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Estimation of Air Pollutants Along with Meteorological Parameters and Study of Their Impact on Human Health

Mehraj Uddin Bhat*, Anish C. Pandey and Mohd Aadil Deva[1]
Department of Chemistry, Jiwaji University, Gwalior, Madhya Pradesh
[1]Pollution Ecology Lab, School of Studies in Botany, Jiwaji University, Gwalior, Madhya Pradesh
✉ Mehrajbhat486@gmail.com

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Abstract: The research studies have shown that air pollution has been well thought-out as the main warning to health globally. It requests the participation of researchers from time to time to address and revive the problem sincerely. In India concentration of air pollutants has become a serious issue. In most Indian cities, the level of air pollutants is above the prescribed level as per the CPCB. Gwalior City of Madhya Pradesh (India) is at the entrance of speedy urbanisation and industrialisation which causes the worsening air quality of the city. As per the reports of 2015, Gwalior is listed among the top polluted city in India. To address this problem an investigation of air pollutant concentration was carried out at three stations in Gwalior. In this study SO_2, NO_2 and RSPM and SPM were collected over three stations categorised as residential, industrial and commercial and estimation was done by chemical methods. Meteorological parameters like temperature and relative humidity were also recorded during the sampling period. Seasonal variations of these pollutants have been analysed and noted. From the study, the concentrations of the pollutants were observed to be high in summer and winter than in monsoon and post-monsoon seasons. In this study, it was noticed that the RSPM and SPM levels at all selected sites exceed the prescribed limits. While the level of gaseous SO_2 and NO_2 are observed to remain under prescribed limits. The main objective of this study was to know the quality of air in Gwalior and study its health impacts as the city has been selected as one of the hundred Indian cities that can be developed into a smart city under PM Narendra Modi's flagship Smart Cities Mission.

Key words: Chemical methods, air pollutants, meteorological parameters, human health, Gwalior.

Introduction

Air pollution is defined as an adverse effect of any substance that can make the atmosphere polluted and result in the deterioration of the environment. Air pollution is the result of both anthropogenic activities and natural phenomena. The pollutants are of various types viz materials in solid, liquid, and gas phases **(**Vallero, 2007)**.** In recent few decades, in both developed and developing countries industrial activities and high vehicular traffic density have become the major environmental concern. These activities result in the long term and short term effects on human health observed by various research studies (Afroz et al., 2003). Various types of complex gases and particulates are mostly observed in urban areas depending on the wide range of factors such as population density, energy consumption, industrial process, and modes of transportation are observed to affect public health, damage agriculture, weather, and climate **(**Pant, 2010). In India pollution has become a major cause of concern and has become a great topic of debate at and research work has been carried out which shows the worsening trend of air

*Corresponding Author

pollution due to the increased anthropogenic activities like rapid urbanisation, industrialisation, enormous uncontrolled increase in the number of vehicles on the poor road conditions (Yang et al., 2004). Gwalior City of Madhya Pradesh (India) is at the threshold of speedy urbanisation and industrialisation causing the worsening air quality of the city. As per the reports of WHO, Gwalior is ranked among the top polluted city in India. The economic growth and development of the industries to increase the product and the rate of their consumption has led to environmental pollution. There is an increase in the industrial emission of harmful pollution into the atmosphere throughout the world (Akbary et al., 2018 and 2019). The particulate matter with an aerodynamic diameter of less than 10 micrometer has critical importance as it can penetrate the lower air ways (Akdi et al., 2020).

Review of Literature

The literature study was carried out to find the pathway to the study of air pollutants and their effects on human health in Gwalior City using Arc GIS mapping. The details are as follows:

Emmanouil et al. (2010) conducted a study that shows the impact of air pollutants (viz, CO, NO, NO_2, SO_2, O_3) together with meteorological parameters (air temperature, humidity and atmospheric pressure) on human health viz (circulatory, respiratory and skin diseases) and the results show that increasing concentration of pollutants SO_2, NO_2, O_3 and CO causes circulatory, respiratory and skin diseases.

Kamath and Lokeshappa (2014) carried out a study on the concentration of air pollutants at three study stations taken as residential, industrial and sensitive areas of Bangalore. The air pollutants SO_2, NO_X and RSPM were collected over about six sites in Bangalore together with meteorological parameters like temperature, relative humidity and wind direction during the sampling periods. Both monthly and seasonal variation of pollutants is carried out and has been analysed and noted accordingly. The study shows that the concentrations of pollutants are high in summer than pre-monsoon and post-monsoon seasons. From the study, it was observed that the RSPM levels at all selected sites exceed the prescribed limits while the level of gaseous pollutants SO_2 and NO_2 are observed to remain under prescribed limits in industrial areas.

