Assessment of particulate matters and its impact on environment: A case study of Aizawl city

[1]Davy Lalruatliana , [2]Lalnuntluanga, [3]S.T.Lalzarzovi

[1]PhD Scholar, [2]Professor, [3]Assistant Professor
[1]Department of Environmental Science,
[1]Mizoram University, Aizawl, Mizoram.

Abstract : Particulate matter is one of the most important pollutants responsible for air pollution. Apart from its impact on human health, exposure to a given concentration of particulate matter may, depending on the mix of deposited particles, lead to a variety of impact on the environment. This study has been carried out to assess the concentration of particulate matters in Aizawl city and to examine its impact on the soil and water qualities. The annual mean concentration of PM_{10} and SPM are found to be 36.38 µg m^{-3} and 95.75 µg m^{-3} respectively. Exceedance factor was found to be 0.6 for PM_{10} and 0.7 for SPM which indicated moderate pollution. The mean mass concentrations of PM_{10} was found to be highest in winter (51.30µg m^{-3}), followed by pre-monsoon (41.67µg m^{-3}) and post-monsoon (31.65µg m^{-3}) and lowest in monsoon (22.58 µg m^{-3}).For SPM, the highest mean mass concentrations is in winter (131.56 µg m^{-3}) followed by pre-monsoon (110.78 µg m^{-3}), post monsoon(90.92 µg m^{-3}) and monsoon (60.42 µg m^{-3}).Soil pH during the study month ranged from 5.28 - 5.5 , water pH ranged from 7.17 - 7.8 and turbidity ranged from 1.27 NTU – 41.03NTU. PM10 concentration and soil pH showed a statistically significant linear relationship (r= .517, p<0.01). SPM and soil pH also showed a moderately strong positive correlation that is statistically significant (r= .539, p<0.01)

IndexTerms – *particulate matters, $PM_{2.5}$, PM_{10}, SPM, Aizawl, environmental impact.*

I. Introduction

Air quality of cities have deteriorated over the years due to various factors such as increase in population, increase in traffic and traffic emissions and decrease in forest cover. Sources of particulate matter are vehicle emissions, coal-burning power plants, industrial emissions, and many other human and natural sources with the traffic–generated emissions accounting for more than 50% of the total particulate matters emissions in the urban areas (Wrobel et al., 2000). Particulate matters has become one of the major air pollutants in urban regions of the world (Mukherjee and Agrawal, 2017). Most of the cities worldwide have exceeded the WHO standard and their country's standard for particulate matters. (WHO 2016).

There have been several reports confirming the negative effect of particulate matters on human health. The World Health Organization estimates that around 7 million people die every year from exposure to fine particles in polluted air that lead to diseases such as stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, including pneumonia. In addition to this, particulate matters have negative impacts on the environment such as reduction of atmospheric visibility (haze) as particulate matters are important component of smog (Singh et al. 2016) . Particulate matters can be carried over long distances and deposited on ground or water. PM deposited directly to the soil can influence nutrient cycling, especially that of nitrogen, through its effects on the rhizosphere bacteria and fungi. Alkaline cation and aluminum availability are dependent upon the pH of the soil that may be altered dramatically by deposition of various classes of PM. (Grantz et al. 2003). When it is deposited in water bodies, it may lead to increased acidity of lakes and streams and nutrient balance changes in coastal waters and river basins.

The present investigation aims to monitor and assess the concentration of particulate matters - PM_{10} and SPM within Aizawl city, the capital of Mizoram and to find the impacts that it may have on soil and water.

