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Investigation of Impacts of Mining and Transportation Activities on Ambient Air Quality of Dhanbad City

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ABSTRACT

The present study was intended to emphasize the assessment of ambient air quality of Dhanbad city with respect to PM_{10}, $PM_{2.5}$, SO_2 and NO_X concentrations, in order to investigate the impact of mining and transportation activities. From the monitoring and analysis at four selected monitoring stations during winter and summer seasons, significant spatial variation in pollutant (PM_{10}, $PM_{2.5}$, SO_2 and NO_X) concentrations is quite evident. The concentrations of PM_{10} were observed highest in mining area (at Dhansar PS; 291 μg/m^3), whereas the $PM_{2.5}$ the concentrations were observed higher along traffic routes (especially, at Bank More; 218 μg/m^3). Higher concentratios of PM_{10} in mining area indicates the substantial impact of dust emanated from mining and associated activities on air quality. Whereas, the higher $PM_{2.5}$ concentration along the transportation routes shows the influence of transportation activities on the airshed of the area. The significant seasonal variation in pollution levels is also apparent, as the concentrations of every pollutant were observed higher during the winter, than the summer season, at all sites. The mean concentration levels of PM_{10} and $PM_{2.5}$ were observed 267 μg/m^3, 173 μg/m^3 and 234 μg/m^3, 108 μg/m^3 during winter and summer seasons, respectively. From the calculated values of air quality index, it is evident that Dhansar PS and Bank More are most polluted sites and PM_{10} is the most alarming pollutant in the area under investigation.

Key words: Air quality, AQI, PM_{10}, $PM_{2.5}$, summer, winter.

Air pollution is a major concern before scientific communities and policy makers all over the world, especially in developing countries. With the rapid growth in population, urbanization, industrialization and economic growth, there is a steady surge in demand of mining and energy sectors. This puts a substantial pressure on the environmental regime, particularly on the ambient air. The mining and energy industries are the foremost sectors responsible for the severe deterioration in air quality besides their significant contribution to the economic development. At present, energy is chiefly produced by fossil fuels (coal, petroleum oil and natural gas)[1]. Among these, coal is the most abundantly present and cheapest source of energy[2].

Jharia coal-field (JCF) located in Dhanbad, is one of the most important and the most exploited coal-field of India because of available metallurgical grade coal reserves. Jharia coal-field is subjected to intensive mining activities and accounts for 30% of the total Indian coal production[3]. The mining and associated activities deteriorate the ambient air quality through the emissions of particulate matters (PM), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2)[4]. This coal field is also of great concern because of the mine fires, spread over an area of approximately

18 km[2 4]. Besides mining and energy sector, another most important activity, deteriorating air quality is vehicular transportation. Vehicular (Paved/unpaved) transportation is known to contribute a considerable load of particulate matter (PM_{10} and $PM_{2.5}$)[5, 6, 7, 8, 9, 10,11], oxides of nitrogen (NO_X)[12].

Particulate matters are pollutants of major concern because of its diverse nature (size and composition) and complexity of sources. The particulate matters carry toxic pollutants such as heavy metals[13] and toxic organic compounds. Metals associated with respirable particles have been shown to increase lung and cardiopulmonary injuries in humans[14]. Particulate matters also reduce visibility and adversely affect surrounding flora and fauna[15, 16].

The huge impacts of mining and transportation activities on the ambient air quality obligates the assessment pollution levels in this area. Further, this area (Dhanbad) is declared as a critically polluted area and ranked 13th among 88 industrial areas, with a score of 78.60 out of 100 by Central Pollution Control Board (CPCB) in consultation with the Ministry of Environment and Forests, Government of India[17]. The objective of the study was to investigate the scenario of air pollution in mining and urban areas of Dhanbad in order to assess the impact of the dominant anthropogenic activities (mining and transportation) on ambient air quality. For the assessment, the monitoring was done during winter and summer seasons at four selected monitoring stations with respect to PM_{10}, $PM_{2.5}$, SO_2 and NO_X. Based on the observed concentration of pollutants, air quality index (AQI) values were also estimated for better understanding and interpretation of the pollution levels.

