mercury compounds. An exposure of a high quantity of mercury is harmful to kidneys, the growing fetus, and brain (Alina 2012).

Hg is available in most foods in the range of <1–50 μg/kg. Organic mercury is lipophilic in environment and can easily enter across the biomembranes; we can easily notice elevated level of Hg in different kinds of fish and in the liver of lean fish (Conor 2007). Microbes easily change mercury available in land and water into methyl mercury; EPA has stated that mercuric chloride and methyl mercury are cancer-causing compounds. The CNS of humans is too responsive to different types of mercury. Elevated level of mercury exposures can alter brain functions which include symptoms like shyness, memory loss, irritability, and degradation of vision and hearing. Lung damage, vomiting, diarrhea, nausea, and high blood pressure are caused due to exposures with vapors of metallic mercury at high levels for shorter span of time. Depression, memory loss, headache, and hair loss are symptoms of organic mercury poisoning (Martin 2009). Environmental Protection Act and WHO (WHO 2004) have set a standard for drinking water that contains low level of mercury 0.002 mg/L.

1.5 Cadmium Sources in Indoor Air and its Health Effect

Metal that arises in the twentieth century is cadmium. It is a secondary product made in the manufacturing of zinc. Soils and rocks, as well as coal and mineral fertilizers, contain some amount of cadmium. Manufacturing of batteries, pigments, plastics and metal coatings, and electroplating industry uses cadmium

(Martin 2009). As per International Agency for Research on Cancer (Henson and Chedrese 2004), Cd and its compounds are known as Group 1 cancer-causing compounds. Natural volcanic eruptions, climate change, and anthropogenic activities such as mining, smelting, smoking, incineration of solid waste, and fertilizer manufacturing release cadmium in the environment. Cadmium toxicity includes acute and chronic effect (Chakraborty and Dutta 2013). It can cause bone damage, and inhalations of high level of cadmium may lead to severe lung damage. Ingestions of higher concentration may lead to gastrointestinal tract irritation and lead to vomiting and bloody diarrhea. For low concentration over a prolonged period of time, it will be deposited in kidney and can cause drastic damages to kidneys (Bernard 2008).

Cadmium and its compounds have high solubility in water as compared to other metals. Long-duration contact with cadmium can lead to morphopathological changes in kidneys. Smokers are at high risk of cadmium intoxication as tobacco is the major source of cadmium; nonsmokers are in contact with cadmium through food and some other sources (Mudgal 2010; Flora 2008). It is connected with vital nutrients; therefore, it causes severe toxicity. If cadmium exposure is high in the duration of human pregnancy, it may lead to birth of premature baby and lower birth weight problems (Henson and Chedrese 2004).

1.6 Chromium Sources in Indoor Air and its Health Effect

Chromium sources are rocks, soil, flora, and fauna, and it is present in different states. Chromium compounds' solubility is very high in water. Chromium (VI) compounds are extremely toxic and carcinogenic in nature. Chromium (III) plays a major role in glucose metabolism and serves as a vital nutrient for animals and humans. Inhalation and digestion of chromium trivalent compounds are slower than hexavalent chromium. Protecting metal coatings, metal and its alloy, magnetic tapes, paint pigments and varnishes, cement manufacturing, paper and pulp, leather tanneries, and metal plating are industrial sources of chromium (Martin 2009). (Schroeder and Nason 1970) As per documented information, 390 g/kg of Cr is present in cigarettes, but there is no notable data regarding quantity of chromium inhaled at the time of smoking. Formation of ulcers is a major problem of chromium exposure with human which lasts long for months, and healing rate is also very slow. Nasal septum ulcers occurred very frequently to chromate workers.

Human contact with high concentration of chromium compounds can lead to erythrocyte glutathione reductase and reduces the capacity to change methemoglobin to hemoglobin. DNA damages are caused by chromate compound which may result in DNA adducts, aberration of chromosomes, exchanges of sister chromatid, and DNA alterations (O'Brien 2001; Matsumoto and Mantovani 2006).

Table 1: Stages of ferrous toxicities

S. No.	Stages	Duration	Effects
1	First	After 6 h of exposure	Gastrointestinal bleeding, vomiting, and bloody diarrhea
2	Second	Between 6 and 24 h after exposure	It is a latency period and can be recovered medically
3	Third	Between 12 to 96 h after exposure	Shock, hepatic necrosis, metabolic acidosis, hypotension, tachycardia, and death
4	Fourth	With 2 to 6 week from exposure	Formation of gastrointestinal ulcers, growth of stenosis, and DNA damage

1.7 Iron Sources in Indoor Air and its Health Effect

Earth's crust richest metal is iron. It is also the vital nutrient required by living creatures; major nutrient also contains iron. Iron reactions help in respiratory process of most aerobic organisms. If not properly protected, it can act as a catalyst in reactions that form radicals and destroy biomolecules, cells, tissues, and the entire organism. Children are very receptive to iron toxicity as they are in contact with lots of iron-containing products. Iron toxicity, i.e., ferrous toxicosis, occurs in four stages (Bhasin and Kauser 2002; RS 2001).

Table 1 explains the symptoms and effect on human due to iron poisoning, and this transition is being categorized into four stages depending upon the time after exposure. Iron poisoning is very common in children, and it can be medically cured within 24 h of exposure.

