Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 21 No. 3 pp. 981-992 2022
Original Research Paper
https://doi.org/10.46488/NEPT.2022.v21i03.005
Open Access Journal

Evaluation of Source Emissions Dispersion Potential Near a Coastal Village of Maharashtra, India

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 05-02-2022
Revised: 15-03-2022
Accepted: 23-03-2022

Key Words:
AERMOD
Meteorology
Emission inventory
Coke oven
Pellet plant

ABSTRACT

Industrial emissions are a serious environmental problem worldwide due to particulates and toxic gases. This study aims to generate an activity-specific emission inventory and estimate emissions dispersion extent in the vicinity of the coastal industrial village by simulating the existing coke oven and pellet plant emissions using the steady-state plume model. Continuous air quality monitoring results were compared with the predicted consequential emissions for the year 2018-19. The maximum ground-level concentrations of particulate and gases within the modeling simulation domain were observed at 9005 m away from the center. They were predicted to be 116.39 $\mu g.m^{-3}$, 79.14 $\mu g.m^{-3}$, 52.97 $\mu g.m^{-3,}$ and 211.86 $\mu g.m^{-3}$. Data analysis showed that air mass transport from the project to the receptor sites resulted in ambient air concentrations higher than those observed in the other sites. Overall predicted results obtained from AERMOD Cloud simulations were shown to have less bias than the measured results. They recommended considering it as appropriate for the prediction of annual average concentration.

INTRODUCTION

Environmental sustainability plays a critical role in the overall sustainable development of a nation. In this scenario, air pollution has become a severe problem for all countries across the globe. This growing problem concerns and needs urgent attention. Air pollution is caused by industrial activity, processes, and operation and is associated with vehicular movement caused due to fossil fuel burning (vehicular emissions). In addition, Air pollution has increased at an alarming speed due to industrial development proliferating. Air pollution's impact on health, property, agriculture, and the atmosphere is a significant concern worldwide. Unwanted and excess material, toxic gaseous dust, aerosol soot particles, and harmful hazardous substances are a substantial concern with the population increasing leads to air pollution. According to a study conducted by the World Health Organization (WHO) in 2006, it was found that 25% of deaths in developed countries occur due to air pollution (Tyagi 2015).

The iron and steel sector is the core of the Indian economy. As per the Ministry of Steel, domestic steel production surged from 109.85 Million Tons Per Annum (MTPA) in 2014-15 to 142.24 MTPA in 2018-19, accounting for a 6.8% compounded annual growth rate (CAGR) during these five years (Ministry of Steel 2014). The sector is exceptionally resource-intensive and polluting. The steel industry is part of the European Union's emissions trade scheme (ETS) for exploring new ways to reduce emissions (Thomas 2021). Since the advent of industry, the steel industry has been a significant emissions source globally, mainly from its furnaces and cupolas (Kim & Worrell 2002, Amodio 2012, Vallero 2014). Used production routes, product mix, production energy efficiency, fuel mix, fuel mix carbon intensity, and electricity carbon intensity account for the steel industry emissions (Arvola et al. 2011). Ferroalloy industries contribute to the economic process and environmental imbalance to express pollution (Reddy et al. 2017). Various air pollution control methods like bag filters, bag Houses, electrostatic precipitators, gas cleaning plants, scrubbers, etc., are applied to control air pollution in integrated steel plants and their effect. Many researchers have contributed to achieving a clean and sustainable environment by reducing exhaust emissions (Li et al. 2019, Smirnova et al. 2020).

Recent studies have shown that a series of models can conduct an air quality assessment pertaining to the study's objective; e.g. plume rise model, dispersion model, photochemical model, meteorological modeling, particle models, deposition models, odor modeling statistical models are present in the present scenario (CPCB 1998, CPCB 2010a, Gulia et al. 2015, Invernizzi 2020). Modeling the behavior of pollutants in the atmosphere using coupled mathematical equations helps understand the existing air environment. The assimilative capacity for the atmosphere of the study area was studied through pollution dispersion potential by process emission estimation and administered through an air dispersion model (Chaulya 2019).

Meteorological elements such as wind speeds, relative humidity, wind direction, temperature, and others influence the dispersion and transportation of released pollutants from point and non-point sources. Given the same, it is vital to do ambient air monitoring for the different pollutant entities in the vicinity of the plant. The prime steel pockets in India are trying to mitigate the air pollution problem through mathematical modeling and have achieved remarkable results (Govender & Sivakumar 2020). The air pollution emission modeling is a numeric tool for describing the causal relationship between emissions, meteorology, atmospheric concentration, and deposition. The pollutant concentration is mainly affected by ground deposits, diffusion, transportation, and chemical transformation factors (Nuterman & Baklanov 2007). Forecasting is critical in evaluating the overall air quality in any region of the world. The results are vital, mainly related to health concerns regarding growing air pollution in developing countries (Sharma & Parvez 2003, Gogikar 2019). Air pollution dispersion study in an integrated steel plant helps understand the concentration and direction to consider action planning further. Present research estimates emissions dispersion pattern from coke oven and pellet plant operations in Dolvi area of Maharashtra. The investigation accounts for the site-specific meteorological and topographical characteristics. This study aimed to determine the diurnal and spatial variability of pollutant emissions that affect air quality levels.

MATERIALS AND METHODS

Study Area

The site is a prime steel unit situated in Dolvi village at 73°00'00"-73°05'00" E longitude and 18°40'00" to 18°45'00" N latitude with an average altitude of 1.7 m above MSL. The area is covered in the Survey of India Topo-sheet No. 47 F/2 [1:50000 scale]. The study area proposed in the present study is an integral part of one of the leading steel units in the country. The Dolvi plant caters to several industries: automotive, projects and construction, machinery, oil and gas, consumer durable, etc. The study domain of a 10 km radius is depicted in Fig. 1.