Study area

Dhanbad is the third largest city in Jharkhand State and is known as the coal capital of India. It lies between 23°37'3" N to 24°4' N latitude and between 86°6'30" E to 86°50' E longitude, having an mean elevation of 222 m. Dhanbad is situated in the subtropical climatic zone and and experiences a cool winter and hot summer season. The temperature varies approximately between 11°C to 22°C during winter and 25°C to 45°C during summer season. This region receives heavy rainfall (approximately 1300 mm) annually. Open-cast coal mines, coal washeries, coke oven plants, mine fires as well as transportation (mining and non-mining) activities are the major sources of air pollution in this city. For the purpose of systematic ambient air quality monitoring, four (4) representative monitoring stations were selected in the study as per the siting criteria provided by IS: 5182 Part XIV[18]. The details of monitoring stations are presented in Table 1 and Figure 1. Among the four stations, Dhansar P.S. represents a mining area and Bank More, Shramik Chowk and ISM Gate represent traffic routes. Bank More and Shramik Chowk are traffic junctions (dominated by the heavy load of vehicular traffic) and also commercial as well as residential areas. ISM Gate is a institutional as well as residential area (dominated by moderate loads of vehicular traffic).

METHODOLOGY

The study was conducted during Winter (January-February) and Summer seasons (April-May) in the year 2015, with respect to PM_{10}, $PM_{2.5}$, SO_2 and NO_X. The samples were collected on 24 hourly basis at 4 different locations once a week. Ambient samples of PM_{10} were collected by resipirable dust sampler (Envirotech APM 460 NL) (flow rate of 1.1 $m^3 min^{-1}$) on Whatman glass fiber filters and $PM_{2.5}$ samples were collected by fine particulate sampler (Envirotech APM 550 MFC) (flow rate 16.7LPM) on PTEF filter papers. The samples of SO_2 and NO_X were collected by thermo-electrically cooled gaseous samplers (Envirotech APM 411 TE) through wet chemical method. SO_2, present in the ambient air is absorbed (flow rate 0.4 LPM) in a of solution 0.04 M potassium tetrachloromercurate (K_2HgCl_4) to form non-volatile dichlorosulfitomercurate ($HgCl_2SO_3$) and analyzed by following the improved West and Gaeke method[19]. The NO_X concentration in ambient air, was determined by absorbing the NO_X by a solution of 0.4% sodium hydroxide (NaOH) and 0.1% sodium arsenite ($NaAsO_2^-$) with a flow rate 0.5 LPM to form sodium nitrite ($NaNO_2$) and analyzed by following the modified Jacob and Hochheiser method[20].

RESULTS AND DISCUSSION

The concentration levels of PM_{10}, $PM_{2.5,}$ SO_2 and NO_X at four selected monitoring locations during winter and summer seasons is presented

Table 1: Ambient air quality monitoring stations in the study area

Monitoring Stations	Geographical Location N	E	Dominating Activities
Bank More	23°47.302´	86°.25.165´	High traffic density, traffic junction, surrounded by commercial and residential areas
Dhansar P.S.	23°46.540´	86°.24.673´	Underground Mining activities, open-cast mining activities on both side of the road, high traffic densities of mining and non-mining vehicles
ISM Gate	23°48.554´	86°.26.555´	Main road in Dhanbad city, vehicle movement, institutional area, residential area
Shramik Chowk	23°47.654´	86°25.529´	Heavy vehicle density, traffic junction

Table 2: Spatial variation in concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_X during winter and summer seasons

Sampling Stations	PM_{10} (μg/m³)		$PM_{2.5}$ (μg/m³)		SO_2 (μg/m³)		NO_X (μg/m³)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Dhansar P.S.	291	281	131	95	89	57	57	48
Bank More	287	251	218	119	28	25	93	90
Shramik Chowk	266	236	202	107	23	18	67	55
ISM Gate	225	169	139	109	19	13	48	32
Mean	267	234	173	108	40	28	66	56
NAAQS, 2009*	60	60	40	40	50		50	

*****annual standards

Table 3: Spatial variation in air quality index (AQI) with respect to PM_{10}, $PM_{2.5}$, SO_2 and NO_X during winter and summer seasons

Pollutants	Seasons	Sampling Stations Dhansar P.S.	Bank More	Shramic Chock	ISM Gate
PM_{10}	Winter	241	237	216	183
	Summer	281	251	191	146
$PM_{2.5}$	Winter	129	195	183	135
	Summer	105	187	146	152
SO_2	Winter	84	35	29	24
	Summer	61	31	23	16
NO_X	Winter	61	93	74	50
	Summer	50	90	59	40