Jayshree (2000) made an attempt to study the various types of pollutants emitted by automobiles in Thiruvananthapuram city and resulted in various types of operating vehicles that influence the amount of pollutants released by them.

Chintan et al. (2015) carried out a comparative analysis of ambient air quality in Ahmedabad and Gandhinagar in Gujarat. The study has been carried out on the basis of land use patterns and meteorological conditions for both cities.

Künzli et al. (2009) and World Health Organization (2010) studied and explained the adverse effects of various types of air pollutants on the human respiratory system. From the study, the most widely accepted explanation that has been observed consistently is when the air oxidants and pro-oxidants present in the air pollutant PM of various sizes and compositions and in gaseous such as nitrogen cause the formation of oxygen and nitrogen free radicals, which induce oxidative stress in the airways.

Minister of Health and Family Welfare, Government of India (2015) reports that have been taken for the steering community on the issue of health has shown that the short-term exposure of both ambient particulate and gaseous pollutants are linked to higher rates of hospital admissions for cardiovascular, respiratory illness, and death through the ischemic heart diseases and strokes.

Description of Gwalior

Gwalior is one of the four major cities of Madhya Pradesh, India and has historical importance.The city is under the smart city plan as decided by the Government of India. It is located 319 kms from south of Delhi. The area of Gwalior is 780 km^2. The population of the Gwalior district according to the 2011 census is 2,030,543 with a population density of 5,478 per km.

Air Pollution Reports of Gwalior

From the air pollution reports of 2015, the city of Gwalior is found to contain the highest particulate stuff in India that stands at 329 cm^3 by the Central Pollution Control Board (CBCP) report on “national ambient air quality standards”. The current statistics explain that the foreign particle in the city stands at 141 micrograms per cubic meter before the year 2016; the CBCP data exposed Gwalior highest in the list of top polluted cities in India. The statistics explained that the permissible limit is 60 micrograms per cubic meter, and particulate matter in Gwalior is 329 micro grams per cubic meter which is more than five times the permissible limit **(**CPCB, 2011**).**

Aim and Objectives of the Study

1. Wet chemical estimation of air pollutants like NO_2, SO_2, SPM, and RSPM at different sampling stations of Gwalior.
2. To estimate the seasonal variation of air pollutants viz SO_2, NO_2, SPM, and RSPM, GIS mapping at three study stations had taken as residential, commercial and industrial areas in Gwalior.
3. To determine the level of air pollutants and their impact on respiratory human health.

The City Gwalior has been selected as one of the hundred Indian cities that can be developed into a smart city under PM Narendra Modi's flagship Smart Cities Mission. This study may help the industrial and urban city development planning of the administrators and planners in industrial zooming and development of Gwalior into a smart city.

Material and Methods

In this study, sampling is located depending upon the objective of the measurement campaign and be kept at an altitude depending upon the type of study region (commercial, industrial, residential areas etc)**.** In the present study, air pollutant samples were collected at an interval of 8 hours. For 8-hour sampling, 10 ml of absorbing solution (stock solution) was taken in impringers and the flow rate was maintained at 0.5 to 1 litre per minute (11 pm). In this study, Handy air Sampler (HS-7A) is used to collect SO_2 and NO_2 and estimation has been done spectrophotometrically by Systronic 108 UV visible spectrophotometer. The West-Gaeke6 and Jacob-Hocheiser (1958) (Jacob et al., 1998) method is used for the determination of SO_2 and NO_2, respectively. Envirotech Fine Particulate matter sampler (APM-550), GF/A What man's filter paper No. 1 is used to collect suspended particulate matter and respirable suspended particulate matter (IS 5182 (part 23), Method IO-2.1.2006). Sulphur dioxide from the air stream is absorbed in sodium tetramer curate solution. It forms a stable dichlorosulphitomercurate. The amount of sulphur dioxide is then estimated by the colour produced when p-rosaniline hydrochloride is added to the solution. Nitrogen oxides as nitrogen dioxide are collected by bubbling air through a sodium hydroxide solution to form a stable solution of sodium nitrate. The nitrate ions produced during sampling are determined calorimetrically by reacting the exposed absorbing reagent with phosphoric acid, sulphaniaamide and an N (1-Napthyl) ethylenediamine dihydrochloride (Goyal, 1998). The interference of NO_2 is eliminated by converting it to H_2SO_4 before analysis. Envirotech Fine Particulate matter sampler (APM-550) and GF/A Whatman's filter paper No. 1 are used to collect suspended particulate matter and respirable suspended particulate matter (Pant (2010) and Pathak (2015)) and are determined by the gravimetric method. The statistical analysis of the health survey has been carried out through a questionnaire for each station to assess the impact of air quality on human health. Meteorological parameters play an important role in ambient air quality. Therefore, meteorological parameters like temperature and humidity are observed by a hygrometer and thermometer (source: IMD, New Delhi) during sampling and rainfall for all the seasons during four respective years (2014-17) in Gwalior. GIS software Arc GIS 10.2.1 version has been used to show the level and distribution of air pollutants at different study stations in Gwalior. The statistical analysis of the health survey has been carried out for each station to assess the impact of air pollutants on human health. Table 1 explains the parameters of air quality.

