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Status of Ambient Air Quality in Khondbond Iron Ore Mines, Orissa (India)

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ABSTRACT

Khondbond Iron Mine is located at Keonjhar district of Orissa, around 18 km from Joda East Iron Mine. Iron ore available in this mine is especially suitable for sponge iron making. Mining is a vital industry for the industrial and economic growth of any country and is 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 Khondbond of Orissa, India. For the decision makers, it has been an important task to keep the air quality within an 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 Air Quality Index (AQI) was also calculated using IND-AQI specified by Central Pollution Control Board (CPCB), New Delhi and it was based on the dose-response relationship of various pollutants. The result illustrates that all the four parameters were well below the maximum allowed limit of National Ambient Air Quality Standards (NAAQS) and the particulate materials were the major pollutants in mining areas 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*

1. Introduction

The air we breathe is a mixture of gases and small solid and liquid particles. Some substances come from natural sources while others are caused by human activities. Keeping the air quality acceptable has become an important task for decision makers as well as for non-governmental organizations [2]. Air pollution occurs when the air contains substances in quantities that could harm the comfort or health of humans and animals, or could damage plants and materials. These substances are called air pollutants and can be either particles, liquids or gaseous in nature [1]. Mining is the extraction of valuable minerals or other geological materials from the earth, usually from an ore body, vein or (coal) seam. Minerals play an important role in the economic development of the country as minerals are the basic raw materials to promote the growth.

Mining is a vital industry for the industrial and economic growth of any country. The mineral industry in India is reckoned not only as an important contributor to the country's GDP and foreign trade, it is also one of the major industries that absorb a considerable amount of the country's working population. The Indian mining industry provides employment to about 1.1 million persons. India's mining industry is projected to touch over $30 billion (about Rs. 1, 27,662 crores) accounting for about 2.5% of the GDP in the next four years, the latest report said.

Mining activities are inherently disruptive to the environment. The environmental deterioration caused by mining activities occurs mainly as a result of inappropriate and wasteful working practices. Over the past few years, with the introduction of mechanized mining techniques and heavy earth moving equipment, the problem has been further aggravated [3] [4]. The magnitude of impact on air quality depends upon the types of mineral being mined, methods, scale and concentration of mining activities [5]. Open-cast mining is more deteriorating to air quality than underground mining. Land clearing, removal of overburden, and vehicular movement on the haul roads, excavation, loading and unloading of ore materials as well as overburden are the major sources of atmospheric emissions from open-cast mining activity.

Air quality monitoring and assessment are required to prevent and minimize the deterioration of air quality due to mining and other anthropogenic activities. The existing evaluation and assessment of air quality in India are based entirely on the compliance of measured 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 sufficiently high to pose serious environmental and health problems.

The use of standards is important in administrating and enforcing the desired policy, but they are not a complete tool for evaluating the environmental quality [6]. The need to quantify air quality and follow the evolution of pollution has led to a large amount 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 large data often do not convey the air quality status to the scientific community, policymakers and the general public in a simple and straightforward manner. This problem can be addressed by determining the Air Quality Index (AQI) of a given area using environmental synthetic indices to summarize complex situations in a single figure, allowing for comparisons in time and in space [8].

The current work has been carried with the objectives of assessment of the ambient air quality in the open cast iron ore mines in the Khondbond of Orissa, India.

2. Materials and methods

2.1. Study Area

Khondbond Iron Mine is located at Keonjhar district of Orissa, around 18 km from Joda East Iron Mine. The Khondbond mine has deposits of sponge grade iron ore and also occurrences of manganese ore. The iron ore deposit in this mine is worked by mechanised open cast mining in a series of 6 m high benches. The Crushing Plant at Khondbond, established in 1994, crushes the ore in three stages to produce lump ore, which is dispatched for sponge iron making to M/s. Tata Sponge Iron Ltd. (TSIL) at Joda, while the fines are transported to the Steel Works at Jamshedpur.

Discovered in 1917, the integrated manganese complex has the capacity to handle 0.3 Million MT of ore and 40000 tones per annum of manganese alloys. The plant recorded its highest ever production and crossed breakeven production with lowest ever cost. Iron ore available in this mine is especially suitable for sponge iron making. The crushing plant established in 1994 by Svedala, crushes the ore in three stages to produce lump ore with a size range of 18 mm to 5 mm. It is then dispatched for sponge iron making to M/s Tata Sponge Iron Ltd at Joda, while the fines are transported to Jamshedpur for steelworks.

2.2. Monitoring and Analysis

Total four monitoring sites were selected for the present study. The first sampling site was near the plant (A–1). The second sampling site was at the mining site (A–2). The third sampling site was near weighbridge (A–3). The fourth sampling site was at the site of Equipment Maintenance (A–4).

The samples of SO_2, NO_2, PM_{10} and $PM_{2.5}$ were collected at all the four sites. SO_2, NO_2, PM_{10} and $PM_{2.5}$ samples were collected for 24 hr 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.

2.3. Air Quality Index (AQI)

Air Quality Index (AQI) is a tool, introduced by Environmental Protection Agency (EPA) in the 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 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.

The AQI method involves the 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]. Table 1 shows the Linear segmented relationship for sub-index values and the corresponding pollutant concentrations that are calibrated to Indian conditions.

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

The mathematical equations 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}

3. Results and discussion

To assess the air quality status of the study area, the CPCB guidelines for sampling and measurement of ambient air quality parameters were followed. The NAAQS [11] for $PM_{2.5}$, PM_{10}, SO_2 and NO_2, is depicted in Table 2. The concentration levels of $PM_{2.5}$, PM_{10}, SO_2 and NO_2 in the Khondbond iron ore mine are presented in Table 2.

