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Ambient Air Quality Status in Noamundi Iron Ore Mines, Jharkhand (India): A Case Study

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ABSTRACT

Noamundi iron ore mine is one of the ten captive mines of Tata Iron Steel Co. Ltd. It is one of the oldest and largest open cast mines in the country. Mining activities are inherently disruptive to the environment. Due to unsuitable and inefficient working practices during mining causes environmental deterioration. The current work has been carried out to assess the ambient air quality in the open cast iron ore mines in the Noamundi of Jharkhand, India. For the decision makers it has been an important task to keep the air quality within acceptable limit. In the present study monitoring and analysis of SO_2, NO_2, PM_{10} and $PM_{2.5}$ have been carried out. The AQI was also calculated using IND-AQI specified by CPCB and it was based on the dose-response relationship of various pollutants. The monitoring result illustrates that particulate materials were the major pollutants to be concerned in mining areas but all the four parameters was well below the maximum allowed limit of National Ambient Air Quality Standards (NAAQS) for different areas. The overall AQI was found to fall under the category of good.

Keywords: AQI, Iron ore mine, Mining, NAAQS, Open cast mine

I. INTRODUCTION

The air we breathe is a mixture of gases and small solid and liquid particles from both the natural sources and human activities. Presence of substances up to that level which could damage the health of humans and animals, or could harm plants and materials causes air pollution. These substances are called air pollutants and can be either particles, liquids or gaseous in nature [1]. Now days it has become an important task for decision makers to keep the air quality within acceptable limit [2].

Mining is a vital industry for the industrial and economic growth of any country. The development of infrastructure and core sector is directly linked to the increased production of minerals, like coal for the power sector, iron ore for steel sector, limestone for cement for housing and infrastructure development. With increased industrialization, urbanization and other developmental activities; there is a greater need for increased production of minerals.

Mining activities are inherently disruptive to the environment. The environmental degradation caused by mining activities occurs mainly due to lack of appropriate working practices. The magnitude of impact on air quality depends upon the types of mineral being mined, methods, scale and concentration of mining activities [3]. Open-cast mining is more deteriorating to air quality than underground mining. In the last few decades, this problem has been further provoked with the introduction of mechanized mining techniques and heavy earth moving equipment [4] [5]. Major sources of atmospheric emissions from open-cast mining activity include land clearing, removal of overburden, and vehicular movement on the haul roads, excavation, loading and unloading of ore materials as well as overburden.

Air quality monitoring and assessment are required to prevent and minimize the fall of air quality due to mining and other anthropogenic activities. The existing evaluation and assessment of air quality in India are based totally on the compliance of calculated concentration levels of pollutants with the National Ambient Air Quality Standards (NAAQS) [6]. This approach is used to maintain the desired quality of the ambient atmosphere, the concentration level of pollutants found below the NAAQS are fair and acceptable air quality, but sometimes the concentrations are adequately high to cause serious environmental and health problems.

The use of standards is important in administrating and enforcing the desired policy, but there is not a complete tool for evaluating the environmental quality [6]. The requirement to quantify air quality and follow the evolution of pollution has led to a huge quantity of Air Quality Indices, giving an idea of the state of pollution in a day [7]. Air Quality Indices are also of specific significance because; air pollution monitoring data are generally complex and not understandable to the general public. The huge data habitually do not communicate the air quality grade to the scientific community, policymakers and the general public in a uncomplicated and clear-cut manner. This problem can be addressed by determining the Air Quality Index (AQI) of a given area using environmental synthetic indices to review complex situations in a single figure, allowing for comparisons in time and in space [8].

Keeping the aforesaid problems in mind, the current work has been carried out with the objectives of ambient air quality assessment in the open cast iron ore mines in the Noamundi of Jharkhand, India.

II. MATERIALS AND METHODS

2.1. Study Area

Noamundi is one of the oldest and largest open cast mines in the country. It is one of the ten captive mines of Tata Iron Steel Co. Ltd. Noamundi is a census town in Pashchimi Singhbhum district in the Indian state of Jharkhand. It is also an administrative block. It is a small mining town located close to the Odisha border. It lies near to Jamshedpur and 64 km from Chaibasa. The deposit was discovered in the year 1917. The mining was started in the year 1925, however fully fledged mining operations commenced from the year 1926. Legend has it that when the first iron ore explorers came to this region, they were amazed to find the local tribal population

(Adivasis) using iron axes. When the explorers asked the tribals where they had found the ore, they pointed to a hill nearby and called it Noamundi, which literally means 'that hill' in their language. The mine passed through phases of manual, semi mechanized and highly mechanized mining. It is one of the earliest mines in India to convince and execute comprehensive ecology promotion programme. The drive included a unique and first slime dam in the country, large scale afforestation in lease hold and surrounding areas and dust suppressing facilities for arresting air pollution. The major produce of this mine is iron ore including blue dust.

