Ambient Air Quality around Coal Mines and Thermal Power Plants in India

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Abstract

The authors present the results of a study on the spatial and temporal variations in the mass concentrations of airborne particulate matter pollutants in the Godavari Valley coalfield located in the State of Telangana, India. This study is based on the data extracted from the statutory filings of coal mines and pithead (mine-mouth) Thermal Power Plants (TPPs) which include data on ambient air pollutant concentrations monitored at 132 locations spread over an area of 3762 km². In general, the Particulate Matter (PM) concentrations are highest in the core areas of the coal mines and decrease rapidly as one moves away from the area of active mining operations. Therefore, high-production opencast (surface) coal mines must implement advanced mining and material transport technologies and also deploy more effective dust control practices to minimize fugitive dust emissions. The annual average concentrations of Suspended Particulate Matter (SPM) in the stack emissions of the two TPPs in the area varied between 45.7 and 107 mg/Nm³ due to the higher efficiency (99.98%) of the Electrostatic Precipitators (ESPs) installed in the TPP which was commissioned only in December 2016. PM pollutants ($\text{PM}_{10}$, $\text{PM}_{2.5}$) have the highest AQI sub-indices in the AQI determinations in the buffer zones of both coal mines and TPPs. Therefore, all TPPs must prioritize the modernization of their ESPs to control SPM emissions well before the deadline of 2022 specified by India’s Central Pollution Control Board (CPCB).

Keywords
Opencast coal mine; Thermal power plant; Air pollution; Ambient air quality standards
1. Introduction

India's per capita electricity consumption of 1154 kWh per year is approximately one-third of the world average (3505 kWh per year) and about one-fourth of that of China (5106 kWh per year) (BP, 2019; World Bank, 2019). Since electricity is a pre-requisite for sustainable development, the Government of India is currently implementing a nationwide development program to provide reliable and affordable electricity to all households. Thanks to the continuous efforts since India’s independence in 1947, all households in India now have electricity access (UDAY, 2019).

India is the second-largest coal producer in the world, producing 771 million tons (MT) of black coal (excluding lignite) in 2018, second only to China which produced more than 3.55 billion tons (BT) during the same period (IEA, 2019). Therefore, coal continues to fuel 74 percent of India’s electricity generation in the Fiscal Year 2018-19 (FY 19), while renewable energy sources contributed just over 10 percent of India’s electricity (CEA, 2019a. CEA, 2019b). Coal is the only energy source that India possesses in abundance. Specifically, the Reserve-to-Production (R/P) ratio in India for coal is 132, while it is 14.1 for oil and 46.9 for gas (BP, 2019). The R/P ratio of 132 indicates that India’s proved coal reserves at the end of 2018 are adequate for 132 years if India continues to mine coal at the same production rate as it did during the year 2018. While mining operations and coal-fired power generation have positive economic impacts on the local area in terms of infrastructure development and provision of employment and business opportunities for the local population, they also create adverse impacts on the ecology and air environment of the local area. These impacts are particularly significant in the case of opencast coal mines which account for about 94 percent of the coal produced in India (Coal Controller, 2019).

Therefore, the purpose of the present study is to analyze the spatial and temporal variations in the Ambient Air Quality (AAQ) in the villages around a cluster of coal-fired Thermal Power Plants (TPPs) and coal mines in Telangana. The ambient air quality is assessed in terms of the mass concentrations of solid pollutants (PM$_{10}$ and PM$_{2.5}$) in the air environment within the core and buffer zones of coal mines and the buffer zones of TPPs. The findings of this study have also helped the authors to develop policy recommendations in terms of future priorities for mitigating the PM pollution caused by opencast coal mines and TPPs in general, but more specifically when they are located in clusters close to one another.