II. Study Area

Mizoram is one of the eight sister states of North-East India bordering Myanmar and Bangladesh, covering an area of 21,081 km^2.It lies between coordinates $21^0$58' N to $24^0$35' N latitude and $92^0$15'E to $93^0$20' E longitudes. The tropic of cancer run through the heart of Mizoram at $23^0$30'N latitude dividing the state into almost two equal halves/parts. Aizawl is the capital of the state of Mizoram situated on a ridge 1,132 meters (3,715 ft.) above sea level. It is located in the northern part of Mizoram with Tlawng river valley to its west and Tuirial river valley to its east. The geographic location of the heart of the capital Aizawl is 23.36° N 92.0° E .The population of the Aizawl is highest within the state with a total population of 400,309 according to 2011 census . Aizawl has a mild, sub tropical climate due to its location and elevation with temperature ranging from 20-35°C in summer and 11-21°C in winter. Annual rainfall received is around 209 cm (Anon. 2011). The main contributors to particulate matter pollution in Aizawl city are traffic emissions, dust particles from unpaved roadsides and construction sites, forest fires and burning of Jhum fields.

III. Materials and Methods

3.1 Sampling

Four sampling stations were chosen to monitor the particulate matter concentration of Aizawl city. The first is located in Mizoram University in the outskirts of the city which is a sparsely populated with low traffic volume. Expected particulate matter source consist mainly of emissions from burning of Jhum fields. The second is located in Bawngkawn , a commercial area with very high traffic volume and dense population located in the northern part of the city. It is one of the most important entry and exit point for transport vehicles going in and out of the city. The third station is located in Laipuitlang, one of the most densely populated locality in the city. It is a residential area with moderate traffic volume located in the central part of the city having a higher elevation of 1134 m. The fourth station is Sikulpuikawn, one of the oldest localities situated in the southern part of the city.

It is a commercial cum residential area and have a very high traffic volume as it is an important crossroad in the city. Sampling was done using ‘Respirable Dust Sampler’, Envirotech Model APM 460 BL which draws air through a size – selective inlet and through a 20.3 x 24.4cm (8x10in) filter at a flow rate which is typically 1132 L/min (40ft3/min). Particles with aerodynamic diameters less than the cut point of the inlet are collected by the filter and the mass of these particles is determined by the difference in filter weights prior to and after sampling. The concentration of suspended particulate matter in the designated size range is calculated by dividing the weight gain of the filter by the volume of air sample. The data collection period was from June 2015 to May 2016.

Soil samples were collected monthly within a 10 m radius from the Respirable Dust Samplers. 10 gm of air dried soil was mixed with 50 ml of De-ionized water and stirred with a glass rod. The pH was measured after one hour using a pH meter with combined electrode.Water samples were collected from three streams that flows through the study area namely Chite river, Tuikual stream and MZU stream at monthly intervals for analysis of pH and turbidity.

3.2 Exceedance Factor:

The ratio of the annual mean concentration of a pollutant with that of a respective standard is termed as the exceedance factor (NAAQMS, 2014). This Exceedance Factor (EF) analyses the air quality deterioration due to rising level of air pollution. It is determined using the following formula

EF =Observed concentration of criteria pollutant/Annual standard for the respective pollutant and area class (1)

Based on this exceedance factor, air quality has been categorized into critical pollution (C) when EF is more than 1.5, high pollution (H) when EF is between 1.0 to 1.5, moderate pollution (M) when EF is between 0.5 to 1.0 and low pollution (L) when EF is less than 0.5.

3.3 Statistical analysis

Maximum, minimum, mean and standard deviation of the concentrations of PM10 and SPM were calculated using SPSS software. Karl Pearson’s coefficient of correlation was used to measure the degree of relationship between particulate matters and the environment.

IV. RESULTS AND DISCUSSION

4.1 Mean mass concentration of PM_{10} and SPM

The mean mass concentration of PM_{10} and SPM are presented in Table 1. The annual mean mass concentration of PM_{10} and SPM is 36.38 µg m^{-3}, and 95.88 µg m^{-3} respectively. Both the values are within the permissible limit of the National Ambient Air Quality Standards which are 60 µg m^{-3} for PM_{10} and 140 µg m^{-3} for SPM. However, the annual mean mass concentration of PM10 exceeds the WHO Air Quality Guidelines 2005 which is 20 µg m^{-3}.