2 Conclusion

The indoor air quality is badly affected due to the presence of heavy metals (mercury, lead, cadmium; chromium, arsenic, and iron). Some of the heavy metals are present in higher concentration and some in low concentration, but even a small concentration is harmful to human as the duration of exposure is quite high and cadmium, chromium, and arsenic are carcinogens (cancer-causing compounds). Sources of these heavy metals are mentioned in this paper; the thing that should be taken into consideration is to eliminate the sources or to reduce the concentration to that level where the effect on human will be negligible and certain techniques should be developed which will remove the presence of heavy metal from indoor air. Proper ventilation system should be installed for proper dilution of air, and substitution of product which is the source of heavy metals should be done.

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Impact of Speed Breakers on Air Contamination and Mileage of Vehicles

Prathyusha Pentapalli, Nihal Anwar Siddiqui, Prasenjit Mondal and Abhishek Nandan

Abstract The rate of traffic accidents is expanding every day. One of the fundamental reasons for traffic speed is over speed. Typically speed breakers, a notable speed regulating devices are enforced. Speed breakers despite an effective control measure have a few hindrances like increment in noise pollution, air contamination, wear and tear of vehicles and moderate reaction for emergency vehicles. This paper manages the effect of speed breakers like contaminating the enclosing environment, wear and tear of vehicles and different effects and measures which can be enforced to decrease these impacts.

Keywords Speed breaker · Wear and tear · Pollution · Remedial measures

1 Introduction

In these days, road transportation is a prominent mode amidst the widely known transportation. Due to the increase in usage of vehicles, accident rates are dilating day by day. This leads to an increase in number of injuries and fatalities (Harney 2016). A large portion of the adversities happen due to the collision of vehicles against one another or due to vehicles colliding pedestrians, stationary objects and so on. The primary impetus of these accidents is due to over speed of vehicles. Studies show that speed control can handle this issue. So, vertical and horizontal quieting measures are utilized to calm down the process (Hempton and Grossmann 2009). These measures utilize physical structures to enhance security for vehiclists and pedestrians. Horizontal measures employ traffic circles, curb extensions, etc., to tranquillize vehicular speed.

Speed breakers exploit the vertical measures to retreat the vehicular activity are utilized comprehensively in light of the fact that they can be introduced on any path

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either wide or tight (Anderson 2003). They are manufactured using different materials like black-top, solid, plastic, metal and vulcanized elastic. Speed breakers are raised couple of inches over the ground to diminish the driving velocity to 15–20 mph. They force the drivers to reach a close quit, crawling over to abstain from harming the bumper. The traverse distance and height decide the decrease in speed of the vehicle. Typically, the short length and incredible stature moderate the vehicle. They are typically introduced in territories with high person on foot traffics like private spots, parking areas, school zones and so forth (Beatley and Manning 1997).

Other than diminishing the accident rate in a successful way, the use of speed breakers has a few drawbacks. There will be a growth in traffic noise, which increments noise pollution in adjacent areas, decelerating emergency vehicles. Because of deceleration and acceleration of vehicles going towards the breaks, the wear of the tires increments (Race 2016). From the exhaust, high amounts of particulate matter which incorporates metals and different contaminations like carbon and nitrogen oxides are discharged which dirties the encompassing condition (Fig. 1).

The types of speed breakers are as follows:

- Speed bumps:

Speed bumps are appropriate to diminish the speed of vehicles to around 15 kmph. They are almost 3 ft long and 15 cm in tallness. They lessen the speed of the vehicle and in this way decreasing the accident rate and its seriousness (Capelotti 1999). They are by and large utilized in parking garages. The utilization of bumps induces distress to drivers and travellers, increments vehicular harm, and builds up response time for emergency vehicles like ambulance, fire engines and increment in air and noise contamination.

- Speed humps:

Speed humps are appropriate to lessen the speed of the vehicles to around 30 kmph. They are almost 14 ft long and 10 cm in height. They can be circular, parabolic and sinusoidal. As they achieve the sidewalk, they are decreased and they permit appropriate drainage (Kimanuka 2009). The long slope of humps is troublesome at low to direct speed but makes a more deflection at a higher speed. They cause an

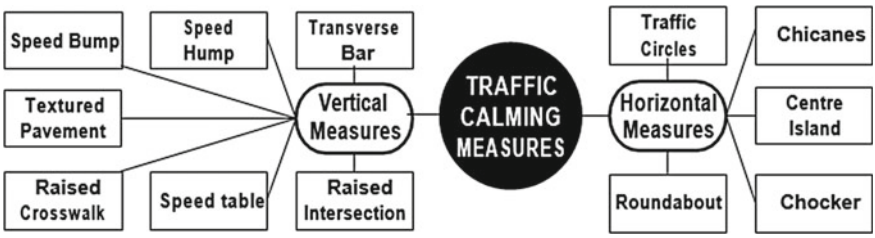

Fig. 1 Traffic calming measures

extreme ride for drivers and travellers and decelerate emergency vehicles. They are by and large utilized in streets.

- Speed table:

Speed tables raise the whole vehicle wheelbase to diminish the speed. They are longer than bumps and are level topped. They are about 22 ft long and 3 in. in height. Speed table have intervals in the middle which is utilized to maintain the speed between 25–45 mph. They are predominantly used when low speeds are required with smooth ride for vehicles like emergency routes.

- Speed cushion:

Speed cushions include wheel cut-outs which allow large and emergency vehicle to pass through them without reducing their speed while reducing passenger car speed. They are made up of several small speed humps across road width with spacing in between them. They are mainly used on emergency response routes.

2 Impact on Vehicles

Vehicle is, for the most part, harmed because of base decay, wear and tear of brakes and tires, suspension and inside segment harm, because of poor street conditions on laying speed breakers.

The other impacts of speed breakers on vehicles are

- Decrease in efficiency due to wear and tear of brakes and tyres;
- Decrease in vehicle life and efficiency due to engine and suspension damage;
- Increased fuel consumption.