2.2. Geology and Geography

Noamundi is located at 22.15°N 85.53°E. It has an average elevation of 487 metres. Noamundi is located in the heart of Saranda forest, which is the densest deciduous forest of Asia. 'Saranda' in the local tribal language means 'The land of 700 hills'. The administrative boundary of the Saranda reserve forest, however, lies a few kilometres away. Along with dense forest cover, Noamundi is highly resourceful region. The formation containing iron ore deposits belongs to the late Archean iron ore series. These deposits have been formed under marine conditions. The origin of iron seems to be weathering of continental rocks under reducing atmospheric conditions which were prevalent during the early Archean age. It consists of an undulating surface with steep to a gentle slope and reddish yellow to the chocolate colour soil.

2.3. Meteorology

The climate of the area is dry tropical. There are four seasons during the year, i.e., (i) Summer season (March to May), (ii) Rainy season (June to September), (iii) Autumn season (October to November), and (iv) Winter season (December to February). During summer months temperature goes up to 47^0 C and in winter it falls to as low as 10^0 C. Annual mean maximum and minimum temperatures are 33.2^0 C and 20.5^0 C respectively. The wind speed (km/h) and direction were monitored during the winter season in order to find the maximum impact of air qualities and its averages values was calculated for three significant ranges in all direction. It was observed during the study that the prevailing wind direction at that time was northwest.

2.4. Study Sites

Total four monitoring sites were selected for the present study. The first sampling site was at the side of the Primary crusher (N – 1) situated at 600 meter RL. The main source of pollution at primary crusher was basically vehicular pollution and pollution caused by the dumping of ore throughout the day and night. The second sampling site was near rakes in Bottom Bin (N – 2). The main source of pollution was basically vehicular pollution, pollution due to movement of locomotors, due to loading and dumping of processed ore throughout the day and night. The third sampling site was at the gate of GM’s office (N – 3). The main source of pollution at GM’s office is basically two wheelers and four wheelers vehicles throughout the day, one of the main places of the Noamundi. The fourth sampling site was Near Hospital (N – 4) where pollution level is almost very low, posse's forest and vegetation covers. The main source of pollution at hospital premises is two wheelers, three wheelers and four wheelers vehicles throughout the day.

2.5. Monitoring and Analysis

The samples of SO_2, NO_2, PM_{10} and $PM_{2.5}$ were collected at all the four sites namely Primary crusher, Bottom Bin, GM's office and Near Hospital. The monitoring was conducted for 24 hrs at four different sites for 2 days per week for four weeks. The concentration of NO_2 was measured with the standard method of Modified Jacobs- Hochheiser method (1958), SO_2 was measured by Modified West and Geake method (1956). SO_2 and NO_2 samples were collected by aspirating air through measured volume (25 ml) of 0.04 M potassium tetra chloro mercurate (K_2HgCl_4:TCM) and a mixture of sodium hydroxide and sodium arsenite ($NaOH + Na_2AsO_2$), respectively at a flow rate of 2 l/min for 24 hr. The collected samples were transferred to pre-washed polypropylene bottles, and preserved in the refrigerator and analysed colorimetrically at 548 nm for SO_2 and 540 nm for NO_2. The apparatus was kept at a height of 2 m from the surface of the ground.

PM_{10} and $PM_{2.5}$ samples were collected on Whatman GF/A and Teflon (Millipore) filter papers by Respirable Dust Sampler (APM 460DX, Envirotech, New Delhi) and Wins-Anderson impactor (APM 550, Envirotech, New Delhi) with the sharper cut point of 10 µm and 2.5 µm, respectively. The Respirable Dust Sampler and Wins-Anderson impactor were operated at flow rates of 1.0 m^3/min and 16.671 m^3/min (or 1 m^3/hr), respectively.