Orange: Poorly polluted, Violet: Moderately polluted
Light green: Satisfactory, Green: Good

in Table 2. The results reveal a significant variation in pollutant concentrations (PM_{10}, $PM_{2.5}$, SO_2 and NO_X) in mining area and along traffic routes. The PM_{10} concentrations were observed highest in the mining area (at Dhansar PS) during the study period (291 µg/m^3 during winter and 281 µg/m^3 during summer), followed by traffic routes (Bank More, Shramik Chowk and ISM Gate). The concentration levels of PM_{10} were found exceeding the NAAQS by the factor of 2.9, 2.9, 2.7 and 2.2 (100 µg/m^3)[21] at Dhansar PS, Bank More, Shramik Chowk and ISM Gate, respectively during winter season. While, during the summer season the PM_{10} concentrations were observed 2.8, 2.5, 2.4 and 1.7 times higher than the NAAQS at the respective sites. The higher concentration of PM_{10} at Dhansar PS is attributed to dust emanated from closely situated open cast coal mines and extensive movement of small and heavy duty vehicles (mining as well as non-mining). Whereas, vehicular emissions (especially resuspension of settled dust particles) are the prime source of elevated concentrations of PM_{10} at Bank More and Shramik Chowk. Shramik Chowk and Bank More are the two busiest traffic junctions in Dhanbad city. The heavy movement of vehicles and restricted ventilation condition (due to closely surrounding buildings) makes the site seriously polluted.

Unlike PM_{10}, the concentrations of $PM_{2.5}$ were observed higher along the traffic routes (highest at Bank More; 218 µg/m^3 during winter and 119 µg/m^3 during summer), followed by mining area (Dhansar PS). The $PM_{2.5}$ concentrations were found to be exceeding the NAAQS (60 µg/m^3)[21] by the factor of 3.7, 3.4, 2.3 and 2.2 at Bank More, Shramik Chowk, ISM Gate and Dhansar PS, respectively during winter season. While, during the summer season, the $PM_{2.5}$ concentration were observed to be 2.0, 1.8, 1.8 and 1.6 times higher than NAAQS at Bank More, Shramik Chowk, ISM Gate and Dhansar PS, respectively. The exceedance of $PM_{2.5}$ at the monitoring locations is attributed to the substantial influence of vehicular emissions at the sites. Because, fine particles are primarily generated from fossil fuel combustion processes and vehicular emission is its leading source in the urban areas. The elevated concentrations of PM_{10} and $PM_{2.5}$, indicates a significant impact of mining and transportation activities on the ambient air quality of the area under consideration.

Apart from the particulate pollutants, a substantial variation in spatial distribution of gaseous pollutants was also observed. The concentration of SO_2 was observed highest at Dhansar (73 µg/m^3) followed by Bankmore (27 µg/m^3), Shermic chock (21 µg/m^3) and ISM Gate (16 µg/m^3) and at Dhansaar SO_2 concentration was 1.1 times higher than the NAAQS (80 µg/m^3)[21]. NO_X concentration was observed at highest at Bankmore (92 µg/m^3)