3 Impact on the Environment

Streets which are laid are for the most part of two classes black-top and non-black-top streets. Because of deceleration and quickening of vehicles while going past speed breakers, the wear and tear of tires increment. This outcomes in increment of emanations of particulate issue which might be strong metal particles like lead, mercury, zinc, toxins like oxides of carbon and nitrogen and various hydrocarbons (Capelotti 1999). From air contamination ponders, the measure of particulate issue discharged into nature while going on non-black-top streets is higher than black-top streets.

Other impacts are

- Speed breakers cause discomfort to drivers and passengers causing them health issues like spinal and back problems.

- To avoid this discomfort, most of the two wheelers avoid speed breakers which may lead to the increase in accident rate.
- Due to laying of speed breakers, uneven pots and holes will develop on the roads. This leads to increase in cost of road maintenance.
- Vehicle damage is observed while travelling past speed breakers. This problem is much more severe with old and heavy vehicles.
- To avoid speed breakers usage of large vehicles is increasing day by day which leads to more pollution.
- Speed breakers cause additional noise and vibration to nearby places.
- Speed breakers which are not laid according to standards cause damage to physical structure of breakers leading to accidents.

4 Remedial Measures

- Speed breakers should be laid according to IRC-99 (Indian Road Congress).
- Design of speed breakers should be developed so that it decreases discomfort for travellers. This encourages drivers to reduce the vehicle speed and in turn reduces accident rate.
- Design of the road should be effectively done.
- Road marking and sign boards indicating speed breakers should be implemented and maintained properly.

5 Summary

Speed breakers are an effective control measure for controlling over speed which is one of the bases for accidents. Use of speed breakers governs the recurrence and severity of accidents. They are primarily utilized at locations where the speed of the vehicles should be moderate like parking areas, sharp bends, wild intersections and areas having high record of accidents and so forth. Despite that, there are a few effects of speed breakers which incorporate the health of the driver and travellers in the vehicles travelling, wear and tear of the vehicle, increment in the fuel intake, reduction in the vehicle efficiency and increment in noise pollution. So, there is a solid need to search for the corrective measures, appropriate examination before the usage of speed breakers and proper maintenance.

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Improving the Performance of Classification Algorithms with Supervised Filter Discretization Using WEKA on NSL-KDD Dataset

Shailesh Singh Panwar and Y. P. Raiwani

Abstract Naive Bayes and Bayes net are critical classification method for data mining and have built up important software tools for the classification, description, and generalization of information. All classification algorithms are open sources, which are implemented in Java (C4.5 algorithms) for WEKA software tool. This paper exhibits the strategy for increasing the performance of Naive Bayes and Bayes net algorithms with supervised filter discretization. We have used the supervised filter discretization on these two classification algorithms and compared the result with and without discretization. The outcomes acquired from experiment showed significant improvement over the existing classification algorithms.

Keywords Naive Bayes · Bayes net · Preprocessing · Discretization · WEKA · NSL-KDD dataset

1 Introduction

Data mining is the way toward separating helpful data, furthermore learning from the knowledge and conflicting raw information. Data mining is some portion of the learning revelation process, which separates data from expansive dataset and changes it to a justifiable frame.

Classification is one of the many techniques which have been implementing and working in various data mining projects. It is a type of data mining techniques that extracts sample and pattern describing crucial statistical classes. These samples and patterns are referred to as classifiers; foresee absolute class names. For example, sample and pattern can be worked to the financial institution that strengthens packages as either protected or risky (Kantardzic 2003).

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Naive Bayes induction is the way closer to studying statistics from magnificence marked preparing tuples. It is a calculation that is normally used to foresee display and find out the sizeable statistics through large amounts of data classification (Mitra and Acharya 2003).

Bayesian classifiers are statistical classifiers. Naive Bayes classifiers count that the impact of a characteristic in a given class is unbiased of the values of the other attributes. This is called class conditional independence. It is designed to simplify related calculations. This experience is taken into consideration "naive" (Tusar 2007).

After the introduction on Phase-1, Phase-2 of this paper gives a brief note about the related work done in the past, Phase-3 presenting our proposed approach; Phase-4 gives the brief description of methodologies. In Phase-5, after experiments, results have been compared and analyzed for performance evaluation. Finally, Phase-6 gives conclusive remark.

2 Related Works

Tusar (2007) finds the parameter settings of the C4.5 decision tree algorithm which can bring the most suitable performance on the special record set. Optimization gives optimum performance and accuracy for the tree which is calculated by 10-fold cross-validation.

Robu and Hora (2012) presented a model for the disease prognosis as they brought about proper accuracy and had been used to make predictions using several classification algorithms like J48 and random forest. Dynamic interfaces can also use built-in models, which suggest that utility works well in each case.

Salama et al. (2012) have used data mining algorithms (decision tree, J48, multi-layer perception (MLP), Naive Bayes (NB), sequential minimal optimization (SMO), and K-nearest neighbor (IBK)) to analyze accuracy on three different databases of breast cancer through the use of confusion matrix and classification.

Ashwinkumar and Anandakumar (2011) proposed a framework for three unique breast cancer databases, which depends on the 10-fold validation method in which classification accuracy is provided. An aggregate class level is exhausted between those classifiers to achieve the method and accuracy for each dataset. The decision of cardiac and diabetes diseases is done by decision trees and progressive learning.

Yi et al. (2011) proposed a new customized set of rules for decision tree. On the idea of ID3, set of rules taken into consideration of the special option in the categories of decision trees and the classification accuracy of the developed set of rules has proved to be better than the ID3.