Seasonal variations in the concentration of PM_{10} and SPM have been observed. The mean mass concentrations of PM_{10} is highest in winter (51.30µg m^{-3}), followed by pre-monsoon (41.67µg m^{-3}) and post-monsoon (31.65µg m^{-3}) and lowest in monsoon (22.58 µg m^{-3}) . For SPM, the highest mean mass concentrations is in winter (131.56 µg m^{-3}) followed by pre-monsoon (110.78 µg m^{-3}), post monsoon(90.92 µg m^{-3}) and monsoon (60.42 µg m^{-3}). This seasonal variation of particulate matters with the highest levels in winter and lowest levels in monsoon have been reported in various cities such as Delhi (Sharma et al.,2014; Tiwari et al., 2015), Lucknow (Pandey et al., 2012), Hyderabad (Gummeneni et al. 2011), Kolkata (Chatterjee et al, 2012), Chennai (Srimuruganandam & Nagendra, 2011 , Agra (Massey et al, 2012). The highest mass concentrations during the winter may be attributed to calm wind speed, low mixing height, low atmospheric boundary layer, increased biomass and coal burning (Misra et al., 2012; Pipal et al., 2014; Villalobos et al., 2015; Gogikar and Tyagi, 2016). The lowest mass concentration of particulate matter in monsoon season may be due to high precipitation (Kumar et al., 2007; Kumar and Sarin, 2009; Deshmukh et al., 2011).

The monthly mean concentrations of PM_{10} and SPM is given in (Fig. 1). The highest monthly mean mass concentration of PM_{10} (86.72 µg m^{-3}) and SPM (216 µg m^{-3}) were observed in January, 2016 while the lowest concentration of PM_{10} (19.21µgm^{-3}) was seen in July 2015 and lowest concentration of SPM(54.67 µg m^{-3}) was seen in August, 2015 .

Table 1: Annual and seasonal mean mass concentration of PM_{10}

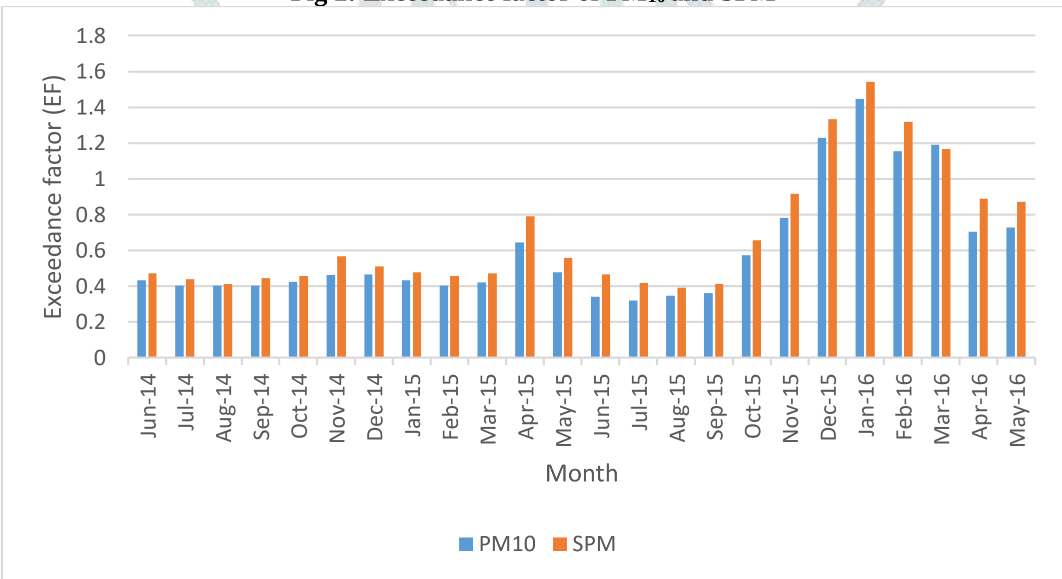
	PM_{10} (µg m^{-3})			SPM (µg m^{-3})		
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum
Annual	36.38±19.463	19.21	86.72	95.88±48.03	54.67	186.67
Pre-Monsoon/Summer (March-May)	41.67±14.94	25.22	71.47	110.78±35.10	66.00	163.33
Monsoon (June-September)	22.58±2.37	19.21	25.95	60.42±4.01	54.67	66.00
Post-Monsoon/Autumn (October-November)	33.65±9.66	27.72	46.96	90.92±27.45	64.00	128.33
Winter (December-February)	51.30±28.27	24.22	86.72	131.56±71.26	64.00	186.67