It covers requisite infrastructure, i.e., standalone jetty, rail, and road connectivity. Domain call out shows the current study's identified point source (stacks) and continuous ambient air quality monitoring stations (CAAQMS). The study area is plain with slightly undulating terrain. Most of the area is gently sloping from East to West and is present in the valley surrounded by small hills of greater than 35% slope gradient. It is located in a valley surrounded by hills having the steepest slope of 57.4°. The study area lies on the bank of River Amba, and there is a sub-creek passing through (Fig. 2). There are six Reserved Forests within a 10 km radius with no major industries in the vicinity.

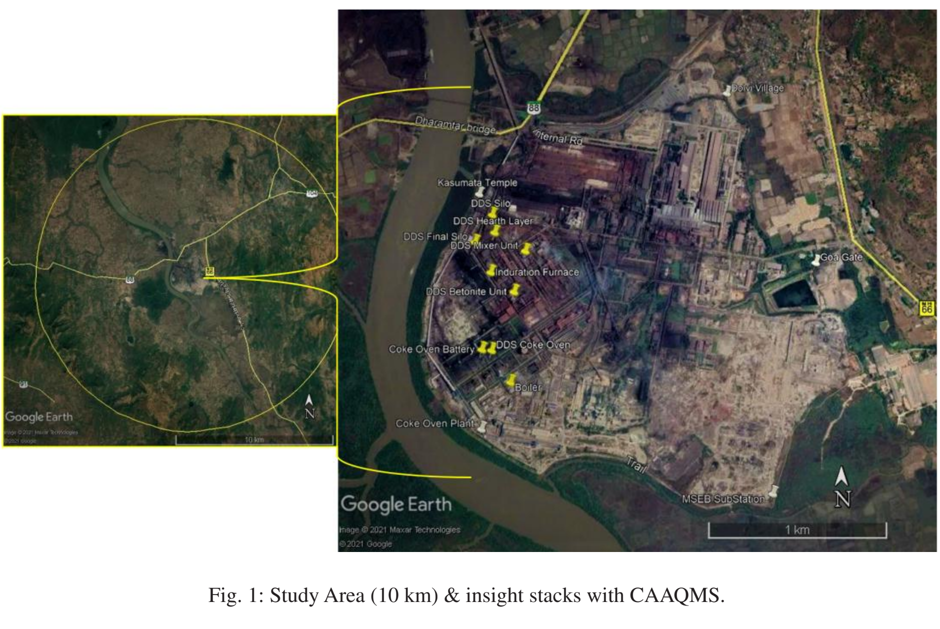


Fig. 1: Study Area (10 km) & insight stacks with CAAQMS.

Meteorological Background of the Study Area

Meteorological conditions have a considerable impact on pollution concentrations in the environment. Wind speed and direction data determine the extent of pollutant transport, dispersion, and dilution from an emission source to a receptor. The local wind rose pattern leads to an optimum network design of air quality monitoring stations (Mukkannawar et al. 2014). The chemical reactions in the atmosphere are influenced by air temperature and solar radiation, while precipitation permits pollutant concentrations to fluctuate. Variations in meteorological factors have an impact on the concentrations and dispersion of pollutants in the atmosphere. The mean rainfall in winters was substantially higher than in other seasons, according to long-term meteorological data shown in Table 1. Several cross-sectional studies and reports on continuous ambient air quality monitoring have identified significant winter pollutants (Joshi & Mahadev 2011, Sancini et al. 2014, NEERI Technical Report 2019, 2021). Furthermore, due to geographical characteristics and lower wind speeds, air pollution levels tend to be trapped.

The study area follows a typical west coast climate, characterized by abundant and regular seasonal rainfall, humid weather in summer, and high humidity throughout the year. The Indian Meteorological Department climatological data from 1951-1980 at Alibaug shows that January is the coldest month (~17°C) and April-May is the hottest month (~40°C), accounting to be oppressive summer. We also explored a global weather service provider, Meteoblue, to study the regional weather pattern. They operate a series of weather models and integrate open data from various sources into