Liu and Xie (2010) resolved the problem of decision tree algorithms primarily on the basis of characteristic importance and improved ID3 algorithm properties to gain insight, which have less attributes. After that Liu and Xie (2010) compared ID3 algorithm with improve ID3 algorithm. An experimental assessment of the facts indicates that the better ID3 sets of algorithms can obtain more realistic and powerful methods.

Agrawal and Gupta (2013) using L-Hospital's rule with C 4.5 algorithm suggests that it facilitates the determining method and raises the performance of decision-making algorithms.

3 Proposed Approach

Step1. Define the problem and select the NSL-KDD data set.
Step2. Apply data preprocessing on dataset.
Step3. Import dataset into software tool.
Step4. Use supervised filter discretization on dataset.
Step5. Select the single classification algorithm.
Step6. Apply classification algorithm on the data set.
Step7. Based on the measure, analyze the performance of classification algorithms.
Step8. If the results are as per measures, consider the classification algorithms for further processing.
Step9. Go to step 2 and repeat from steps 2–8 for other classification algorithms.
Step10. Analyze the results of classification algorithms based on performance measures and evaluate the best results (Fig. 1).

4 Algorithms

4.1 Naive Bayes Classifier

Naive Bayes classifiers are a family of "probabilistic classification," which implements with the powerful independence hypothesis between the features. It is particularly scalable and requires a number of linear parameters inside the wide variety of irregular capabilities in a learning hassle. Naive Bayes is an easy technique for building classifiers: sample and pattern that gives magnificence labels to difficult situation time, which are shown as feature value vectors, where the labels are exhausted from some limited set. This is not the only algorithm for such classification, but the group of algorithm is entirely based on a general preaching. All Naive Bayes classifiers anticipate that the significance of a specific attribute is independent of the significance of any other attribute, given the class variable (http://cis.poly.edu/∼mleung/FRE7851/f07/naiveBayesianClassifier.pdf).

a. ***Bayes Net***

In machine learning, Bayes net classification techniques are a group of belief networks. Bayesian networks are probabilistic networks. This algorithm use Bayesian net functions and various search algorithms and quality measures. It

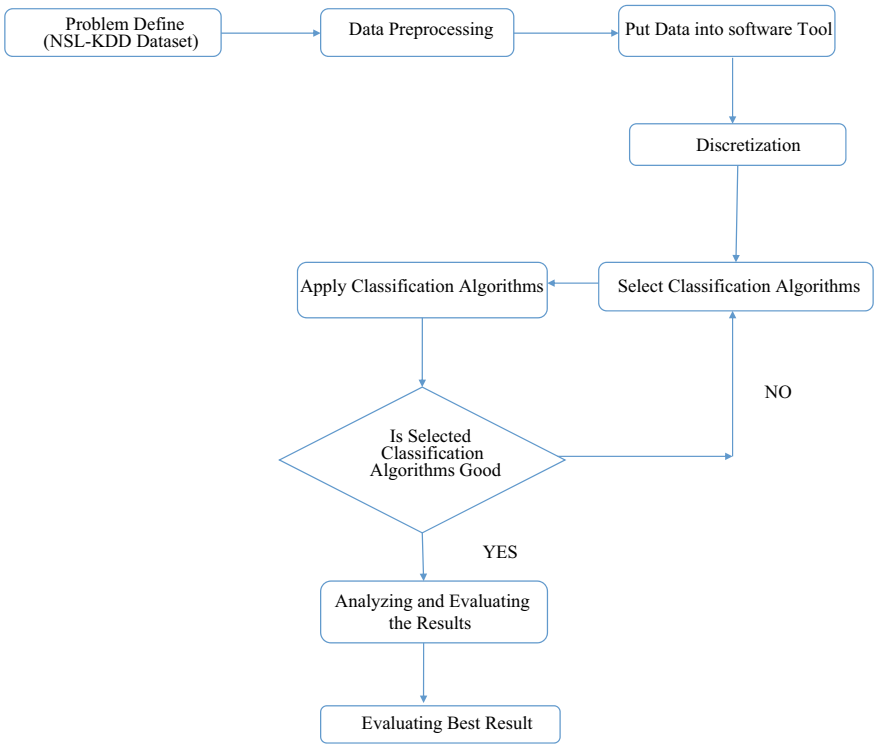

Fig. 1 Proposed approach

provides data structure and facilities common to Bayes network learning algorithms (http://web.ydu.edu.tw/∼alan9956/).

b. ***Preprocessing and Discretization***

Records and information generally come in assorted layout: nominal, continuous, and discrete. Discrete and continuous statistics having orders among values are ordinal records types. But the nominal values do not have any sequence among them. Preprocessing is done by supervised filter discretization technique.

Discretization is a method for execution, which changes for some machine learning calculations. The basic advantage of discretization is that some classification techniques can only work on ostensible properties, although not numerical characteristics. Further, favorable position is that it will increment the order exactness of the tree and decide based calculations that rely upon ostensible information.

Discretization categorized into two different types, supervised and unsupervised discretization. In unsupervised discretization, it is connected to datasets having no class data. It has equal width binning; equal recurrence binning for the most part yet more perplexing ones depend on grouping strategies (Gama and Pinto 2006).