All the filter papers were pre-weighed on a Metler analytical weighing balance before the sampling and desiccated for 24 hr. To avoid the contamination, the conditioned and weighed filter papers were placed in filter holder cassette ($PM_{2.5}$) and zip lock polybag (PM_{10}) and were taken to the field for sampling. Before loading the filter papers on the samplers, initial volume and timer readings were noted for $PM_{2.5}$ and the manometer reading for PM_{10} sampler. Then the filter papers were loaded on respective samplers and screwed properly before starting the samplers. After sampling, the loaded filter of $PM_{2.5}$ was removed with forceps and placed in a cassette and wrapped with aluminium foil. Similarly, the PM_{10} filter paper was wrapped in aluminum foil and placed back in zip lock polybag and both the filter papers were brought back to the laboratory. In the laboratory, filter papers were conditioned and weighed again to determine the mass concentration of the PM_{10} and $PM_{2.5}$. The weighed filter papers were preserved in the freezer until further chemical analysis.

2.6. Air Quality Index (AQI)

Air Quality Index (AQI) is a tool, introduced by Environmental Protection agency (EPA) in USA to measure the levels of pollution due to major air pollutants. An AQI is defined as an overall scheme that transforms weighted values of individual air pollution related parameters into a single number or set of numbers [9]. In the present study the AQI was calculated using IND-AQI specified by Central Pollution Control Board, New Delhi (CPCB). The index has been developed based on the dose-response relationship of various pollutants. AQI concept transforms weighted values of individual air pollutants into a single number or set of numbers which may be widely used for air quality communication and decision making. This IND-AQI has 6 categories and presented in table 1.

The AQI method involves formation of sub-indices for each pollutant and aggregation of sub-indices. It has been developed on the dose-response relationship of various pollutants [10]. The table 1 shows the Linear segmented relationship for sub-index values and the corresponding pollutant concentrations that are calibrated to Indian conditions.

The mathematical equation for calculating sub-indices is as follows:

$$I_P = \left(\frac{I_{HI} - I_{LO}}{B_{PHI} - B_{PLO}} X \left(C_P - B_{PLO} \right) \right) + I_{LO}$$

Where: I_P is AQI for pollutant "P" (Rounded to the nearest integer),
C_P the actual ambient concentration of pollutant "P",
B_{PHI} the upper end breakpoint concentration that is greater than or equal to C_P,
B_{PLO} the lower end breakpoint concentration that is less than or equal to C_P,
I_{LO} the sub index or AQI value corresponding to B_{PLO},
I_{HI} the sub index or AQI value corresponding to B_{PHI}

TABLE 1. Various Categories of IND-AQI and Break Points of Various Pollutants (National Air Quality Index, CPCB, October 2014), (Units: µg/m^3)

AQI Category	Range	PM_{10} (24hr)	$PM_{2.5}$ (24hr)	SO_2 (24hr)	NO_2 (24hr)
Good	0-50	0-50	0-30	0-40	0-40
Satisfactory	51-100	51-100	31-60	41-80	41-80
Moderately Polluted	101-200	101-250	61-90	81-380	81-180
Poor	201-300	251-350	91-120	381-800	181-280
Very Poor	301-400	351-430	121-250	801-1600	281-400
Severe	401-500	>430	>250	>1600	>400

III. RESULTS AND DISCUSSION

To evaluate the air quality condition of the study area, the CPCB guidelines for sampling and measurement of ambient air quality parameters were followed. For $PM_{2.5}$, PM_{10}, SO_2 and NO_2, NAAQS, 2009 [11] were followed. The NAAQS for $PM_{2.5}$, PM_{10}, SO_2 and NO_2, in the Noamundi iron ore mine is depicted in Table 2.

TABLE 2. Concentration levels of $PM_{2.5}$, PM_{10}, SO_2 and NO_2 in the Noamundi iron ore mine and NAAQS

Location	Primary Crusher (N-1)	Bottom Bin (N-2)	G.M's Office (N-3)	Near Hospital (N-4)	NAAQS

PM $_{2.5}$	29.38	28.38	15.25	9.9	60
PM $_{10}$	49.5	49	35.38	25	100
SO_2	9.61	9.53	8.6	8.28	80
NO_2	9.84	9.74	8.66	8.45	80