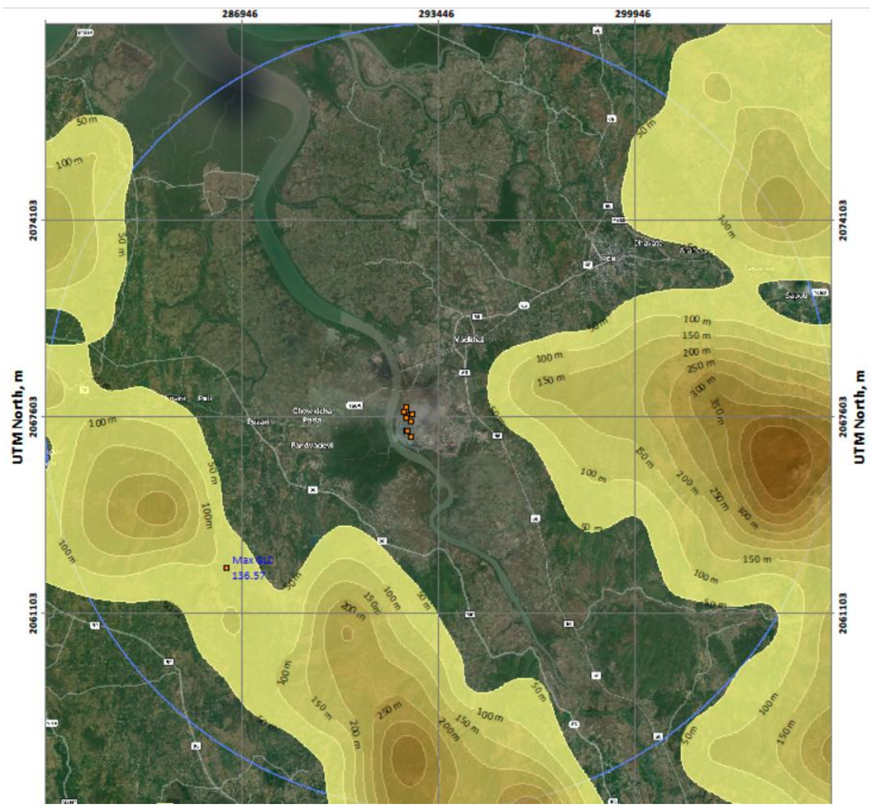


Fig. 2: Topographic contour levels of the study area.

Table 1: Dispersion coefficient sy and sz for stability class ‘C’.

Dispersion co-eff.	Distance from source						
	400 m	700 m	1000 m	2000 m	4000 m	7000 m	10000 m
sy	44 m	74 m	105 m	200 m	370 m	610m	840 m
sz	26 m	43 m	61 m	115 m	220 m	360 m	510 m

(Source: Baines & Turner 1969)

the weather database to give valued data. Climate diagrams were based on 30 years of hourly weather model simulations that illustrate typical climate patterns.

Fig. 3 presents 30 km resolution simulated information in graphical format. Here, the minimum annual temperature varies between 17°C to 26°C and the maximum temperature between 27°C to 38°C. Conventionally the wind direction at IMD station at Alibaug is the North-West. At the onset of the monsoon, the winds move the course at 90° south and start blowing from South-West. From June to September, the sky remains moderately covered with clouds heavily.

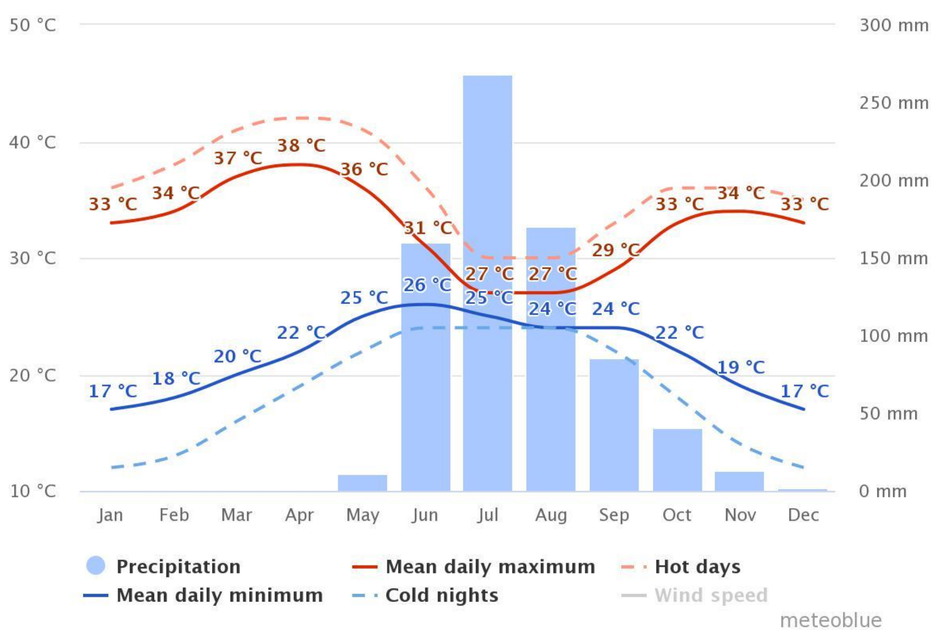
The summer and cold seasons are the driest part of the year when relative humidity levels vary from 64-90%. The relative humidity is higher in the Southwest monsoon and retreating monsoon season, generally 81-90%. With the onset of the monsoon, the weather becomes slightly more relaxed and continues to be so throughout the monsoon period. The region experiences rainfall for about 75.6 days a year. The analysis of long-term rainfall data indicates July – is a higher rainy month with >300 mm rainfall, followed by August (~250 mm) and June (~200 mm). Average annual rainfall over the district averages 2200-3000 mm on the plains and >5000 mm in the hilly areas. Uran (2197 mm) and Mahad (3360 mm) are comparatively the least rainy northwest regions.

Data Collection and Analysis

The project is part of an integrated steel plant located on the west coast of Maharashtra. The 615.14 ha premises accommodate a series of processing units, i.e. Sponge iron plant, oxygen plant, Sinter plant, Blast furnace, Hot strip mill, Billet caster Bar mill, Coke oven Plant, Pellet plant, etc. We have considered a dedicated coke oven plant and pellet plant, where foremost processing occurs. We have identified potential conventional and non-conventional sources of pollutant emissions and estimated the load. Historical patterns and information about the monitoring station are essential considerations when interpreting air quality data. The unit has five continuous air quality monitoring stations in the region that record ambient pollutant levels at a pre-defined daily interval.

Regional weather data collected from the IMD Alibaug office and onsite weather station helped in site-specific details. The weather in the region is slightly unstable, as stated in IMD data, and the Pasquill atmospheric stability criteria for a wind velocity of one centimeter per second is class C. According to the guidelines on air quality models (PROBES/70/1997-1998), the model employs rural dispersion and regulatory defaults. The current study used meteorological data from one season (October–December) to determine the dispersion of pollution concentrations. The data on the mixing heights were obtained from the atlas of the meteorological monograph of the Indian meteorological department (Attri et al. 2008).