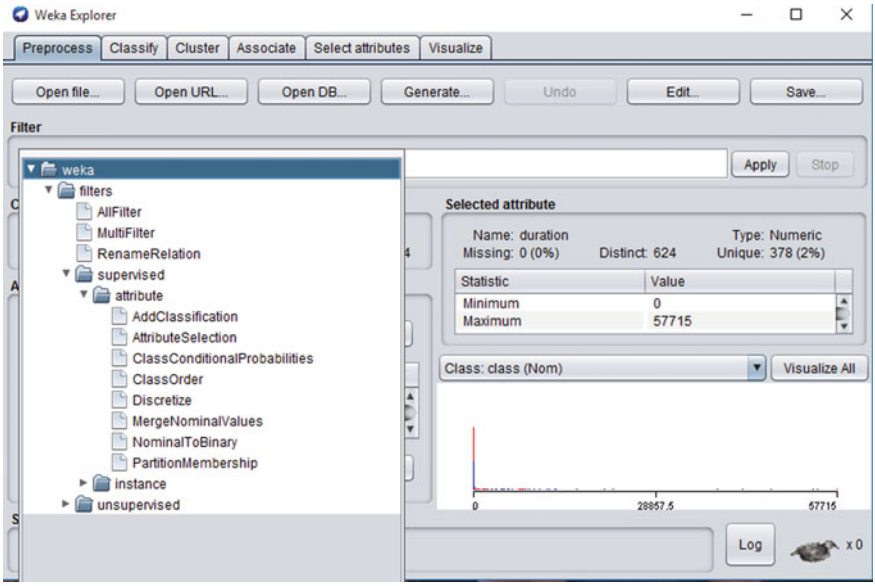

Fig. 2 Selecting discretization from preprocessing tab

Regulated discretization procedures, as the name recommends, consider the class data before making subgroups. Administered strategies are predominantly in light of Fayyad-Irani (1993) or Kononenko (1995) calculations.

In preprocessing, WEKA has the unsupervised discretization and supervised discretization algorithm. Figure 2 (Screen Shot) shows the steps of selecting discretization from preprocessing tab.

Class data entropy is a quantity of immaculateness and it evaluates the data which should be expected to determine classes an occasion has a place. In every single estimation of an element, it thinks of one as large interim containing and after that recursively segments this interim into littler subintervals until an ideal number of interims are accomplished.

5 Experiments and Results

To assess the performance of our approach, a sequence of experiments has been performed.

5.1 WEKA Tool

In this paper, we have used the WEKA software tool to investigate and analyze the NSL-KDD dataset with two different machine learning algorithms. This is an open-source GUI application which is referred to the Waikato Environment for knowledge learning. A university of Waikato in New Zealand developed the WEKA software tool, which identifies the data from the larger amount of records that have been collected from the different domain. It helps on several data mining and machine learning applications along with preprocessing, clustering classification, regression, feature selection, and visualization.

The essential premise of WEKA software is to use computer software that can be trained machine learning capabilities and useful data can be obtained inside in the form of tendencies and styles. It works on the prediction that the information is available as a document or relationship. For this reason, each data object is described by a variety of characteristics that are usually a special type such as normal alphanumeric or numeric value. WEKA software gives file system information to novice users with information hidden from the database and easy to implement an alternative system and visual interfaces (www.gtbit.org/downloads/dwdmsem6/dwdmsem6lman.pdf).

5.2 NSL-KDD Dataset

NSL-KDD dataset was used to solve some of the implied issues of KDD-99 dataset. The new version of the dataset of KDD still suffers from some problems and due to the lack of public data units for the network based IDS; the real network cannot be the ideal representative, agreeing that this is still a powerful standard dataset, which helps researchers for comparing specific detection of intrusion strategies. There are no duplicate data in the test set proposed in the NSL-KDD dataset. Therefore, the performance of newcomers is not biased through the methods which have a better identification rate in common data. This dataset contains a variety of attributes, which can be supportive for measure the attacks. NSL-KDD dataset have 22,544 instances at dataset (KDD Test) and 125,973 instances for training dataset (KDD Train) (http://iscx.ca/NSL-KDD/).

5.3 Performance Measures

All classifiers are performed on the basis of accuracy, sensitivity, specificity, and time. The performance was calculated by True Positive (TP), False Positive (FP), False Negative (FN) and True Negative (TN). All above values are derived from the confusion matrices.

Accuracy gives the possibility that the algorithm can accurately predict positive and negative instances and is calculated:

$$\text{Accuracy} = (\text{TP} + \text{TN})/(\text{TP} + \text{TN} + \text{FP} + \text{FN})$$

There is a possibility of sensitivity that the algorithm can accurately predict positive instances and is calculated:

$$\text{Sensitivity} = \text{TP}/(\text{TP} + \text{FN})$$

There is a possibility of specification that algorithms can accurately predict negative instances and are calculated

$$\text{Specificity} = \text{TN}/(\text{TN} + \text{FP})$$

5.4 Results

Tables 1, 2, and 3 show the training dataset with and without preprocessing confusion matrix and Tables 2 and 4 shows the testing dataset with and without preprocessing confusion matrix. The results indicate that by preprocessing and discretization of dataset, accuracy of both machine learning algorithms (Naive Bayes, Bayes net) has been improved.

WEKA software tool has been applied to both training and testing datasets (NSL-KDD datasets) and computed the accuracies by Naive Bayes and Bayes net algorithms without supervised discretization and with supervised discretization. The accuracies obtained by this are shown in Fig. 3. The final result indicates that supervised discretization has improved the overall performance of both machine learning algorithms. Naive Bayes improves the performance of NSL-KDD training dataset to approximately 6.84% and NSL-KDD testing dataset to approximately 14.42%. The Bayes net improved the overall performance of NSL-KDD training dataset to approximately 0.01% and NSL-KDD test dataset to approximately 0.09%.