2. Materials and Methods

2.1. Study location

The State of Telangana which has a population of 3,50,03,674 within an area of 112,077 km$^2$ was formed on 2nd June 2014 as the 29th State of India (Government of Telangana, 2019). The area chosen for this Study is bound by Latitudes \(N 18^0 31' 6.24``\) to \(N 19^0 4' 48.36``\) and Longitudes \(E 79^0 13' 11.28``\) to \(E 79^0 47' 48.48``\) and covers an area of approximately 3762 km$^2$ in the newly-formed Mancherial and Peddapalli districts in the State of Telangana which were carved out from the Karimnagar and Adilabad districts in the State in October 2016. The locations of these three coal mine clusters (Mine areas, 2, 3, and 5), three TPPs (of which TPP4 and TPP6 account for more than 98 percent of the power generated in this area), and their respective AAQ monitoring stations are depicted in Figure 1.
The State of Telangana is located in a semi-arid area that receives about 700 mm of rainfall mainly during the monsoon season which starts in June and lasts until September (Government of Telangana, 2019). A dry, mild winter starts in late November and lasts until early February during which the average temperature is 22-23°C. The topography of the Study Area is plain and the mean sea level elevation varies in a narrow band between 144 and 152.50 m (TSPCB, 2015; 2018a). While most of the area is covered with dry and open barren land, this region is industrially well-developed based on the rich coal reserves and availability of water from the Godavari River which flows through the area. The overall micro-meteorological scenario in the area is described in the Environmental Impact Assessment (EIA) reports submitted to the Ministry of Environment, Forest and Climate Change (MoEF&CC) and/or the Telangana State Pollution Control Board (TSPCB) by Government-controlled companies (NTPC Ltd. and Singareni Collieries Company Limited or SCCL) for the expansion of their operations (TSPCB, 2015; 2018a; 2018b). The predominant wind directions are from the NE, S, and SE directions with wind speeds ranging between 0.2 and 19 kilometres per hour (TSPCB, 2015).

The Study area contains five open cast and 19 underground coal mines grouped in three clusters (Mine areas 2, 3, and 5) as well as three coal-fired Thermal Power Plants (TPPs) operated by three Government companies (viz., TSGENCO, NTPC Ltd., and SCCL) which depend on the adjacent coal mines for their fuel supplies. NTPC Ltd is a Government Company (in which the Government of India (GOI) owns more than 56 percent of the shares) operates a 2600 MW (3 x 200 MW + 4 x 500 MW) TPP.
commissioned in three stages between 1983 and 2004 (TPP6 in this paper). Singareni Collieries Company Limited (SCCL) is a Joint Venture of the Government of Telangana and the GOI which owns all the coal mines in the Study area and has also commissioned a 1200 MW (2 x 600 MW) TPP (TPP4 in this paper) in December 2016 to meet the shortfall of power in Telangana. Telangana State Power Generation Corporation Limited (TSPGenco) also operates a TPP with a capacity of 62.5 MW in this area (TPP7 in Figure 1). The co-location of coal mines and TPPs in this area makes it an ideal location to assess the combined impact of coal mining and power generation on ambient air quality.

As per SCCL’s production records, the coal production and overburden volumes mined from the opencast coal mines in the Study area (which account for 81 percent of the total coal produced here) are shown in Figure 2. As shown in Figure 2, between Financial Year (FY) 2013-14 and FY 2018-19, the annual coal production from opencast coal mines in this area increased from 14.5 million tonnes (MT) to 23.3 MT at a Compounded Annual Growth Rate (CAGR) of 8 percent (SCCL, 2017; 2018a; 2019a). However, the volume of overburden (non-coal material to be excavated to extract the coal in opencast mines) excavated from these opencast coal mines every year increased from 67 million cubic meters (Mm$^3$) to 168 Mm$^3$ at a CAGR of 16.5 percent. Put together, the total excavation from the opencast mines in the Study area increased from 77 Mm$^3$ during FY 2013-14 to 182 Mm$^3$ in FY 2018-19 at a CAGR of 15.6 percent. However, the highest coal production and overburden removal quantities were recorded in FY 2017-18 (23.5 Mt and 208 Mm$^3$ respectively) leading to a record high excavation of 223 Mm$^3$ from the opencast coal mines in this area (SCCL, 2018a).