AERMOD's excellent efficiency for dispersion modeling of air pollutants up to a 50-km diameter of the pollutant



(Source: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/18.690N73.040E)

Fig. 3: Typical regional weather phenomenon.

source has been established in several studies throughout the world (Hanna et al. 2001, Cimorelli et al. 2005, Mohan et al. 2011, Gulia et al. 2015, Peter & Nagendra 2021). AERMOD (version 21112) is a steady-state Gaussian Plume Model used worldwide in a single wind field to transport emitted species, and it relates to surface upper air and meteorological observation. It also combines geophysical data (Gulia et al. 2015). AERMOD Cloud® application incorporates popular U.S. EPA air dispersion models AERMOD and ISCST3 into one integrated graphical interface to plot resultant isopleths. The model takes care of the rural dispersion and regulatory defaults options as per guidelines on air quality models (PROBES/70/1997-1998). AERMOD Cloud® algorithm has three separate components: dispersion model – AERMIC, terrain preprocessor – AERMAP, and meteorological preprocessor – AERMET. Standalone integral processors enable smooth data flow across the modules and model. The application is used mainly to comply with the regulatory requirements (Cimorelli et al. 2005, Nagendra et al. 2012).

The primary pollutants of concern are PM_{10}, $PM_{2.5}$, Sulphur Dioxide (SO_2), and Nitrogen Oxide (NOx). The total emissions from different sources depend upon source configuration, type and amount of fuel used emission factors, combustion/burning process rate, and the performance of control devices. The emission factors are obtained from the secondary sources classified by the end-use, fuel type, and furnace/boiler used in the industries and power plants. An emissions factor describes the link between the number of pollutants emitted into the atmosphere and the number of raw materials processed or fuel used in any polluting process. It is a relationship between the types and amounts of pollutants emitted and production capacity, the amount of fuel consumed, or the number of vehicle miles driven.

The EPA's emissions factor and process information for more than 200 air pollution source categories has been compiled in the AP-42 database since 1972. The present study refers to the fifth edition of AP-42 and updates in Volume I, Stationary Point and Area Sources (EPA 1995), and Emission Factor Documentation for AP-42 Section 12.2 Coke Production final report (EPA 2008). Stack height calculations referred from Emission Regulations – Part IV, CPCB'86, and the pollution control board consented criteria were implied. The widespread method based on the data available was to use emissions in terms of pollutant mass emitted per second.

Pollutant Dispersion

A three-decade-old air quality dispersion model assisted in predicting local or regional air pollution levels in various circumstances, including weather, topographic features, and divergent sources (Venkatram 1979, Weil et al. 1992, US-EPA 1998, Stein et al. 2007, Irwin 2014). When it is technically impossible to measure specific spots or areas due to contaminants from many sources, dispersion models are considered an alternate option (US-EPA 2009, Li et al. 2019).

Ground-level concentrations directly downwind at a distance of x meter from the source are given by following the Gaussian Plume source dispersion equation,

$$C_{(x,y,z)} = \frac{Q}{2\pi \bar{u}_x \sigma_y \sigma_z} exp\left\{\frac{y^2}{2\sigma_y^2}\right\} exp\left\{\frac{z^2}{2\sigma_z^2}\right\} \quad \ldots(1)$$

Where, $C_{(x,y,z)}$ = Concentration at ground level at a distance x meter from the bottom of chimney the downwind direction, μg/s; X = Downwind distance along plume mean center from source (200m to10000m); Q = Emission rate, μg/s; H = (h + Δh), effective height, m; Δh = Plumb rise, m; H = Height of the chimney, m; sy = standard deviations plume concentration (dispersion co- efficient) in horizontal direction, m; sz = standard deviations plume concentration (dispersion co- efficient) in Vertical direction, m

The value of the dispersion coefficient is determined by distance x, wind speed, and atmospheric stability conditions. The regional meteorological station determines a stability class. The wind direction fluctuation approach (Slade 1965) estimates hourly stability as suggested by the CPCB (PROBES/70/1997-1998). The determined Dispersion coefficients are given in Table 1.

Emission Estimation

An emission inventory summarizes the pollutant emission potential in the immediate region of the proposed project activity under present conditions (Jang et al. 2020). Because they do not account for atmospheric reactions or unequal impacts of air pollutants on a mass basis, emission inventories have limitations (Wang et al. 2020). The plant has two major emission areas: the coke oven plant and the pellet plant having coke oven batteries, boiler, and dusting units attached to sub-units and silos.

Stack parameters considered are; height, diameter, temperature, velocity, volumetric flow rate, and emission rates. Table 2 and Table 3 illustrate stack details and emission estimated. A total of eight stacks were presently attached to their respective equipment through which the emissions are likely to come out.

Model Input Parameters

AERMOD Cloud has been used for evaluating the emission scenarios for the proposed project. The inputs to the model are defined in five functional pathways, as represented in the following sections. Each of these operational parameters includes several options that may be user-defined or set as default; the details of some of these essential elements used in the model run have given below.