Table 1: Parameters and methodology for air quality monitoring

S.No.	*Parameters*	*Time weighted average*	*Methods of measurement*
1	SPM	8 hr	Gravimetric method
2	RSPM	8 hr	Gravimetric method
3	NO_2	8 hr	Modified Jacob & Hochhesier
4	SO_2	8 hr	Improved West Gaeke

Results and Discussions

Table 2 shows seasonal variation of meteorological parameters in Gwalior.

Seasonal Variation of Temperature (2014-17)

- The maximum temperature of 33.16ºC is observed in summer and the minimum temperature of 19ºC for the year 2014 is observed in winter. The temperature during monsoon and post monsoon is observed as 29.66ºC and 22.33ºC.
- The maximum temperature of 31.66ºC is observed in summer and a minimum average temperature of 19.5ºC is observed in winter for the year 2016. The average temperature during monsoon and post monsoon is 30.16ºC and 22ºC.

- For the year 2016, the maximum temperature is 33.5ºC in summer and the minimum average temperature of 21.5ºC is observed in winter. The observed temperature during monsoon and post monsoon is 30.5ºC and 22.33ºC.
- It is observed that the maximum temperature is observed as 33.16ºC in summer and the minimum average temperature is observed as 19ºC for the year 2017 in winter. The average temperature during monsoon and post monsoon is 31.16ºC and 21.83ºC respectively.

Seasonal Variation of Humidity (2014-17)

- The maximum average humidity is observed as 67.16% in monsoon for the year 2014 and the minimum humidity of 54.83% is observed in summer.
- The maximum humidity is 70.66% as observed in monsoon and the minimum average humidity is 56.33% in monsoon for the year 2015 as found in summer. The humidity during winter and post monsoon is 62.83 and 60.83, respectively.
- The maximum average humidity is observed as 75.16% in the moonsoon season and minimum average humidity is observed as 50.83 in Summer. The average humidity during winter and post monsoon is observed as 58.66 and 61.33, respectively.
- The maximum humidity is observed as 70.33% in monsoon in Gwalior City and the minimum humidity is 52.16% in summer. The average humidity during winter and post monsoon is 57.33 and 60.16%, respectively.

Seasonal Variation of Rainfall (2014-17)

- It is observed that the maximum rainfall is 180.4 mm in monsoon and minimum rainfall 11 mm as observed in summer for the year 2014. The rainfall observed during winter and post monsoon is 33.3 mm and 12.76 mm.
- It is observed that the maximum average rainfall is 192.63 mm in monsoon. The minimum average rainfall of 28.43 mm is observed in monsoon for the year 2015. The average rainfall during winter and post monsoon is 53.4 mm and 11.53 mm.
- It is observed that the maximum rainfall is 142.33 mm monsoon in Gwalior City and the minimum average rainfall for the year 2016 is 5.23 mm found in winter. The average rainfall during summer and post monsoon is 53.66 mm and 9.13 mm.
- It is observed that the maximum rainfall is 165.73 in monsoon in Gwalior City and the minimum average rainfall peak of 1.83 mm for the year 2017 is observed in post monsoon. The average rainfall during winter and summer is 2.7 mm and 31.33 mm.