![Figure 2: Coal and overburden production from opencast coal mines in the Study area](image-url)
2.2. Data Analysis

This study includes analysis of data from 132 AAQ monitoring stations submitted to the MoEF&CC and the Telangana State Pollution Control Board (TSPCB) by the SCCL coal mines to comply with the environmental clearances under the Environment Protection Act (e.g., SCCL, 2018b; 2018c; 2018d; 2018e; 2018f; 2018g; 2018h; 2018i; 2018j; 2018k; 2018l; 2018m; 2018n; 2018o; 2018p; 2018q; 2018r; 2018s; 2018t; 2018u; 2018v; 2018w; 2018x; 2018y; 2018z; 2018aa; 2019b; 2019c, 2019d). Additional data was collated from compliance reports submitted by the TPPs owned by SCCL and NTPC Ltd. which included bi-weekly monitoring data from five core zone sampling stations and seven buffer-zone sampling stations, respectively (NTPC, 2016a; 2016b; 2016c; 2017a; 2017b; 2017c; 2018a; 2018b; 2018c; 2019; TSPCB, 2015; 2018a; 2018b).

As per MoEF (2010) guidelines, the Core Zone in the mining sector is confined to the mining lease area (within which mining operations are carried out), while the Buffer zone is the area falling within a distance of 10 km around the periphery of the core zone in case the area of the core zone exceeding 0.25 km². The AAQ monitoring stations referred to in this Study have been installed and monitored by SCCL and NTPC as per CPCB/MoEF guidelines (CPCB, 2011a; TSPCB, 2015; 2018a; 2018b).

As per the CPCB (2011a) guidelines, a High Volume Sampler (HVS) is used to measure ambient air PM₁₀ concentrations by drawing in air through a size-selective inlet and a Glass-fibre filter (size of 20.3 X 25.4 cm) at a flow rate of 1132 L/min (TSPCB, 2015; 2018a; 2018b). A CPCB-approved air sampler is used to measure PM₂.₅ concentrations in the ambient air, by sucking in air at a constant volumetric flow rate of 16.7 L/min with a specially-designed inertial particle-size separator where the PM₂.₅ particles are collected on a 47 mm polytetrafluoroethylene (PTFE) filter (CPCB, 2011a).

3. RESULTS AND DISCUSSION

3.1. PM concentrations in the ambient air in and around coal mines and TPPs

Particulate matter pollution from coal mining activities poses a significant hazard to public health unless controlled effectively at the source. While each of the unit operations in coal mining (drilling, blasting, excavation, transportation, and dumping) can contribute to pollution, the major sources of airborne dust in coal mining are the transportation and dumping of overburden and coal using trucks. Similarly, TPPs also emit particulate matter pollutants from their stacks as well as from activities involving storage/transportation of coal or ash. According to EPA (2013), “exposure to fine particle pollution can cause premature death and harmful cardiovascular effects such as heart attacks and strokes and is linked to a variety of other significant health problems.”

Several researchers have published papers on the air pollution impacts of coal mines and coal-fired power plants in India (Bhanu Pandey et al., 2014; Dongmei Li, et al., 2012; G Kumar et al., 2013; Gurdeep Singh and Amarjeet Singh, 2015; Sarath Guttikunda and Puja Jawahar, 2014). However, there are very few studies on the combined impact of coal mines and pithead power plants on the regional air environment in India (Kelkar, 2012; Trivedi et al., 2010).
PM concentrations in the core zones of coal mines
The PM$_{10}$ concentrations in the core zones (within the mining lease area) of the three mining clusters in the Study Area between June 2012 and March 2019 are shown in Figure 3. The PM$_{10}$ levels in all core zones of the coal mines varied between 108 – 176 µg/m$^3$ in Mine area 2, 104 - 201 µg/m$^3$ in Mine area 3, 117 - 203 µg/m$^3$ in Mine area 5. As shown in Figure 3, the PM$_{10}$ concentrations in the core zones of the three mining clusters generally increased till 2017 before showing a declining trend from 2018. These changes appear to be related to the increase in total excavation between FY 2012-13 and FY 2017-18 and the decline in excavation volume during FY 2018-19 (April 2018 – March 2019) as shown in Figure 2. The limits specified by CPCB (2000) for ambient air quality in the core zones of coal mines are higher than the corresponding limits as per the National Ambient Air Quality standards (CPCB, 2009) since these areas fall within the mining lease of the respective mines. Further, Trivedi et al. (2010) also indicate that mining activities do not contribute significantly to the ambient air dust concentrations beyond 500 meters under “normal” meteorological conditions. While the total excavation quantity in the case of Mine area 5 exceeds the sum of the excavation quantities in Mine areas 2 and 3, the PM$_{10}$ levels in the core zone of Mine area 5 are consistently lesser than those in Mine 3. This may also be due to the more environment-friendly, advanced mining technologies like draglines and in-pit crushing & conveying systems used in the largest coal mines in Mine area 5. Further, the dip in the PM$_{10}$ level in Mine area 2 during 2016 also corresponds with the decline in total excavation quantities in Mine area 2 during this period. However, no specific relationship could be derived between total excavation and PM$_{10}$ levels during this Study. The fact that Mine area 2 could control the PM$_{10}$ levels in the core zones below the applicable standard of 180 µg/m$^3$ set by CPCB (2000) indicates that ambient airborne dust levels in coal mines can be controlled by implementing suitable dust control technologies and practices (Colinet, 2010; OMSHR, 2014).