A. Control pathway inputs

- Default option with Rural Setting
- Background concentration
- Averaging period of 24 hrs. as per NAAQS pollutant type

B. Source pathway inputs

- Includes definition of source, its locations
- Stack source parameters include emissions (g/s)

C. Receptors pathway inputs

- Cartesian grid starting at the SE corner of the ward with 2000m increment over X & Y coordinates, thus forming a receptor output grid radius of 13km

D. Meteorology pathways inputs

- One hourly data for the study period was used as an input in the meteorology processor to generate model ready one hourly input surface & profile meteorology files.
- Roughness length of 1m of measurement height, displacement height of 0.2m, Albedo of 0.2 at 10m height above ground
- The minimum wind speed (0.5 $m.s^{-1}$ lower than 1$m.s^{-1}$ considered as calm by IMD), predominant wind direction – SW, mixed layer height (900-750 m) denoting slightly unstable, and minimum heat flux 20 $W.M^{-2}.s^{-1}$)
- The Bowen ratio=Sensible Heat flux/Latent Heat Flux as a function of the month to allow smaller Bowen Ratios during the Indian monsoon season when the ground is wet and latent heat fluxes become significant (from 2 in non-monsoon to 0.5 in monsoon)
- The potential temperature gradient above the mixed layer (0.008 degrees/m)

E. Output Pathway

Model run executed for the pollutant at stipulated average period and compared with NAAQS standards criteria. The contour for 1st highest reading is shown for each pollutant based on the uncontrolled and controlled scenario. Model outputs pollutant spatial distribution isopleths were plotted

Table 2: Stack details.

Sr. No.	Stack Attached to	Gas Quantity [$kg.h^{-1}$]	Height [m]	Diameter [m]	Temperature [°C]	Velocity [$m.sec^{-1}$)	Pollution Control Device
1	Coke Oven (Battery A & B)	3375	145	4.50	200	12.0	Natural Draft
2	Ground De-dusting system	162000	31	2.50	100	20.0	Bag Filters
3	Boiler	3475	40	2.00	150	12.0	-
4	Dedusting 1 & 2 (Mixer Unit)	NA	30.5	1.15	50	15.8	Bag Filters
5	Dedusting 3 (Betonite Unit)	NA	30.5	0.89	50	17.2	Bag Filters
6	Main ESP (Induration Furnace)	42100	100	6.25	110	20.0	ESP
7	Dedusting 7 (Hearth Layer)	NA	30.5	1.35	50	15.3	Bag Filters
8	Dedusting 8 (Final Product Silo)	NA	30.5	2.00	50	15.8	Bag Filters
9	Dedusting 9 (Final Product Silo)	NA	30.5	0.69	50	15.8	Bag Filters

Table 3: Stack emission estimates (g/sec).

Sr. No.	Stack Attached to	PM_{10}	$PM_{2.5}$	SO_2	NO_X
1	Coke Oven (Battery A & B)	36.2	24.6	18.1	72.5
2	Ground De-dusting system	2.9	2.0	-	-
3	Boiler	27.1	18.4	13.6	54.4
4	Dedusting 1 & 2 (Mixer Unit)	1.3	0.9	-	-
5	Dedusting 3 (Betonite Unit)	1.0	0.7	-	-
6	Main ESP (Induration Furnace)	19.9	13.5	9.9	39.9
7	Dedusting 7 (Hearth Layer)	1.6	1.1	-	-
8	Dedusting 8 (Final Product Silo)	2.3	1.6	-	-
9	Dedusting 9 (Final Product Silo)	0.8	0.5	-	-

across the impact zone. These isopleths were superimposed on the road-satellite hybrid tile map of the proposed region.

RESULTS AND DISCUSSION

Ambient Air Quality

The ambient air quality (AAQ) in a research region reveals the overall state of the environment. AAQ is a critical requirement for a healthy environment, and its depletion has a variety of long-term health consequences. Only if there are proportionate amounts of natural gases like oxygen and nitrogen and harmful gases like SO_2, NOx, CO, CO_2, Hydrocarbons, and others, introduced from diverse polluting sources can AAQ be regarded as exemplary. During the 2018-19 year, the study area's ambient air quality was measured using a network of five dedicated continuous ambient air quality stations located around the campus (Fig. 1). Ambient levels of PM_{10}, $PM_{2.5}$, SO_2, and NO_X were studied at 24 hourly average. During the study period, the missing information period varies between 0.3% and 33.3%. The maximum variation was mainly due to onsite construction activity disrupting power and communications supply, at times due to routine maintenance. The daily mean concentrations of particulates varied between 17.4-25.1µg.m^{-3} and 43.7-49.1 µg.m^{-3} for $PM_{2.5}$ and PM_{10}, respectively. At the same time, the daily mean gaseous concentrations varied between 5.9-9.9 µg.m^{-3} and 7.3-31.8 µg.m^{-3} for SO_2 and NO_X, respectively. The observed levels were compared with the permissible National Ambient Air Quality Standard (NAAQS) stipulated by Central Pollution Control Board, New Delhi (CPCB 2009). A comparative account of observed concentration with the prescribed standards is given in Table 4. The average concentrations were found within the prescribed NAAQS.

Meteorology

The plant has dedicated standalone weather stations installed within premises for uninterrupted meteorological data gathering. The local representative wind data play an essential role in processing the meteorological information. And the same as defined in the AERMOD-AERMET metrological pathway.

Fig. 4 exhibits an annual and seasonal wind rose to integrate the prevailing wind directions for the modeling period. The wind rose was analyzed based on the wind direction, wind speed, and wind blowing frequency (Zelenko & Lisac 1994). Western winds were found dominant in the study area. Annual average winds blow from the southeast direction, i.e. 53% predominantly 132° directions. The study area shows minor variation in the predominant wind direction and does not vary much during the three seasons. Though, the wind flow intensity differs considerably. Post-monsoon winds blow from eastern areas. The annual average wind speed was 1.41 m.s^{-1}, and the seasonal average was 1.84 m.s^{-1}, 1.86 m.s^{-1}, and 0.84 m.s^{-1}, respectively, during pre-monsoon, monsoon, and post-monsoon, respectively. The calm winds' annual frequency was 11.07%.