Table 2: Seasonal variation of meteorological parameters in Gwalior from 2014-17

Year	*Season*	*Temperature*			*Humidity*			*Avg. rainfall*
		Min	*Max*	*Average*	*Min*	*Max*	*Average*	
2014	Winter	6	35	19	27	100	65.16	33.3
	Summer	17	46	33.16	18	96	54.83	11
	Monsoon	24	38	29.66	25	100	67.16	180.4
	Post monsoon	5	37	22.33	27	100	63	12.76
2015	Winter	5	36	19.5	22	100	62.83	53.4
	Summer	18	44	31.66	14	98	56.33	28.43
	Monsoon	22	38	30.16	31	100	70.66	192.63
	Post monsoon	5	33	22	22	100	60.83	11.53
2016	Winter	5	40	21.5	16	98	58.66	5.23
	Summer	21	46	33.5	10	98	50.83	53.66
	Monsoon	24	38	30.5	46	100	75.16	142.33
	Post monsoon	8	37	22.33	22	100	61.33	9.13
2017	Winter	4	41	21.5	11	100	57.33	2.7
	Summer	15	45	32	11	100	52.16	31.33
	Monsoon	23	38	31.16	36	100	70.33	165.73
	Post monsoon	6	38	21.83	21	98	60.16	1.83

Table 3: Seasonal concentration of air pollutants at different study sites in Gwalior during 2014-2017

S.No	*Season*	*Parametres*	*Thatipur*			*Maharaja Bada*			*Deen Dayal Nagar*		
			Min	*Max*	*Average*	*Min.*	*Max.*	*Average*	*Min.*	*Max.*	*Average*
01	Winter	SO_2	16.2	22.02	19.02	17.1	23.7	20.7	17.18	25.4	22.24
		NO_2	16.41	25.56	21.59	18.7	22.61	21.07	17.7	24	21.47
		SPM	267	499	359	381.72	393.9	493.2	409.11	617.9	517.2
		RSPM	83.89	123	123	97.12	166	128.5	123.93	387.7	287
		Avg.±SD	**95.87± 118.44**	**167.39± 225.96**	**130.65± 159.74**	**128.66± 172.79**	**151.55± 175.03**	**165.86± 24.03**	**141.98± 185.02**	**263.75± 291.59**	**211.97± 238.80**
02	Summer	SO_2	16.3	24.41	21.17	17.9	24.54	21.54	19.2	24.24	21.99
		NO_2	19.2	25.9	22.9	19.2	24.8	21.9	19.4	28.6	24.6
		SPM	423.31	447.5	423.16	397.51	627.28	535	571.41	616.7	596.65
		RSPM	114.8	250.5	156.744037	123.7	348.19	248	278.81	309.18	309
		Avg.±SD	**143.40± 192.13**	**187.07± 203.53**	**155.99± 189.09**	**139.57± 178.95**	**256.20± 290.61**	**206.61± 243.53**	**222.20± 262.98**	**244.68± 281.56**	**238.06± 274.39**
03	Monsoon	SO_2	12.7	23	16.92	11.7	25.6	17.8	11.2	23.35	17.33
		NO_2	9.7	18.47	15.01	14.2	23.16	17.94	12.1	21.1	16.9
		SPM	223.21	256.06	226	208.21	438.5	338.1	326.23	411	411
		RSPM	79.3	108.19	95	97.23	197.15	137	103.21	171.4	139
		Avg.±SD	81.22± 99.95	101.43± 111.04	88.23± 99.11	82.83± 92.55	**171.10± 195.99**	**127.71± 151.08**	**113.18± 148.44**	**156.71± 183.53**	**146.05± 185.73**
04	Post monsoon	SO_2	13.2	25.9	17.9	14.8	24.6	19.6	12.1	23.35	17.35
		NO_2	11.8	23.47	16.72	15.3	24.16	20.16	15.2	24.1	21.1
		SPM	234.21	335	335	278.21	448	448	367.21	646.27	514
		RSPM	71.78	167.49	114	97.23	225.2	155.015	152.8	352.5	251
		Avg.±SD	82.74± 104.77	137.96± 147.60	120.90± 149.83	101.38± 124.08	180.49± 201.90	160.69± 201.85	136.82± 167.01	261.55± 299.66	200.86± 235.62

Winter (2014-2017)
Table 3 shows the (±) of air pollutants in winter at different study centres of Gwalior is observed as Thatipur (130.65±159.74), Maharaja Bada (165.86±24.03), and D.D Nagar (211.97±238.80).

Summer (2014-2017)
Table 3 shows the (±) of air pollutants in summer at different study centres of Gwalior city is found as Thatipur (155.99±189.09), Maharaja Bada (206.61±243.53), and D.D Nagar (238.06±274.39).