Figure 3: Annual average PM$_{10}$ concentrations in the core zones of coal mines
The PM$_{2.5}$ concentrations in the core zones of the three mining clusters between June 2012 and March 2019 are shown in Figure 4. The PM$_{2.5}$ levels in the core zones of coal mines varied between 48 – 72 µg/m$^3$ in Mine area 2, 51 - 60 µg/m$^3$ in Mine area 3, and 56 - 67 µg/m$^3$ in Mine area 5. The PM$_{2.5}$ concentrations in the core zones of the three mining clusters generally increased till 2017 before showing a declining trend from 2018. These variations also appear to be related to the increase in total excavation between FY 2012-13 and FY 2017-18 and the decline during FY 2018-19 as shown in Figure 2. While there are no CPCB standards for PM$_{2.5}$ levels in coal mines in India, the Directorate General of Mine Safety (DGMS) in India regulates inter alia the exposure of mine workers to airborne respirable dust levels in coal mines (DGMS, 2017).

Airborne dust from overburden removal activities (blasting, loading, transportation, and dumping) and coal mining operations (blasting, loading, transportation, and unloading) is more difficult to control at source than dust from point sources like blast-hole drilling. In order to minimize the exposure of mine workers to higher dust concentrations during their working hours, DGMS (2017) has also mandated the use of other measures like, remote control operation, limiting exposure durations, and use of Personal Protective Equipment (PPEs) to limit a miner’s exposure to respirable dust below the applicable standard of 2 mg/m$^3$ (when the free respirable silica content is less than 5 percent) after all other control measures are found to be inadequate.

**PM concentrations in the buffer zones of coal mines**

The PM$_{10}$ concentrations in the buffer zones (within a radius of 10 km from the periphery of the mining lease area) of the three mining clusters between 2012 and March 2019 are shown in Figure 5. The PM$_{10}$ levels in all buffer zones of the coal mines varied between 62 – 84 µg/m$^3$ in Mine area 2, 67 - 85 µg/m$^3$ in Mine area 3, 71 - 81 µg/m$^3$ in Mine area 5. The annual

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**Figure 4:** Annual average PM$_{2.5}$ concentrations in the core zones of coal mines
average PM\textsubscript{10} concentrations in the buffer zones of all coal mines are generally higher than the NAAQ Standard (60 µg/m\textsuperscript{3}).

As shown in Figure 6, the PM\textsubscript{2.5} levels in the buffer zones of the coal mines varied between 33 – 46 µg/m\textsuperscript{3} in Mine area 2, 38 - 47 µg/m\textsuperscript{3} in Mine area 3, 38 - 46 µg/m\textsuperscript{3} in Mine area 5. While the annual average PM\textsubscript{2.5} concentrations in the buffer zones of all coal mines are slightly higher than the NAAQ Standard (40 µg/m\textsuperscript{3}), they are significantly higher than the US EPA annual standard (12 µg/m\textsuperscript{3}).

The environmental clearances granted to opencast coal mines in India mandate the use of a green belt “consisting of a 3-tier plantation of a width not less than 7.5 m” along the boundary of the mining lease so that airborne dust particles from the mining areas are restricted from leaving the mining area (MoEF&CC, 2018). Therefore, all coal mines must maintain a suitable green belt along their boundaries so that the public health is not affected by fugitive airborne dust from mining operations.