The site-specific hourly meteorological data is processed with an AERMET meteorological processor. It generates two different model-ready databases, namely surface (*.sfc) and upper (*.pfl) meteorological profile formats (Cimorelli et al. 2004, Kumar et al. 2021). The AERMAP processor assigns a surface property to the receptor and source locations. Discrete grids assess dispersed pollutants' impact on the receptors and sensitive points (USEPA 2018). The domain of the study area had complex rural terrain, having process buildings, a river, hill range, etc., in the surrounding area. Air pollution dispersion contour maps are generated as isopleths, i.e. modeling study outputs, using both characteristic terrain data and emissions of the identified source. The modeling steps are illustrated (Fig. 5).

Dispersion of Air Pollutants

The dispersion maps of the estimated particle and gaseous ground level concentrations were constructed based on the

Table 4: Summary of AAQ monitoring results (2018-19).

Station Code	AAQM Station	$PM_{2.5}$ [µg.m^{-3}]	PM_{10} [µg.m^{-3}]	SO_2 [µg.m^{-3}]	NO_X [µg.m^{-3}]
Permissible NAAQS (CPCB)	Residential, Industrial, rural area & other area	60	100	80	80
	Sensitive	60	100	80	80
Locations		Mean(±SD)	Mean(±SD)	Mean(±SD)	Mean(±SD)
AQ1	Kasumata Temple	17.7 (±8.0)	49.1 (±21.3)	7.3 (±2.3)	31.8 (±14.5)
AQ2	Coke Oven Plant	23.3 (±10.2)	43.7 (±18.2)	5.9 (±4.1)	8.8 (±2.1)
AQ3	MSEB Substation	19.5 (±13.0)	43.7 (±24.1)	7.3 (±2.0)	21.7 (±9.3)
AQ4	Goa Gate	25.1 (±9.9)	46.7 (±19.5)	9.9 (±2.4)	15.7 (±6.7)
AQ5	Dolvi Village	17.4 (±9.3)	47.7 (±22.5)	7.3 (±10.0)	7.3 (±2.5)

AERMOD analysis results for the highest averages of daily (24 h) concentrations obtained from Cartesian grid receptors. A POST FILE section in the model output pathway gives reporting choices. During the analysis, it uses hourly meteorological data when it calculates daily as 24 h mean. Continuing the maximum daily concentrations by year are reported. A similar algorithm is also used for the annual output, assuming full years and taking a yearly average. The ground-level concentration (GLC) estimates and incremental concentrations with respect to identified sources were mapped within the assigned domain. The daily limits for ambient air pollutant concentrations were compared with

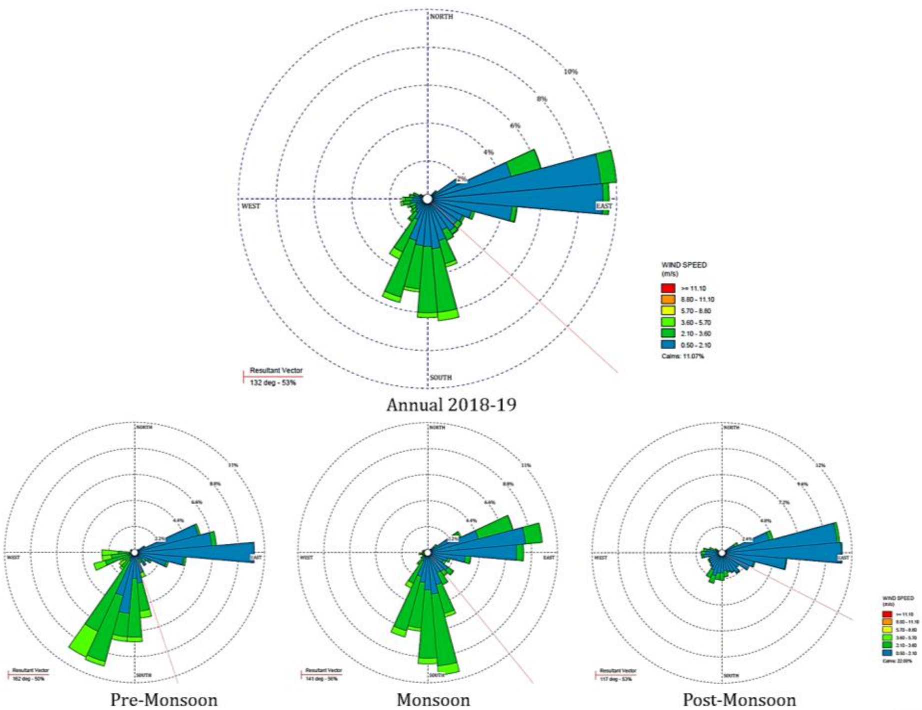


Fig. 4: Wind-rose 2018-19.