Monsoon (2014-2017)
Table 3 shows the (±) of air pollutants in monsoon at different study centers of Gwalior city is found as Thatipur (88.23±99.11), Maharaja Bada (127.71±151.08), and D.D Nagar (146.05±185.73).

Post monsoon (2014-2017)
Table 3 shows the (±) of air pollutants in post monsoon at different study centres of Gwalior city is found as Thatipur (120.90±149.83), Maharaja Bada (160.69±201.85), and D.D Nagar (200.86±235.62).

Health Survey
As per Table 4, a health survey was carried out during different seasons of the study sites from 2014 to 2017 to get information on respiratory admissions and the season wise distribution of the respondents, which were observed by hospital admissions, clinics,

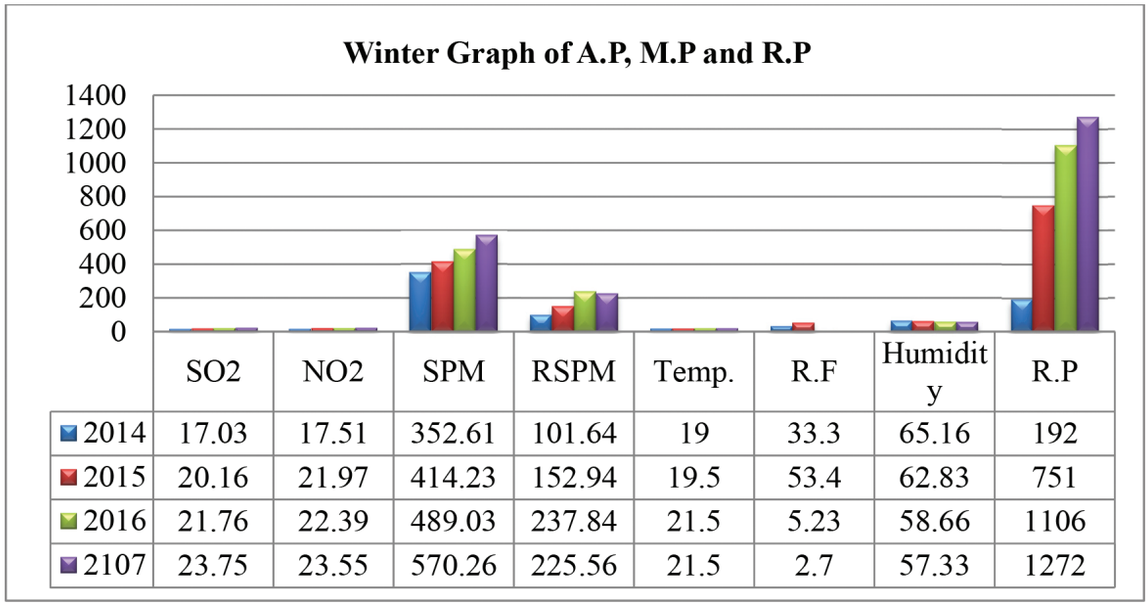
Table 4: Hospital admissions, clinics, pathological labs for the treatment of respiratory cases in the particular study areas

Year	*Season*	*Adult male*	*Adult female*	*Male child*	*Female child*	*Month with high rate of admission*
2014	Winter	53	74	40	25	Apr. and May
	Summer	210	400	222	220	Sep. and Oct.
	Monsoon	45	310	37	193	Nov. and Feb
	Post monsoon	92	262	190	98	
	Total	308	1046	489	536	
	Avg.±SD	**100±70.50**	**261.5±127.26**	**122.25±90.35**	**134±82.90**	
2015	Winter	132	279	156	184	During all months
	Summer	170	322	156	150	July to Sep.
	Monsoon	198	364	105	157	Nov to Feb
	Post monsoon	120	205	82	98	
	Total	620	1170	499	589	
	Avg.±SD	155±33.07	292.5±62.83	124.75±34.52	147.25±33.28	
		33.07135	62.83993	34.52018	33.28985	
2016	Winter	282	329	354	141	During all months
	Summer	314	341	325	474	July to Sep.
	Monsoon	139	236	278	360	Nov to Feb
	Post monsoon	98	126	210	235	
	Total	833	1032	1167	1210	
	Avg.±SD	**208.25±97.93**	**258±92.33**	**291.75±58.19**	**302.5±134.54**	
2017	Winter	278	312	358	324	During all months
	Summer	327	366	367	398	July to Sep.
	Monsoon	262	210	284	276	Nov to Feb
	Post monsoon	126	208	237	202	
	Total	993	1096	1246	1200	
	Avg.±SD	248.25±79.67	274±72.42	311.5±57.44	300±76.27	

and pathological labs for the treatment of respiratory problems. From the survey study, it was generally observed that both men and women suffered from respiratory problems in the concerned air pollutant monitoring zones. Females are found to be more affected and were more in number for respiratory treatment. Furthermore, children (both boys and girls) were observed to have respiratory issues.