Fig 1 : The monthly mean mass concentration of PM_{10} and SPM

4.2 Exceedance Factor

The exceedance factor was found to be 0.6 for PM_{10} and 0.7 for SPM which indicated moderate pollution(Fig.2). Monthly exceedance factor has shown that during the study period, pollution load of SPM was critical only in January 2016

Fig 2: Exceedance factor of PM_{10} and SPM



4.3. Physico-chemical properties of soil and water and their relationship with PM10 and SPM concentrations

During the study period, the minimum value for soil pH was recorded in the months of September, 2014 ; May, 2015 and October 2015(5.28) while the maximum value was recorded in the month of January, 2016 (5.50). The minimum value for water pH was recorded in month of October, 2014 (7.17) while the maximum value was recorded in the month of May 2015 (7.8). Turbidity was found to be minimum in the month of May,2016 (1.27 NTU) and maximum in the month of March,2016 (41.03 NTU).

Analysis of the relationship between PM_{10} concentration and soil pH showed a statistically significant linear relationship (r= .517, p<0.01). SPM and soil pH also showed a moderately strong positive correlation that is statistically significant (r= .539, p<0.01)

Table 2. Monthly average of soil pH, Water pH and Turbidity

Year	Month	Soil pH	Water pH	Turbidity
2014	June	5.40	7.47	2.77
	July	5.35	7.73	5.17
	August	5.28	7.43	15.27
	September	5.33	7.63	7.83
	October	5.33	7.17	12.27
	November	5.38	7.57	1.70
	December	5.40	7.27	2.57

2015	January	5.48	7.53	6.77
	February	5.40	7.37	5.00
	March	5.35	7.70	35.27
	April	5.30	7.70	13.70
	May	5.28	7.80	1.90
	June	5.38	7.57	3.20
	July	5.40	7.60	4.77
	August	5.33	7.37	6.27
	September	5.30	7.47	10.40
	October	5.28	7.30	12.83
	November	5.43	7.53	3.00
	December	5.38	7.23	1.87
2016	January	5.50	7.50	11.73
	February	5.45	7.40	10.33
	March	5.43	7.80	41.03
	April	5.45	7.60	16.53
	May	5.48	7.77	1.27

Table 3: Pearson's coefficients of correlation between variables

	PM_{10}	SPM	Soil pH	Water pH	Turbidity
PM_{10}	**1**	.989**	.517**	-.009	-.009
SPM		**1**	.539**	. 005	.187
Soil pH			**1**	.102	-.033
Water pH				**1**	.276
Turbidity					**1**

****. Correlation is significant at the 0.01 level (2-tailed).**

V. CONCLUSION

The annual mean concentration of PM_{10} and SPM were assessed for a period of two years from June, 2014 to May, 2016 and were found to fall within the permissible limit of the National Ambient Air Quality Standards. However, calculation of exceedance factor has indicated that the air in Aizawl city is moderately polluted (M). The main source of particulate matter in Aizawl city can be attributed to traffic emissions as there are no major industries in the state of Mizoram. Annual mean concentration of particulate matters, both PM_{10} and SPM have been found to have a significant correlation with soil pH.

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