**PM\textsubscript{10} concentrations in the buffer zones of TPP4 and TPP6**

The two TPPs (TPP4 and TPP6) studied in this paper have stacks with heights of 225/275 m in compliance with the applicable MoEF norms between 1983 and 2016. Analysis of the data submitted by TPP6 (owned by NTPC) to the TSPCB in the form of annual environmental statements indicates that the total load of Suspended Particulate Matter (SPM) emitted from the TPP6 stacks varied between 32,049 (FY 2017-18) and 32,573 (FY 2015-16) kilograms per day, while the average concentration of SPM in the stack emissions varied more widely between 73.7 and 107 mg/Nm\textsuperscript{3}, possibly due to varying efficiencies of the ESPs installed over a period of 21 years in TPP6 (NTPC, 2016c; 2017c; 2018c). On the other hand, the average SPM concentration in the stack emission of TPP4 (owned by SCCL) varied between 45.2
and 68.9 mg/Nm$^3$ with an average of 55.8 mg/Nm$^3$ (SCCL, 2018b). This variation in the SPM concentrations in the stack emissions from these two TPPs (and even within different units in TPP6) may be due to varying levels of efficiency of the ESPs. Since TPP4 is a modern plant commissioned by SCCL only in December 2016 compared to TPP6 (commissioned by NTPC in three stages between 1983 and September 2004), ESPs with 99.98% efficiency have been installed in TPP4 in conjunction with a 275 m tall chimney to disperse the pollutants over a wider area (SCCL, 2018b). Since TPP6 has also placed orders to upgrade the ESPs installed in their older (3 x 200 MW) units to comply with the applicable SPM standard of 100 mg/Nm$^3$ notified by MoEF&CC in 2015 (Economic Times, 2018; MoEF&CC, 2015), NTPC must expedite this work in the interest of public health.

The PM$_{10}$ and PM$_{2.5}$ concentrations in the buffer zones of TPP4 and TPP6 are extracted from the compliance reports and/or environmental statements submitted by SCCL and NTPC to MoEF&CC and TSPCB, respectively (NTPC, 2016a; 2016b; 2016c; 2017a; 2017b; 2017c; 2018a; 2018b; 2018c; 2019; SCCL, 2018b; 2019d). While power generation in TPP4 increased from 4099 to 9575 GWh between FY 17 and FY 18 before decreasing marginally to 8698 GWh during FY 19, the PM$_{10}$ concentrations in the buffer zone of TPP4 decreased sharply from 78.4 µg/m$^3$ to 59.8 µg/m$^3$ during this period (CEA, 2017; 2018; 2019c). This may be due to the stabilization of the ESPs and other Pollution Control Technologies (PCTs) in TPP4 during its first full year of operation in 2017. In the case of TPP6, electricity generation decreased by 5.4 percent from 19,598 GWh to 18,548 GWh between FY 17 (April 2016 – March 2017) and FY 19 (CEA, 2016; 2018; 2019c). However, the average PM$_{10}$ concentrations in the buffer zone of TPP6 increased by more than 36 percent from 50.4 µg/m$^3$ in FY 2016-17 to 68.4 µg/m$^3$ during FY 2018-19. While this increase in

![Figure 6: Annual average PM$_{2.5}$ concentrations in the buffer zones of coal mines](image)
Airborne dust levels may be reversed through more effective operations & maintenance (O & M) practices in the short run, NTPC has also realized the need to upgrade the ESPs installed in TPP6 immediately for which they have already placed purchase orders (Economic Times, 2018). Therefore, NTPC is in a position to prioritize the installation and commissioning of modern ESPs to control PM pollution in compliance with the new environmental norms notified by MoEF&CC (2015) by delinking the required ESP upgradation projects from the FGD installation deadlines fixed by CPCB (2018a).

The annual average PM$_{2.5}$ concentrations in the buffer areas of TPP4 and TPP6 are shown in Figure 8. The PM$_{2.5}$ levels in the buffer zone of TPP6 during FY 19 were higher than those recorded in FY 17 and FY 18. As shown in Figure 8, average PM$_{2.5}$ concentrations in the buffer zone of the TPPs varied between 31 and 40 µg/m$^3$ in the case of TPP4 and in the 24 -
30 µg/m³ range in the case of TPP6. These pollution levels are lower than the NAAQ annual standard of 40 µg/m³ for ambient air PM$_{2.5}$ concentrations though they are significantly higher than the US EPA annual standard of 12 µg/m³ (CPCB, 2009; EPA, 2013). Since MoEF&CC (2015) has notified more stringent standards for air pollution from TPPs, CPCB and the SPCBs must conduct detailed studies on ambient air pollution levels in various parts of India to monitor the progressive compliance of TPPs with these norms.