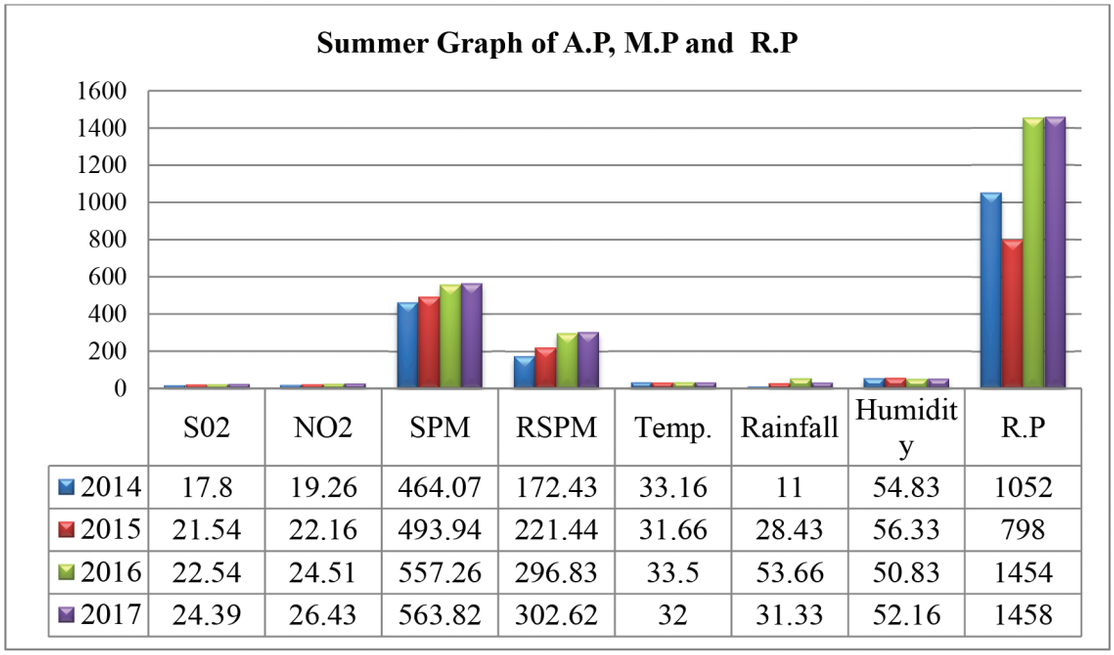
Correlation Analysis

The seasonal distribution of respiratory admissions in hospital admissions, clinics, and pathological labs and the level of pollutants shows a positive correlation with air pollutants during all seasons for all stations during 2014-17 (Figure 1a-d). The level of pollutants shows a