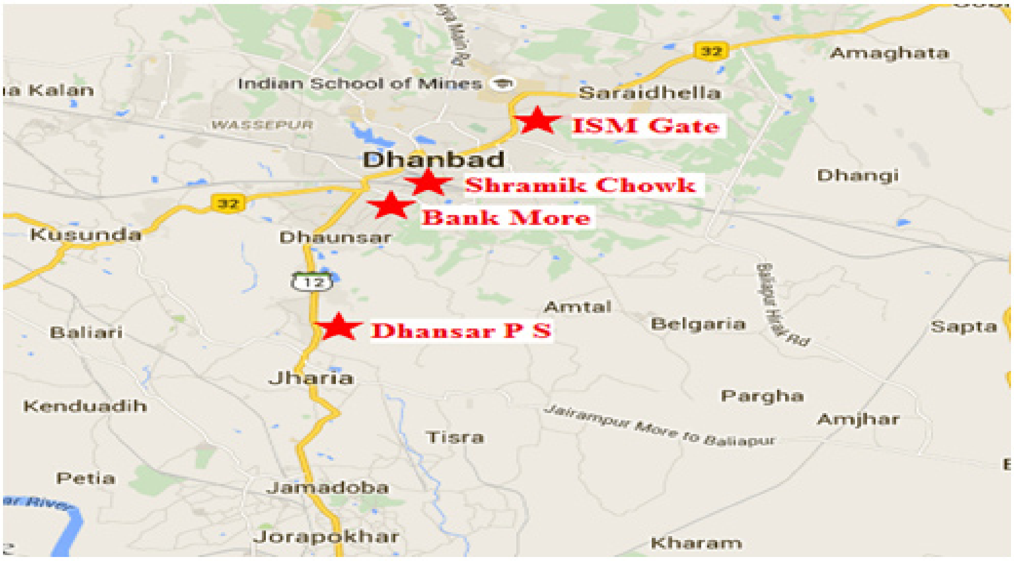

Fig. 1: Map of study area indicating monitoring stations

followed by Shermik Chowk (61 μg/m^3), Dhansar (53 μg/m^3) and ISM Gate (40 μg/m^3). The main reason of higher concentrations of SO_2 and NO_X at Dhansar PS are mine fire and vehicular emission.

The seasonal variation in concentration of pollutants under consideration (PM_{10}, $PM_{2.5,}$ SO_2 and NO_X) is also quite evident. The concentrations of each pollutant was observed higher during the winter, than the summer season, at all sites. Higher concentration during winter is attributed to the prevalence of anti-cyclonic conditions, characterized by calm or light winds and limited mixing depth due to a stable or inversion of atmospheric lapse rate[22]. The respective mean concentrations of PM_{10} and $PM_{2.5}$ in the study area were observed 267 μg/m^3, 173 μg/m^3 during winter and 234 μg/m^3, 108 μg/m^3 during summer. Whereas, the mean concentration levels of SO_2 and NO_X were observed 40 μg/m^3, 66 μg/m^3 and 28 μg/m^3, 56 μg/m^3 during winter and summer seasons, respectively. Similar trends of seasonal variation in particulate matter concentrations were also observed in different areas of India such as Jharia Coalfield[23], around Dhanbad city[24], around Dhanbad city[4], Sambalpur region[22] and Raniganj-Asansol area[25].

For better understanding and interpretation of the pollution levels as well as to identify the levels of health concern, air quality index (AQI) was calculated and selected monitoring stations were categorized accordingly on the seasonal basis. The indexing was done by following the Indian National Air Quality Index (INAQI)[26]. The calculated AQI for each monitoring station is depicted in Table 3. The AQI values with respect to PM_{10} were found poorly polluted at Dhansar PS as well as Bank More and were found moderately polluted at ISM Gate, during both seasons. Whereas, Shramik Chowk was observed poorly polluted during winter and moderately polluted during the summer season. The air quality status with respect to $PM_{2.5}$ was observed moderately polluted at all monitoring stations during both seasons. While, with respect to SO_2 and NO_X, the air quality status was found satisfactory and good. The observed AQI values and the respective categories illustrate that Dhansar PS and Bank More are the most polluted sites and PM_{10} is the most alarming pollutant.

CONCLUSIONS

The aim of this study was to investigate the ambient air quality of Dhanbad city with respect to PM_{10}, $PM_{2.5}$, SO_2 and NO_X monitored at four representative locations. The spatial and seasonal variations in pollutant concentrations were quite significant, which may be caused by diversity among emission sources and prevailing meteorological conditions. From the observation, PM_{10} and $PM_{2.5}$ were found as major pollutants to be concerned, because, the concentration levels of PM_{10} as well as $PM_{2.5}$ at all monitoring stations exceeded the NAAQS (2009) annual permissible limit. The concentration of SO_2 was observed highest at Dhansar PS (73 μg/m^3), whereas NO_X concentration was observed highest at Bank More (92 μg/m^3), which may be attributed to mine fire and vehicular emissions, respectively. Air quality index (AQI) was also calculated by following the National Air Quality Index (NAQI CPCB, 2014). The air quality index revealed that, the airshed of the area is moderately to poorly polluted with respect to PM_{10} and $PM_{2.5}$, while good to satisfactory with respect to SO_2 and NO_X. From the careful observation of the AQI values and its respective categories, Dhansar PS and Bank More are found most polluted sites and PM_{10} is identified as the most alarming pollutant in the area under investigation. Based on the observations, the study portrays the need of detailed time series study of pollutant concentrations, source apportionment study of particulate pollutants (to understand the source profile) and study on dispersion characteristics of the airshed in the future.

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