PM$_{10}$ particles also include fine (PM$_{2.5}$) and ultrafine particles (PM$_{1}$). The ratio of PM$_{2.5}$/PM$_{10}$ can be used for ex post facto analysis for predicting PM$_{2.5}$ mass concentration without direct measurement of PM$_{2.5}$ (Limin Jiao et al, 2017). The PM$_{2.5}$/PM$_{10}$ ratio in the core zone of all coal mines studied vary between 0.24 and 0.58 (mean: 0.37), while the value of this ratio in the buffer zone of the mines ranged between 0.40 and 0.84 (mean: 0.56). On an average, PM$_{2.5}$ pollutants contribute 37 percent of PM$_{10}$ concentrations in the core areas of the coal mines studied, while they account for 56 percent of the PM$_{10}$ levels in the buffer zones of these coal mines. The lower PM$_{2.5}$/PM$_{10}$ ratio in the core zone may be due to the higher content of coarser particles (with aerodynamic diameters ranging between 2.5 and 10 microns) within the mining lease areas which settle down closer to the point of generation than the finer PM$_{2.5}$ particles which may remain entrained for longer periods. This also confirms the findings of Trivedi et al. (2010) who have carried out ambient air quality measurements around five opencast coal mines in the Wardha Valley coalfield which is approximately 140 km north of the Study area.

3.2. Air Quality Index (AQI) in the core and buffer zones of coal mines

The ambient air quality assessment method designed by CPCB is used to calculate the Air Quality Index (AQI) using the mass concentrations of four pollutants (PM$_{10}$, PM$_{2.5}$, SO$_2$ and NO$_2$) along with their respective

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**Figure 9:** Annual average AQI in the Core and Buffer zones of coal mines
As shown in Figure 9, the AQI in the buffer zones of the coal mines is in the “Satisfactory” category (AQI between 51 and 100), while the AQI in the core zones (within the mining lease) of the coal mines is in the “Moderately polluted” category. As explained earlier, DGMS regulates inter alia the exposure of mine workers to airborne respirable dust levels in coal mines (DGMS, 2017).

As shown in Figure 10, the AQI in the buffer zones around TPP4 and TPP6 is in the “Satisfactory” category (AQI: 51-100). PM pollutants (PM$_{10}$, PM$_{2.5}$) have the highest AQI sub-indices in the AQI determinations in the buffer zones of both coal mines and TPPs. Electrostatic precipitators and bag (fabric) filters are commonly used for high-efficiency control of TPP particulate emissions since “they also provide over 99 percent control of PM10 and over 95 percent control of PM2.5” (Illinois Environmental Protection Agency, 2004). Most TPPs in India are upgrading their PCTs to comply with MoEF&CC (2015) norms.

3.3. Spatial Variation in Core Zones and Buffer Zones of Coal Mine areas and TPPs

The Inverse Distance Weighted (IDW) Kriging technique was used in conjunction with GIS software to analyze the combined impact of the particulate matter pollution caused by mining activities and power generation (Documentation QGIS2.8). The spatial variability of the annual average PM$_{10}$ concentrations measured by SCCL and NTPC during 2017 at 132 AAQ monitoring stations located in the Study area is shown in Figure 11 while the spatial distribution of annual average PM$_{2.5}$ concentrations during the same period is shown in Figure 12. As shown in Figures 11 and 12, the PM concentrations are highest in the core areas of the coal mines and decrease rapidly as one moves away from the area of active mining operations. The annual average concentrations of PM$_{10}$ and PM$_{2.5}$ during 2017 are generally higher than the NAAQ annual standards of 60 µg/m$^3$ and 40 µg/m$^3$, respectively. This indicates the importance of maintaining a suitable green belt along the periphery of all opencast mines to
control airborne dust in the buffer zones around these mines as well as the need for NTPC to upgrade the ESPs installed in TPP6 well before the deadline of 2022 specified by CPCB (2018a).