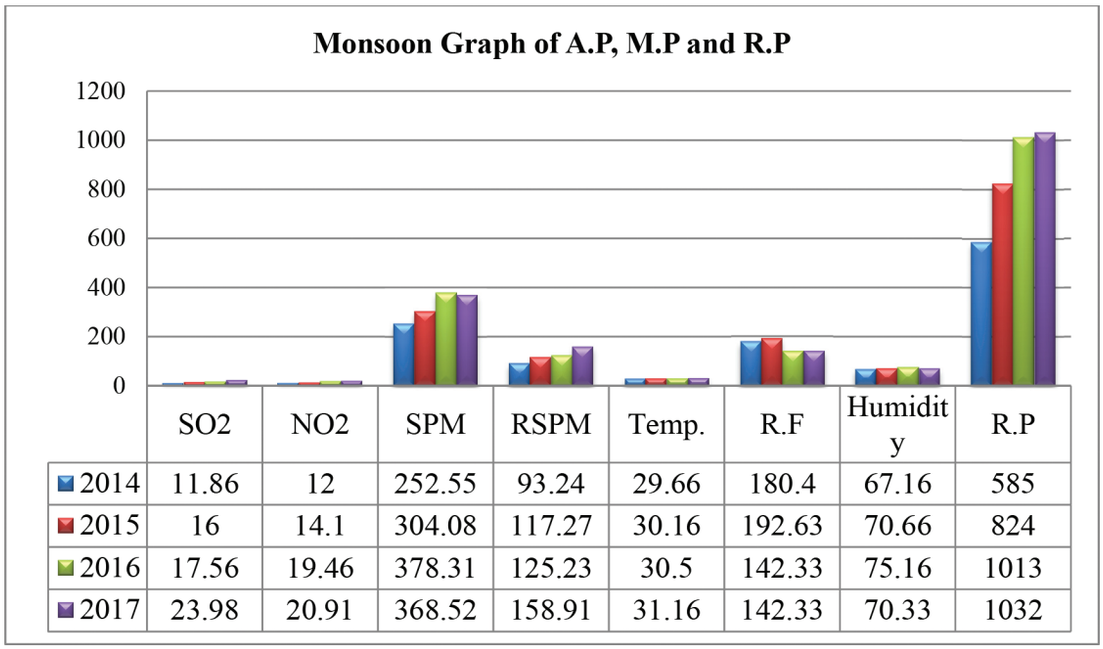
	SO2	NO2	SPM	RSPM	Temp.	R.F	Humidity	R.P
2014	17.03	17.51	352.61	101.64	19	33.3	65.16	192
2015	20.16	21.97	414.23	152.94	19.5	53.4	62.83	751
2016	21.76	22.39	489.03	237.84	21.5	5.23	58.66	1106
2107	23.75	23.55	570.26	225.56	21.5	2.7	57.33	1272

Figure 1a: A.P=Air Pollutant, M.P= Meteorological parameter, R.P=Respiratory Problem.



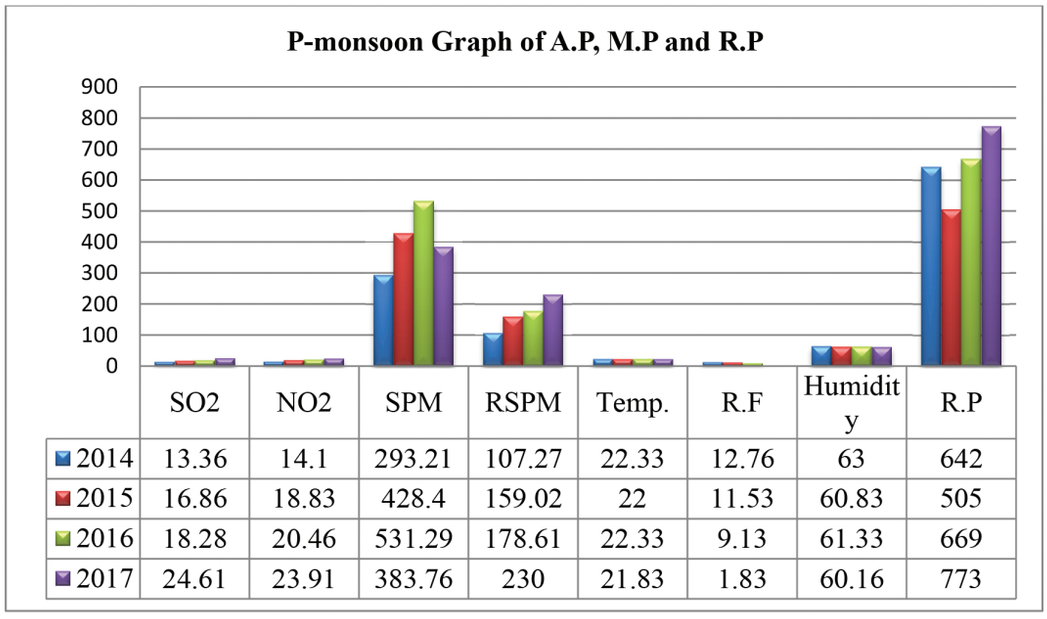
	S02	NO2	SPM	RSPM	Temp.	Rainfall	Humidity	R.P
2014	17.8	19.26	464.07	172.43	33.16	11	54.83	1052
2015	21.54	22.16	493.94	221.44	31.66	28.43	56.33	798
2016	22.54	24.51	557.26	296.83	33.5	53.66	50.83	1454
2017	24.39	26.43	563.82	302.62	32	31.33	52.16	1458

Figure 1b: A.P=Air Pollutant, M.P= Meteorological parameter, R.P=Respiratory Problem.