Table 1 Training dataset confusion matrix (Naive Bayes)

Without discretization			With discretization		
Normal	Anomaly	Actual class	Normal	Anomaly	Actual class
63,060	4283	Normal	66,915	428	Normal
7832	50,798	Anomaly	3192	55,438	Anomaly

Table 2 Test dataset confusion matrix (Naive Bayes)

Without discretization			With discretization		
Normal	Anomaly	Actual class	Normal	Anomaly	Actual class
9225	486	Normal	9276	435	Normal
3858	8975	Anomaly	657	12,176	Anomaly

Table 3 Training dataset confusion matrix (Bayes net)

Without discretization			With discretization		
Normal	Anomaly	Actual class	Normal	Anomaly	Actual class
66,908	435	normal	66,920	423	normal
3129	55,501	anomaly	3128	55,502	anomaly

Table 4 Test dataset confusion matrix (Bayes net)

Without discretization			With discretization		
Normal	Anomaly	Actual class	Normal	Anomaly	Actual class
9263	448	Normal	9281	430	Normal
650	12,183	Anomaly	653	12,180	Anomaly

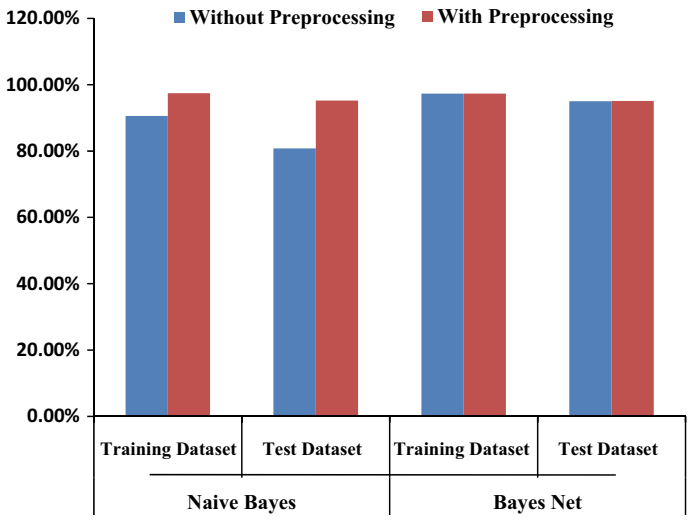

Fig. 3 Performance analysis with accuracy

6 Conclusion

In this paper, we have used filtered supervised discretization strategy to increase the characteristic accuracy of datasets, with continuous valuable attributes.

In a first step, we discretized the continuous valuable features from the given datasets. In the second step, we are going to execute Naive Bayes and Bayes net with and without supervised discretization and finally, the results have been compared.

According to Table 5, when we use Bayes net algorithm, there is almost same accuracy and performance in both cases, i.e., with discretization and without discretization. When we use Naive Bayes algorithms, the accuracy is largely increases in both cases, i.e., with discretization and without discretization for training and testing data set. So, we may conclude that:

1. Naive Bayes algorithm is more accurate for training and testing NSL-KDD dataset.
2. Naive Bayes algorithm is most suitable and accurate with discretization compared to without discretization.

The results show that Naive Bayes classifier algorithms with filtered supervised discretization can decrease time taken by algorithms and increase the prediction accuracy, sensitivity, and specificity (Tables 5, 6, and 7). It also shows that the filtering supervised discretization has a larger effect in the execution of the classification algorithms.

Table 5 Performance analysis table for the accuracy

Classifier				
	Naive Bayes		Bayes net	
	Training dataset (%)	Test dataset (%)	Training dataset (%)	Test dataset
Without preprocessing	90.59	80.79	97.30	95.02%
With preprocessing	97.43	95.21	97.31	95.11

Table 6 Time taken, Kappa value, correctly and incorrectly classified instances, sensitivity, and specificity for the two classifiers on test dataset

Classifier		Time (s)	Kappa value	Correctly classified instances	Incorrectly classified instances	Sensitivity	Specificity
Naïve Bayes	Without preprocessing	0.14	0.623	18,200	4344	94.99	69.93
	With preprocessing	0.02	0.9045	21,452	1092	95.92	94.99
Bayes net	Without preprocessing	0.59	0.9009	21,446	1098	95.38	94.93
	With preprocessing	0.09	0.9023	21,461	1083	95.57	94.98

Table 7 Time taken, Kappa value, correctly and incorrectly classified instances, sensitivity, and specificity for the chosen classifiers on training dataset

Classifier		Time (s)	Kappa value	Correctly classified instances	Incorrectly classified instances	Sensitivity	Specificity
Naïve Bayes	Without preprocessing	0.98	0.8060	113,858	12,115	93.64	86.64
	With preprocessing	0.08	0.9456	122,353	3620	99.48	94.95
Bayes net	Without preprocessing	8.86	0.9430	122,409	3564	99.35	94.66
	With preprocessing	0.89	0.9432	122,422	3551	99.37	94.71

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Noise Control Mechanisms for Industry Operations—A Review

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Abstract The development of technology has lead to widespread increase in machinery and also increase in the number of industries, with this also came the noise. Noise interferes with the efficiency of the work done by the employees whose work is highly skilled and involves decision making. The noise in the refinery, at some places, can exceed 90 dBA, which can affect the worker and also the environment. The risk involved in exposure to the noise for 8 working hours is very high. In this paper, we discuss the mechanisms which are used in the industries for reducing the amount of noise in a refinery; engineering applications and protective techniques which reduce the impact of noise; administrative techniques reducing the amount of exposure of noise to the worker.