Figure 11: Spatial variability of the PM$_{10}$ concentrations

Figure 12: Spatial variability of the PM$_{2.5}$ concentrations


This paper documents the key results of an extensive study of the ambient dust (PM$_{10}$ and PM$_{2.5}$) concentrations in a Study area which has several clusters of coal mines (both opencast as well as underground) as well as two TPPs with a combined capacity of 3800 MW. The key findings of this research are summarised as follows:

- In general, the PM$_{10}$ concentrations in the core zones of the three mining clusters appear to be linked with the quantity of total excavation from opencast coal mines. Therefore, high-production coal mines must utilize more environment-friendly mining and transportation systems (e.g., in-pit crushing/conveying systems) and deploy more effective dust control technologies as total excavation volumes increase in opencast coal mines.

- All opencast coal mines and TPPs must maintain an effective “green belt” along the boundary of their respective core zones to limit public exposure to airborne respirable dust.

- Fine particulate pollutants have a prolonged impact on public health (EPA, 2013). While the emissions from the two TPPs studied are dispersed over a wide area due to the height of the stacks (225 m - 275 m), the installation of ESPs with a guaranteed efficiency of 99.98 percent (or equally effective PCTs) in TPPs must be expedited by delinking the upgradation of ESPs from the installation of FGDs as per CPCB (2018a) deadlines.

- CPCB and/or the relevant SPCB must...
carry out source apportionment studies to identify and quantify the contributions of major emission sources to ambient pollutant concentrations in all areas containing clusters of mines and pithead TPPs.

• Given the increased public concern regarding the impact of air pollution on public health, India’s National Green Tribunal (NGT) has already directed CPCB to expand the list of non-attainment cities by including other cities and towns which do not meet the prescribed NAAQ Standards so that the National Clean Air Program is not limited to only 102 cities as proposed (Economic Times, 2019). Therefore, MoEF&CC must increase funding for CPCB and the SPCBs to install, maintain, and monitor a greater number of ambient air quality monitoring stations in India.

• CPCB must commence the process of reviewing the NAAQ Standards (CPCB, 2009) which are more than a decade old today. This process must take account of the data obtained from AAQ monitoring stations and the Continuous Emission Monitoring Stations (CEMS) installed by TPPs and other industries. Besides, CPCB/SPCBs must conduct interdisciplinary research to correlate the results from source-apportionment studies with systematic investigations into public health in all “non-attainment” areas of the country.

• MoEF&CC must mandate all coal mines and TPPs to upload on their website, the continuous emission monitoring data as well as the stack monitoring data collected by them. In addition, MoEF&CC must direct all industries who have been ordered to install CEMS as well as the CPCB and SPCBs to ensure that these CEMS are properly sealed in the presence of an authorized CPCB/SPCB official after periodic calibration is carried out in the approved calibration facility as prescribed in the CPCB (2018b) guidelines. This mandate towards enhanced transparency and quality assurance will improve the effectiveness of regulation through public participation.

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Abstract:
The authors present the results of a study on the spatial and temporal variations in the mass concentrations of airborne particulate matter pollutants in the Godavari Valley coalfield located in the State of Telangana, India. This study is based on the data extracted from the statutory filings of coal mines and pithead (mine-mouth) Thermal Power Plants (TPPs) which include data on ambient air pollutant concentrations monitored at 132 locations spread over an area of 3762 km². In general, the Particulate Matter (PM) concentrations are highest in the core areas of the coal mines and decrease rapidly as one moves away from the area of active mining operations. Therefore, high-production opencast (surface) coal mines must implement advanced mining and material transport technologies and also deploy more effective dust control practices to minimize fugitive dust emissions. The annual average concentrations of Suspended Particulate Matter (SPM) in the stack emissions of the two TPPs in the area varied between 45.7 and 107 mg/Nm³ due to the higher efficiency (99.98%) of the Electrostatic Precipitators (ESPs) installed in the TPP which was commissioned only in December 2016. PM pollutants (PM_{10}, PM_{2.5}) have the highest AQI sub-indices in the AQI determinations in the buffer zones of both coal mines and TPPs. Therefore, all TPPs must prioritize the modernization of their ESPs to control SPM emissions well before the deadline of 2022 specified by India’s Central Pollution Control Board (CPCB).

Keywords: Opencast coal mine; Thermal power plant; Air pollution; Ambient air quality standards

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