3.1. Near plant (A–1)

The sampling point A–1 was near crushing plant. The main source of pollution near the plant is vehicular pollution, crushing, screening and processing. The concentration of SO_2 at near crushing plant varies from 9.4 to 9.90 µg/m^3, which is within the permissible limit of 80µg/m^3. The concentration of NO_2 varies from 9.6 to 10.40 µg/m^3, which is within the prescribed limit of 80 µg/m^3. $PM_{2.5}$ shows variation in the concentration from 21.00 to 37.00 µg/m^3 which is within the permissible limit. The concentration of PM_{10} varies from 41.00 to 58.00 µg/m^3 which comes under the permissible limit.

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

Location	Near Plant (A-1)	Mining Site (A-2)	Near Weighbridge (A-3)	Equipment Maintenance (A-4)	NAAQS
PM $_{2.5}$	27.6	26.5	23.25	14.8	60
PM $_{10}$	50.7	47.4	43.63	35.4	100
SO_2	9.63	9.59	9.61	9.34	80
NO_2	9.96	9.8	9.84	9.58	80

3.2. Mining site (A–2)

The second sampling point A–2 was not fixed it is a mobile point for sampling because excavation of ores will take place at the different location. The source of pollution in mining area is basically the movement of the vehicle, excavation of ores, drilling and blasting. The concentration of SO_2 varies from 9.20 to 10.00µg/m^3, which is within the permissible limit of 80µg/m^3. The concentration of NO_2 varies from 9.40 to 10.30µg/m^3, which is within the prescribed limit of 80 µg/m^3. $PM_{2.5}$ shows variation in the concentration from 16.00 to 33.00 µg/m^3 which is within the permissible limit. The concentration of PM_{10} varies from 37.00 to 53.00 µg/m^3 which comes under the permissible limit.

3.3. Weigh Bridge (A–3)

The main pollution near Weigh Bridge is vehicular pollution. Sampling point was at the side of Weigh Bridge. The RDS and FPM have been started at 6.0 AM and stopped at 6.0 AM next day. The concentration of SO_2

varies from 9.20 to 10.20 µg/m^3, which is within the permissible limit of 80 µg/m^3. The concentration of NO_2 varies from 9.40 to 10.30 µg/m^3, which is within the prescribed limit of 80 µg/m^3. $PM_{2.5}$ shows variation in the concentration from 16.00 to 30.00 µg/m^3 which is within the permissible limit. The concentration of PM_{10} varies from 35.00 to 50.00 µg/m^3 which comes under the permissible limit.

3.4. Equipment Maintenance (A–4)

The sampling point A-4 was nearer to the restroom the main source of pollution at equipment maintenance is vehicular pollution and population. The concentration of SO_2 varies from 9.00 to 9.70 µg/m^3, which is within the permissible limit of 80 µg/m^3. The concentration of NO_2 varies from 9.3 to 9.90 µg/m^3, which is within the prescribed limit of 80 µg/m^3. $PM_{2.5}$ shows variation in the concentration from 9.00 to 22.00 µg/m^3 which is within the permissible limit. The concentration of PM_{10} varies from 29.00 to 42.00 µg/m^3 which comes under the permissible limit.

The high concentration of PM_{10} at Near Plant (A–1) and Mining Site (A–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 the vehicle on paved/unpaved roads, vehicular exhaust (diesel-based), mining activities particularly drilling, blasting and crushing of rocks. The emission inventory indicates that heavy-duty diesel trucks were accountable for the majority of the exhaust particulate matter [14].

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 the engine is diesel operated. Tunnel studies indicated that diesel engine produces five times the amount of NO_2 per mass of fuel burned when compared to gasoline vehicles [15].

3.5. Results of AQI

Data obtained from monitoring of ambient air at four different sites are 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 at equipment maintenance is under good category but for Near Plant (A-1), Mining site (A-2) and Near Weighbridge (A-2) under satisfactory category in case of PM_{10} the calculated AQI values lies under good category for A-2, A-3, and A-4 but lies under satisfactory category for A-1. The overall air quality was assessed using AQIs. The AQIs were calculated 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 category of good.

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

Location	Near Plant (A-1)	Mining Site (A-2)	Near Weighbridge (A-3)	Equipment Maintenance (A-4)
$PM_{2.5}$	46	44	39	25
PM_{10}	51	47	44	35
SO_2	12	12	12	12
NO_2	12	12	12	12
AQI	51	47	44	35

3.6. Air pollution control equipment and prevention techniques

As mechanized open cast iron ore mines are becoming larger, deeper and more capital intensive, resulting in environmental pollution. Continuing efforts have 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 which are mobile water sprinkler, fixed water sprinkler, dry fog system at the primary crusher, dust extractor at the primary crusher, wet drilling, the addition of dust suppresscent in sprinkling water, wet processing of iron ore and transportation by conveyors.

4. Conclusion

The mineral industry in India is an important contributor to the country's GDP and foreign trade, and it also absorbs a considerable amount of the country's working population. 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 near the plant (A–1), at the mining site (A–2), near weighbridge (A–3), and at the site of Equipment Maintenance (A–4).

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. The high concentration of PM_{10} at Near Plant (A–1) and Mining Site (A–2) was mainly due to different mining activities as well as running of vehicles. According to the present study, NO_X 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 AQIs were calculated 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 category of good. Continuing efforts has been made to improve ambient air quality condition upon the open cast mining activities and many management strategies were formulated for effective control of air pollution at source.

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