Keywords Noise exposure · Noise control · Noise reduction mechanisms · Engineering control · Administrative control

1 Introduction

Nausea a Latin word from which the word noise has been derived which means unpleasant sound or unwanted sound (Coates 2005). Human activities are the main source of noise, mainly due to technology development, urbanization, and also mainly industrialization (Singh and Davar 2017). Seeing that the noise has become omnipresent, Indian Government has framed Noise Regulation and Control Rules—2000 under the Environment Protection Act—1986 (Mangalekar et al. 2012) (Bansal 2014). These rules and regulations specify the ambient levels of noise in different areas or zones, which are specified below (Table 1).

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Table 1 The ambient limits of noise are as given in Environmental Protection Act —1986

Sl. No.	Areas/zones	Day time (dB)	Night time (dB)
1	Commercial	75	70
2	Industrial	65	55
3	Residential	55	45
4	Silence	50	40

Workers in the industries are more prone to noise pollution, with exposure to noise reaching up to 90 dB sometimes (Raffaello and Maass 2016) (Stearn 2018). Exposure to that high dB of noise can cause some serious health effects (Nagi, Dhillon et al. 1999). Continuous exposure to noise may lead to: problems related to hearing (Bergström and Nyström 1986), rise of blood pressure (Kjellberg, Landström et al. 1996), insomnia (Kjellberg and health 1990), heart troubles (Kristensen and health 1989), deafness, and nervous breakdown. Some other effects related to mental health include: loss of productivity in work (Cohen, Evans et al. 2013), distraction, and quality of life reduction. It is grim to measure the effects of noise on every individual, since the characteristics of every individual are different along with the resistance levels of the individual to the exposure to noise (Ferguson 2015).

Long-period exposure, more than 8 h, to noise exceeding 75 dB can root to deafness. As the intensity of the noise increases along with the time of exposure, so is the risk (U. S. O. o. N. 1974). Acute exposure to high intensity of sound, such as a firecracker producing noise exceeding 150 dB, can cause tinnitus which can affect hearing permanently (Table 2).

Exposure to noise should be kept on check due to the adverse effects of noise on the human ear. The techniques or the technology used for the reduction of noise or noise control depends on the level of noise reduction required (de Kluijver and Stoter 2003).

Table 2 The response of a health ear varies for different noise levels, and the response is given in the table below (Harris 1991)

Noise level (dB)	Effect on human ear
0	Hearing begins
50	Quite
70	Telephone use difficult
80	Annoying
90	Hearing damage (8 h)
100	Very loud
110	Extremely loud
120	Maximum vocal stress when speaking
140	Painfully loud
180	Irreversible hearing loss

2 Noise Control Techniques

The requirement of noise in industry is necessary for the reasons are conserving the hearing of the workers/employees, reducing interference to work and speech, providing quiet and peaceful accommodation for personnel, and preventing annoyance to communities situated in the vicinity (Bronstein 2008).

Reducing the noise at the source itself is the effective action against excessive noise. Industrial noise can be controlled by redesigning or replacing the noisy equipment (Jerng and Sodini 2005). If the problem still persists, then the following techniques can be adopted: structural modifications, installation of mufflers, mechanical modifications, vibration isolators, and enclosures to protect from noise.

In industries, noise control at the source is achieved by adopting techniques like: using noise absorbing materials—carpets, acoustic foams, and rubber mats (Yilmaz 2016). Reducing the vibrations—material vibrations can be controlled through proper foundations using paddings made of rubber, reducing the noise levels caused by the vibrations. Machinery selection—ideal selection of equipment also plays a vital role in noise reduction.

Machine Maintenance: Not only noise control but also the life of the machine will increase because of regular maintenance (Lee et al. 2011). Loose parts and vibrations in machines are signs that the machine or equipment is not properly maintained. These conditions lead to the generation of unnecessary noise. So, proper maintenance is an important technique in noise control.

Irrespective of industrial/commercial noise, a noise control problem has mainly three components: sound energy emitting source, the path taken by the sound energy to travel, and the recipient.

The main objective of the noise control is reducing the noise for the recipient's sake that is the human ear. The economical noise control mechanisms, yet effective, involve three components with reference to the components of a noise problem (Kluger and DeNisi 1996). They are: the sound energy from the source, diverting the sound energy, and recipient protection.

Industrial noise control can be controlled by not only using the high-priced noise reduction technology. Low cost or economical techniques are also available for reducing the noise. Some of the commonly used industrial techniques are: Timely maintenance or regular maintenance, changing the operational procedures, optimizing the process, relocating the machine/equipment, and replacing the equipment.

In an industry, there can be various noise or sound energy sources. Some sound energy sources are listed below: leaks in steam pipelines, conveyor belts, damaged bearings, damages gears/shafts, improper alignment of belts, rotating parts, inadequate lubrication, machine guards improperly installed, air leakage in compressors, vibrations in metal sheets, and improper links or connections.

All of the above-listed noise-producing sources can be removed with proper maintenance or timely maintenance. It generally includes replacing the part which is producing the sound energy or repairing the part.

The location of the work area also plays an important role in employee's exposure to noise. The greater the distance between the sound energy source and the employee, the lees will be the exposure of the employee to noise (Lie et al. 2016). If the work of the employee with the equipment producing noise is intermittent, then providing "quite areas" can reduce the exposure of noise to the employee. If the employee had to work continuously, then providing a soundproof booth will suffice.

Optimization of a process involves money, personnel, equipment, resources, which are used effectively to achieve optimization. Optimization can only be possible if proper maintenance is in place. Changing the operating procedures, altering the equipment, or even substitution the materials, which means that noise is controlled at the source itself rather than controlling after the sound energy is produced.

Relocating an equipment may also be a feasible option for reduction of noise. The idea is to disperse the noise-producing equipment to increase the distance, which in turn reduces the noise levels. Isolating the noisy equipment is also an option, if at all the equipment needs monitoring (Parnell 2015).