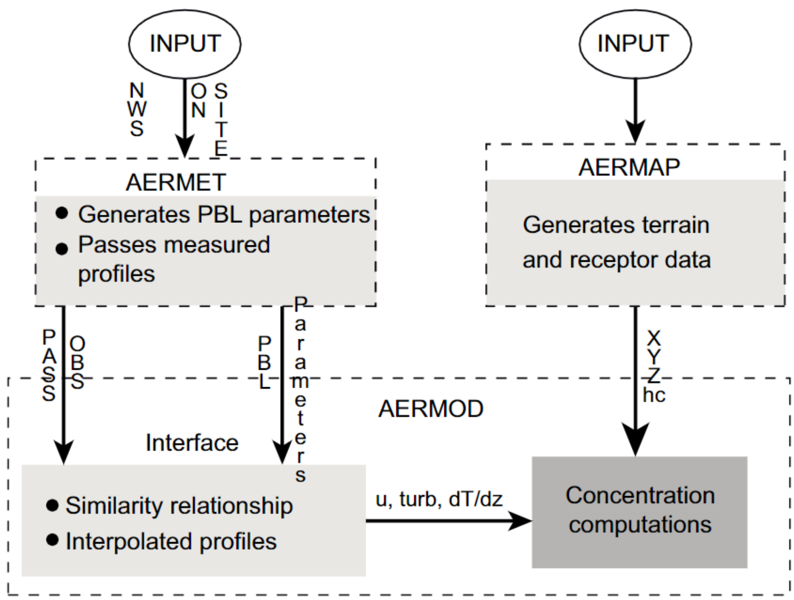


Fig. 5: AREMOD process flow (Cimorelli et al. 2004).

the stipulated NAAQS standards to assess the influence of specified activity.

According to the AERMOD modeling result, It is noticeable that the wind direction was observed from the West for the specific day and time when the maximum daily concentration was predicted.

October 24, 2018, was a highly polluted day at an elevation of 131.9m at a distance of 9,055m to the West of the reference point. The emission source's hourly modeled concentrations of identified pollutants illustrate the maximum daily peaks (Fig. 6-9). The maximum GLC of pollutants PM_{10}, $PM_{2.5}$, SO_2, and NO_X is predicted to be 116.39 μg.m^{-3}, 79.14 μg.m^{-3}, 52.97 μg.m^{-3}, and 211.86 μg.m$^{-3,}$ respectively. Particulate matter and oxides of nitrogen have been found to exceed the prescribed limits of 100 μg.m^{-3}, 60 μg.m^{-3}, and 80 μg.m$^{-3,}$ respectively (CPCB 2009). The maximum daily concentration of SO_2 from the activity conforms to the official limits. Target unit of an iron and steel industry operates through closed environments, the preparation of raw materials, accumulation of fines in Pellet plant, manufacturing of coke in coke ovens for feeding of burden to blast furnace, conversion of hot metal to steel, and shaping of steel, granulation of slag, recovery of chemicals in by-product plant, etc. All the processes mentioned above impact the surrounding environment (NEERI Technical Report 2019, 2021). Similar observations were reported in iron and steel industry-associated book chapters by Vallero (2014) along with Kumar and Kumar (2016). A concomitant effort is being made in the steel sector to explore the possibilities of using newer technologies to conserve the surrounding environment.

Along with a series of sectors, the Central Pollution Control Board (CPCB), in collaboration with the Ministry of Environment Forest and Climate Change, decreed several rules and regulations for industrial units that run on various fossil fuels and emit harmful emissions gases. The manufacturing activity regulations articulate, that the most regulated process exhaust emissions should pass through an unobstructed, vertical stack. The stack should be of sufficient height to ensure appropriate upward dispersion of the exhaust. It will minimize the ground level concentration of air pollutants where individuals may be exposed (Tadmor 1971, CPCB 1998, Bhanarkar et al. 2002). Also, the upward dispersion will not affect the wind blowing over adjacent buildings or buildings in the closest proximity. This may result in eddies in the downwind building cavity and wake areas, resulting in a significant increase of pollutant GLC and pulling the contaminated air back into the building through air intakes, windows, and doors (Lee & Stern 1973, Schnelle et al. 2015). The nine stacks of the present study have variable heights ranging from 30.5 m to 145 m based on the emission intensity and prescribed limits. The isopleth resultant justifies the phenomenon with a higher process stack accounting for a distant ground-level concentration. This simulation defends the released emissions continually from the stack, resulting in spread out toward further downwind locations, showing the meteorological parameters' significant influence.

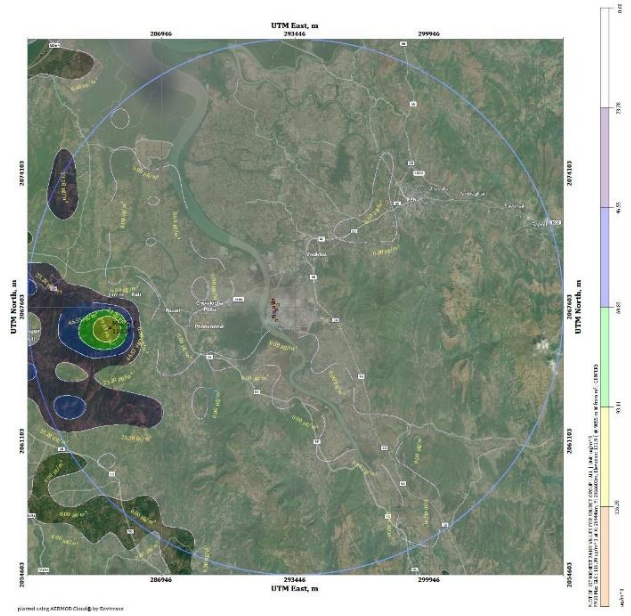


Fig. 6: AREMOD PM_{10} dispersion isopleth.