3.1. Site-specific variations

The monitoring results illustrate that particulate materials were the major pollutants to be concerned in mining areas. The ambient air concentration of PM_{10} concentrations at the monitoring station was well below the maximum allowed limit of National Ambient Air Quality Standards (NAAQS) for different areas. It ranged from 37.00 to 59.00 µg/m^3, 39.00 to 57.00 µg/m^3, 28.00 to 42.00 µg/m^3 and 19.00 to 31.00 µg/m^3 at site N-1, N-2, N-3 and N-4 respectively (Figure 1). Further, it was observed that average concentrations of $PM_{2.5}$ ranged from 18.00 to 39.00 µg/m^3, 19.00 to 36.00 µg/m^3, 9.00 to 21.00 µg/m^3 and 9.00 to 11.00 µg/m^3 at site N-1, N-2, N-3 and N-4 correspondingly (Figure 2). Highest value of PM_{10} and $PM_{2.5}$ was attained at the Primary crusher (N – 1), while lowest value was attained at Near Hospital (N – 4).

The high concentration of PM_{10} at Primary crusher (N – 1) and Bottom Bin (N – 2) was mainly due to different mining activities as well as running of vehicles on the unpaved road including abrasion of road materials, tires and brake linings as well as re-suspension of soil material because of traffic induced turbulence [12] [13]. The sources of $PM_{2.5}$ have generally been confined to movement of vehicle on paved/unpaved roads, vehicular exhaust (diesel based), mining activities particularly drilling, blasting and crushing of rocks. The release inventory indicates that heavy duty diesel trucks were accountable for majority of the exhaust particulate matter [14].

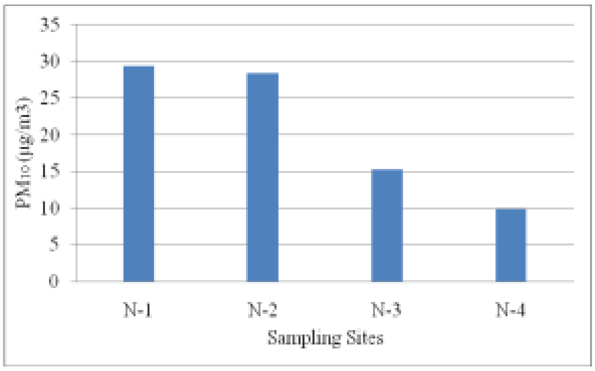

Fig. 1. Variation in the concentration PM_{10} at sampling sites

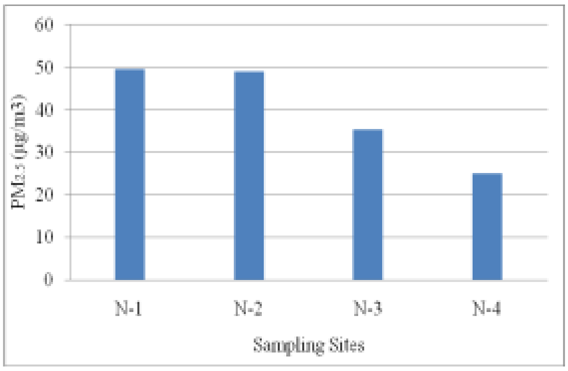

Fig. 2. Variation in the concentration $PM_{2.5}$ at sampling sites

According to the present study, NO_2 and SO_2 concentrations at the monitoring station were well below the maximum allowed limit of National Ambient Air Quality Standards (NAAQS) for different areas. The concentration of NO_2 ranged from 9.30 to 10.30 µg/m^3, 9.30 to 10.20 µg/m^3, 8.30 to 9.00 µg/m^3 and 8.10 to 8.70 µg/m^3 at site N-1, N-2, N-3 and N-4 respectively (Figure 3). The concentration of SO_2 ranged between 9.10 to10 µg/m^3, 9.10 to 9.90 µg/m^3, 8.20 to 9.10 µg/m^3 and 7.90 to 8.60 µg/m^{3}at site N-1, N-2, N-3 and N-4 respectively (Figure 4).

The main sources of NO_2 in mining rejoin are vehicular exhaust, blasting operations, etc. During combustion process (at high temperature) atmospheric nitrogen combines with oxygen to form NO_2 which is aggravated when engine is diesel operated. According to tunnel studies while comparing to gasoline vehicles diesel engine produce five times the amount of NO_X per mass of fuel burned [15].