	SO2	NO2	SPM	RSPM	Temp.	R.F	Humidity	R.P
2014	11.86	12	252.55	93.24	29.66	180.4	67.16	585
2015	16	14.1	304.08	117.27	30.16	192.63	70.66	824
2016	17.56	19.46	378.31	125.23	30.5	142.33	75.16	1013
2017	23.98	20.91	368.52	158.91	31.16	142.33	70.33	1032

Figure 1c: A.P=Air Pollutant, M.P= Meteorological parameter, R.P=Respiratory Problem.



	SO2	NO2	SPM	RSPM	Temp.	R.F	Humidity	R.P
2014	13.36	14.1	293.21	107.27	22.33	12.76	63	642
2015	16.86	18.83	428.4	159.02	22	11.53	60.83	505
2016	18.28	20.46	531.29	178.61	22.33	9.13	61.33	669
2017	24.61	23.91	383.76	230	21.83	1.83	60.16	773

Figure 1d: A.P=Air Pollutant, M.P= Meteorological parameter, R.P=Respiratory Problem.

positive correlation with the temperature and a negative correlation with rainfall and humidity (Figure 1a-d).

Conclusion

High particulate concentration is due to the heavy transport activity in the study area apart from industrial emissions, dust from paved roads and conventional fuel for domestic purposes. Air pollutants were found high during winter and summer than during monsoon and post monsoon. The average ambient air concentration of both SO_2 and NO_2 is below the permissible limits of NAAQS and CBCP India at all three zones such as residential, commercial, and industrial. In the study, the concentration of air pollutants SO_2, SO_2, SPM, and RSPM are observed during all the seasons and are

found to be very high and are closely associated with increased health problems. The major source of the pollution is found to be the increased traffic congestion with damaged roads at all the study centres in Gwalior city. During the study, it has been observed that the rapid increase in vehicle transportation with damaged and narrow roads and lack of infrastructure with an increase in the number of vehicles like auto rickshaws, tempos, and mini buses. Two wheelers that run on diesel emit dangerous pollutants viz. RSPM, SPM, NO_2, SO_2. Also the role of industries in polluting the environment cannot be ignored. All these activities result in polluting the environment. In order to bring the level of pollution down, steps should have been taken as early as possible to control, monitor and rectify the damage that has been done by the pollutants. The problem of air pollution is due to various activities so diverse and needs to be taken seriously because the transportation and industrial activities are growing both in number and size. It is very important to keep an eye on the level of pollutants and control measures so that we can be able to maintain the environment in an acceptable condition for future generations. In general, some sites always remain above the prescribed standard of SPM and RSPM in all the seasons but in winter and summer seasons maximum violence of prescribed standards occur in comparison to the other two seasons. All the monitoring sites are observed to have high winter and summer values than pre-monsoon and low values in post monsoon season.

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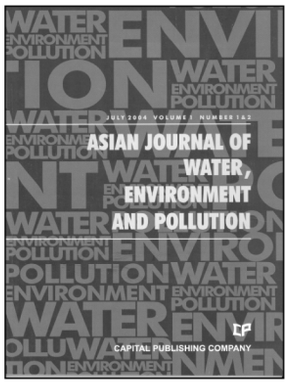

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Aims and Scope
Asia, as a whole region, faces severe stress on water availability, primarily due to high population density. Many regions of the continent face severe problems of water pollution on local as well as regional scale and these have to be tackled with a pan-Asian approach. However, the available literature on the subject is generally based on research done in Europe and North America. Therefore, there is an urgent and strong need for an Asian journal with its focus on the region and wherein the region specific problems are addressed in an intelligent manner. In Asia, besides water, there are several other issues related to environment, such as; global warming and its impact; intense land/use and shifting pattern of agriculture; issues related to fertilizer applications and pesticide residues in soil and water; and solid and liquid waste management particularly in industrial and urban areas.

Asia is also a region with intense mining activities whereby serious environmental problems related to land/use, loss of top soil, water pollution and acid mine drainage are faced by various communities.

Essentially, Asians are confronted with environmental problems on many fronts. Many pressing issues in the region interlink various aspects of environmental problems faced by population in this densely habited region in the world. Pollution is one such serious issue for many countries since there are many transnational water bodies that spread the pollutants across the entire region. Water, environment and pollution together constitute a three axial problem that all concerned people in the region would like to focus on.

Editor-in-Chief
Prof. V. Subramanian
Formerly Dean, School of Environmental Science
Jawaharlal Nehru University
New Delhi, India
Email: ajwep@capital-publishing.com

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