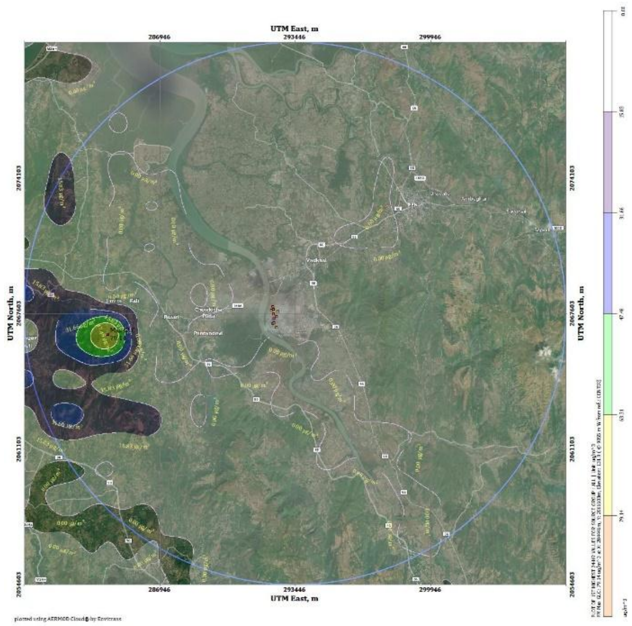


Fig. 7: AREMOD $PM_{2.5}$ dispersion isopleth.

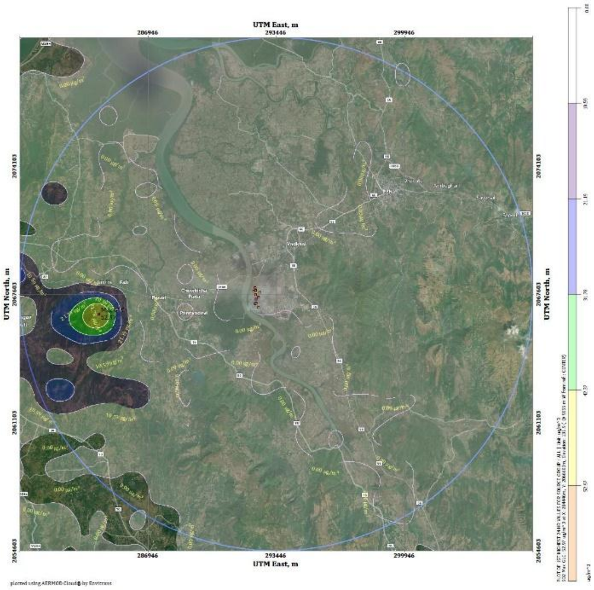


Fig. 8: AREMOD SO_2 dispersion isopleth.

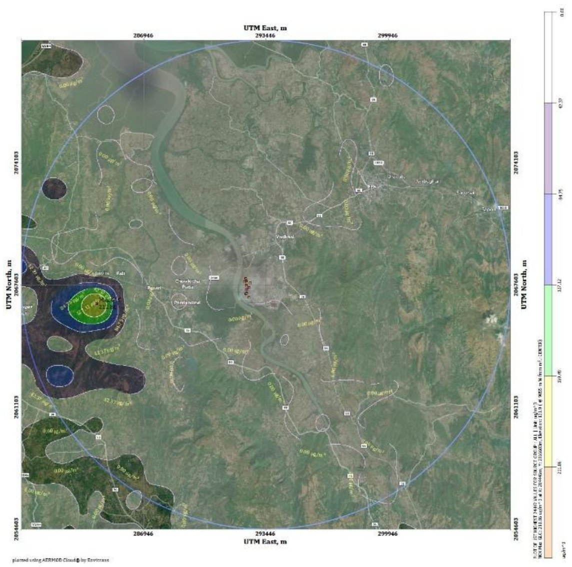


Fig. 9: AREMOD NOx dispersion isopleth.

CONCLUSION

Understanding an atmospheric pollutant dispersion pattern is essential for meeting the stipulated emission reduction goals and minimizing adverse health impacts. Therefore, the emissions inventory and dispersion modeling studies have proven to be instrumental in limiting the environmental effects and responding to related concerns of urban local bodies and societies. The current research was the first to use an independent air quality modeling approach to examine pollutant dispersion discharged into the atmosphere by a coke and pellet mill near a seaside village. The American Meteorological Society/ Environmental Protection Agency Regulatory Model (AERMOD) was used to estimate the causative influence on the surrounding communities. The decade weather data illustrates the prevailing direction is southwestern winds. The source, including all active stacks with requisite air pollution control, devices attached to the coke oven plant, and pellet plant were considered to study dispersion extent. Considering the source effect shows a noticeable determination that the village area was in the background (upwind) of the source. Predicted isopleths were resultant of point source emissions only, and no other area or fugitive sources showed distant GLC during the study. There is always a risk of double-counting or omission of estimating emissions in processes peculiar sectors. It is evident that the emission factor assumes various fuel combustion practices. These were used to produce heat in the charging, sintering, purification, refining, etc. Coke ovens are heated by the mixture of blast furnace and coke oven gas, which is also transferred to the plant's on-site pellet production processes. The present study put a stage for continual improvement in emission estimation with periodically available contemporary emissions factors. Also, the technological advancements will reduce the efforts and monitory implications for the same.

ACKNOWLEDGEMENT

The authors express sincere thanks to Prof. Suresh Gosavi, Head, Department of Environmental Sciences, Savitribai Phule Pune University (SPPU), and also thankful to Dr. Anand Rai, General Manager and Head, Department of Environment, and Mr. Gajraj Singh Rathore, President of JSW steel plant Geetapurm Dolvi, Tal. Pen and District Raigad, Maharashtra (India) for providing necessary equipment facilities to carry out the present research work and giving their constant support and encouragement to complete this research work and Amba River Coke Ltd. (ARCL) management for their continued support during the study. Appreciations also go to the Indian Institute of Tropical Meteorology, Indian Meteorological Department, Pollution Control Board, Faculty of Environment Science SPPU, and AERMOD Cloud model development team for providing valuable inputs for smooth operations during the study. We extend a special thanks to members of the ARCL for their general assistance.

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