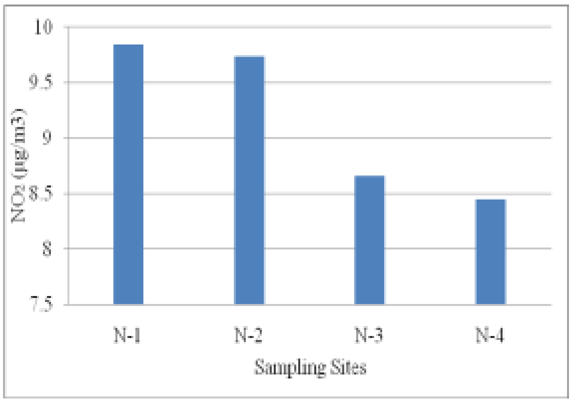

Fig. 3. Variation in the concentration NO_2 at sampling sites

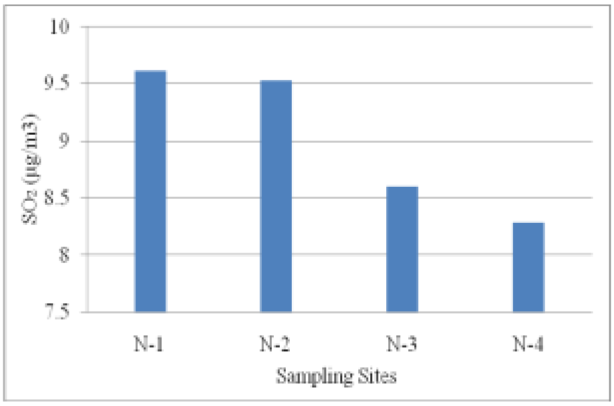

Fig. 4. Variation in the concentration SO_2 at sampling sites

3.2. Results of AQI

Data obtained from monitoring of ambient air at four different sites is used to calculate the sub- indices for critical parameters. The calculated AQI values for 24 hourly averages SO_2 and NO_2 concentrations are categorized as good during the study period at all the four sites. The AQI values calculated for $PM_{2.5}$ showed G.M's Office (N-3) and Near Hospital (N-4) under good category but Primary Crusher (N-1) and Bottom Bin (N-2) under satisfactory category in case of PM_{10} the calculated AQI values varied 25 to 50 µg/m^3 at four different sites which lies under good category. The overall air quality was evaluated using AQIs. The AQIs were estimated for criteria pollutants SO_2, NO_2, PM_{10} and $PM_{2.5}$ using IND-AQI procedure. The overall AQI was found to fall under the good category.

TABLE 3. AQI and Sub- indices at different sampling sites

Location	Primary Crusher (N-1)	Bottom Bin (N-2)	G.M's Office (N-3)	Near Hospital (N-4)
$PM_{2.5}$	49	47	25	17
PM_{10}	50	49	35	25
SO_2	12	12	11	10
NO_2	12	12	11	11
AQI	50	49	35	25

3.3. Air pollution control equipments and prevention techniques

As mechanized open cast iron ore mines are becoming larger, deeper and more capital intensive, resulting in environmental pollution. Continuing efforts has been made to improve ambient air quality condition upon the open cast mining activities. A management strategy was formulated for effective control of air pollution at source and other mitigative measures including green belt design have also been devised for sensitive areas [16]. Some pollution prevention measures and techniques were employed like mobile water sprinkler, fixed water sprinkler, dry fog system at primary crusher, dust extractor at primary crusher, wet drilling, addition of dust suppresscent in sprinkling water, wet processing of iron ore and transportation by conveyors.

IV. CONCLUSION

Open-cast mining is more deteriorating to air quality than underground mining. To assess the environmental impact of different mining activities, SO_2, NO_2, PM_{10} and $PM_{2.5}$ were measured at all the four sites namely Primary crusher, Bottom Bin, GM's office and Near Hospital. The analysis result illustrates particulate materials as the major pollutants to be concerned in mining areas. The ambient air concentration of PM_{10} concentrations at the monitoring station was well below the maximum allowed limit of National Ambient Air Quality Standards (NAAQS) for different areas. Highest value of PM_{10} and $PM_{2.5}$ was observed at the Primary crusher (N – 1), while lowest value was found at Near Hospital (N – 4). According to the present study, NO_2 and SO_2 concentrations at the monitoring station were well below the maximum allowed limit of National Ambient Air Quality Standards (NAAQS) for different areas. The calculated AQI values for SO_2 and NO_2 concentrations are categorized as good during the study period at all the four sites. The AQI values calculated for $PM_{2.5}$ showed under good category for two points but under satisfactory category for the other 2 points. In case of PM_{10}, the calculated AQI value lies under good category. The overall AQI was found to fall under the category of good. Many measures and management strategies were formulated for effective control of air pollution at source.

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