Employee rotation is the most successful technique, which comes under administrative controls, to protect the employees from continuous exposure to noise. Scheduling the production which involves running the production such that the noise levels are under acceptable limits. Employee resistance, skills, and wages are all the factors which are to be considered during employee rotation.

Using sound-absorbing materials to absorb the reflecting sound. Presence of reflecting materials may amplify the sound emitting from the sound energy source resulting in more noise than that is being produced (Kolarik et al. 2014). This amplification can be controlled by covering or coating the reflective surfaces with sound-absorbing materials like baffles. Vibrating equipment can also be a source of increased noise. This can be reduced by covering the equipment internally reducing the potential of amplification which eliminates the noise substantially.

Replacing the equipment is generally the final technique. Purchasing equipment with latest technology (Black 1999). However, it does not guarantee that purchasing a new equipment means the noise will be reduced. The specification of the equipment determines the level of reduction of noise (Table 3).

Industrial noise control is mainly based on four principles. They are namely: Isolation, Vibration isolation, Vibration damping, and Absorption.

These principles give great results if they are used together rather being used individually.

Isolation—separating the sound-producing equipment physically is called isolation. This reduces the amplifying effect or the combined effect of noise which is the result of several noises producing equipment present in a single area. Isolation along with enclosure constructed by using sound-absorbing material is an effective way for noise reduction. Transmission loss states the sound isolation properties of a

Table 3 Possible solutions for noise reduction in industries are given below (Lou 1973)

Sound energy sources	Noise reduction techniques
Noise caused due to aerodynamic—intake and discharge through fan, jets, vents, etc.	1. Reducing the velocity 2. Using sound-absorbing material 3. Installing silencers
Flow in gas pipelines, compressors inlet and discharge pipes, etc.	1. Reducing the velocity 2. Increasing the pipe diameter 3. Avoiding sudden contractions in pipes 4. Avoiding sudden change in direction
Noise produced by metal contacts—grinders, mills, conveyors, etc.	Material substitution with sound-absorbing materials like wood, plastic or rubber
Stamping	Substituting stamping with shearing
Machine vibrations	Usage of damping materials and rugged design
Noise produced by turbines, fans and blowers	Noise can be reduced by increasing the gap between the blades
Sonic flow into safety relief valves	Dissolving the excess energy or reducing the pressure drop
Noise produce by siding equipment—conveyors, gears, etc.	Proper lubrication of the equipment can reduce noise substantially
Noise amplification—pump house	Covering the reflecting material with noise absorbing materials
Noise produced by electromagnetic forces	Noise can be reduced by making sure that AC frequency does no resonate with the machine parts

material. It is the amount of energy which is transmitted through the material in comparison with the amount of energy incident on the material (Lou 1973). It is expressed as follows:

$$\mathrm{TL} = 10\log(\text{incident energy})/(\text{transmitted energy})$$

Vibration isolation—vibration objects are the main source of sound energy; therefore, vibration control is based on the noise reduction at the source. Vibration isolation simply means separating the vibrating part from its source (Norton and Karczub 2003). This may involve redesigning the machine or improving the maintenance of the equipment eliminating the imbalance or the removing the contact between the parts which are in motion and the parts which are stationary. Other techniques involve separating the vibrating member by using elastic materials to reduce the sound production. Commonly used elastic materials are rubber, cork, wood, neoprene, glass fiber, etc; the main function of the vibration isolator is to prevent the transmission of energy. The lowest vibration frequency (f) to natural resonant frequency of the isolator (f_n) ratio gives the effectiveness of the isolator (Jensen, Jokel et al. 1978) (Table 4).

Vibration damping—sound-absorbing materials are called damping materials. The mechanism involved in the damping materials is; the sound energy which is

Table 4 f/f_n versus effectiveness

f/f_n	Effectiveness
1	Amplifier
2	Begins to act as an amplifier
Greater than 2	Isolator

absorbed by the damping materials is converted to heat energy, this reduces the resonance effect of sound ultimately reducing the noise. 10–15 dBA reduction can be achieved by using viscoelastic damping materials (Purcell and VIBRAT. 1982).

Absorption—every material absorbs sound up to a certain limit. Sound absorption occurs when sound energy is absorbed by a material and that energy is converted to heat energy. Sound-absorbing materials commonly are porous in nature, light in weight, and are fibrous. Commonly used sound-absorbing materials in industry are: glass fiber, foams, acoustic ceiling, etc; the extent of sound energy absorbed by a material is denoted by its absorption coefficient and the performance of the material is expressed in terms of sabins. The relation between absorption coefficient and sabins is as follows:

$$\text{Sabins} = \alpha \times A$$

A area of the absorbing material (m^2)
α absorption coefficient.

3 Conclusion

Noise has many adverse health effects if an employee or worker is exposed to it continuously. So, it is required to control the noise levels in industry by applying the noise control mechanisms like changing the operating procedures, timely maintenance, enclosure, or by applying engineering controls like isolation, enclosing the equipment, using sound-absorbing materials, also using administrative controls like, job rotation, relocating the equipment. Noise reduction can also be done by removing the sound amplifying media or by separating the vibrating member of equipment. Noise reduction mechanisms are based on four main principles: Isolation, which is isolating the sound-producing equipment; Vibration isolation, isolating the vibrating member of equipment; Vibration damping, using viscoelastic sound-absorbing materials to absorb the sound energy produced; Absorption, using sound-absorbing materials to prevent the amplification of the sound energy, thus reducing the noise levels. These techniques are used in the industries for effective noise reduction.

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