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SULPHATION RATE IN CHANDRAPUR INDUSTRIAL CLUSTER, CENTRAL INDIA

R. K. Kamble

Centre for Higher Learning and Research in Environmental Science

Department of Environmental Science, Sardar Patel College, Chandrapur 442 402, India

Corresponding author: rahulkk41279@yahoo.com

Abstract

Sulphation rate in Chandrapur industrial cluster was carried out by using lead peroxide candle turbidimeteric method in December 2014-January 2015 (winter season). Sampling was carried out at four sampling locations; two sampling locations were in upwind direction whereas other two in downwind direction. Minimum sulphation rate in study area was 0.68 mg SO_3/100 cm^2/day at Tukum, whereas maximum at Ballarpur 1.41 mg SO_3/100 cm^2/day. Average sulphation rate in study area was 1.12±0.31 mg SO_3/100 cm^2/day. On comparison of sulphation rate at two road sides, it was observed that at Babupeath–which was adjacent to state highway–had sulphation rate 1.16 mg SO_3/100 cm^2/day whereas for Nakoda 1.23 mg SO_3/100 cm^2/day which was adjacent to local road. From the results it was evident that sulphation rate was more in upwind direction as compared with downwind direction may be due to presence of pulp and paper mill. Industrial activities in Chandrapur industrial cluster contributes significant sulphur emissions from pulp and paper mill, super thermal power station where coal is used, ore smelting, number of cement industries, emissions from diesel driven heavy and light motor vehicles along with domestic coal burning. As wind progresses from upwind to downwind direction sulphur concentration was reduced due to dilution, dispersion and transportation, which result into reduced sulphation rate in downwind direction.

Keywords: Air pollution, Chandrapur, Lead peroxide candle method, Sulphation rate, Sulphur dioxide

Introduction

Air considered as one of the important natural source. It is one of the most essential components for human life. An average man can breathe 22,000 times a day and takes approx. 16 kg of air each day. It is estimated that man can live for five weeks without food and five days without water, but only few minute without air (Rao and Rao, 2003).

The magnitude of air pollution problem has increased alarmingly due to increase in population, industrialization, urbanization, automobile and other anthropogenic activities. Today, sulphur dioxide remains one of the major atmospheric air pollutant. Sulphur dioxide is a product of fossil fuel combustion usually oil and coal, manufacture of sulphuric acid and fertilizers, smelting industries account about 75 % of total SO_2 emission while automobile and refineries contributes to the rest 25 % (Sharma, 2001). According to Environment Canada (2001), the industrial sector is responsible for the largest emissions of SO_2 in Canada where the smelting of metal concentrates and power generations are important contributors. In Alberta, the industrial activities leading to the largest releases of SO_2 are upstream oil and gas activities (which include natural gas processing), electric power generation and oil sands activities.

Sulphur dioxide gas produced by chemical interaction between sulphur and oxygen. Sulphur dioxide is colourless, non-flammable and non-explosive gas with suffocating odour (Peavey, 1985). Sulphur dioxide can act either as reducing or oxidizing agent reacting photochemically or catalytically with other components in atmosphere. Sulphur dioxide can produce sulphur trioxide, H_2SO_4 droplets and salt of sulphuric acid. Oxides of sulphur (SO_x) and SO_2 is second most important contributor of air pollution as it account for about 29 % of total weight of all pollutants. Sulphur dioxide irritates mucus membrane of respiratory tract of human and animal. Plants are particularly sensitive to sulphur dioxide. Wet chemical Modified West and Gaeke spectrophotometric method has been developed for analysis of atmospheric sulphur dioxide. However, for general sulphation of the atmosphere a relatively inexpensive method of lead peroxide candle method is rarely been adopted.

According to Central Pollution Control Board (CPCB), India in association with Indian Institute of Technology Delhi (IITD) conducted a survey and published a report of comprehensive environmental pollution index (CEPI) in December 2009 by ranking industrial clusters/areas in India. In this ranking Chandrapur industrial cluster was placed at fourth most polluted cluster position in India and first in Maharashtra state. The CEPI includes parameters such as air, water and land. In air environment different parameters such PM10, PM2.5 were estimated (CPCB, 2009). However, sulphation rate studies had not been considered and carried out. In this regard, the objective of study was sampling and analysis of sulphation rate in Chandrapur industrial cluster and ascertain contribution of industries present in the cluster for the same. Sulphation rate study is an uncommon parameter for air pollution analysis and very few studies pertaining to it have been carried out includes Tyagi and Tomar (2013).

Study Area

Chandrapur city is located on 19^{o}57' N latitude and 79^{o}18' E longitude in the Vidarbha region of Maharashtra state in Central India and situated at an altitude of 189.90 m above mean sea level.

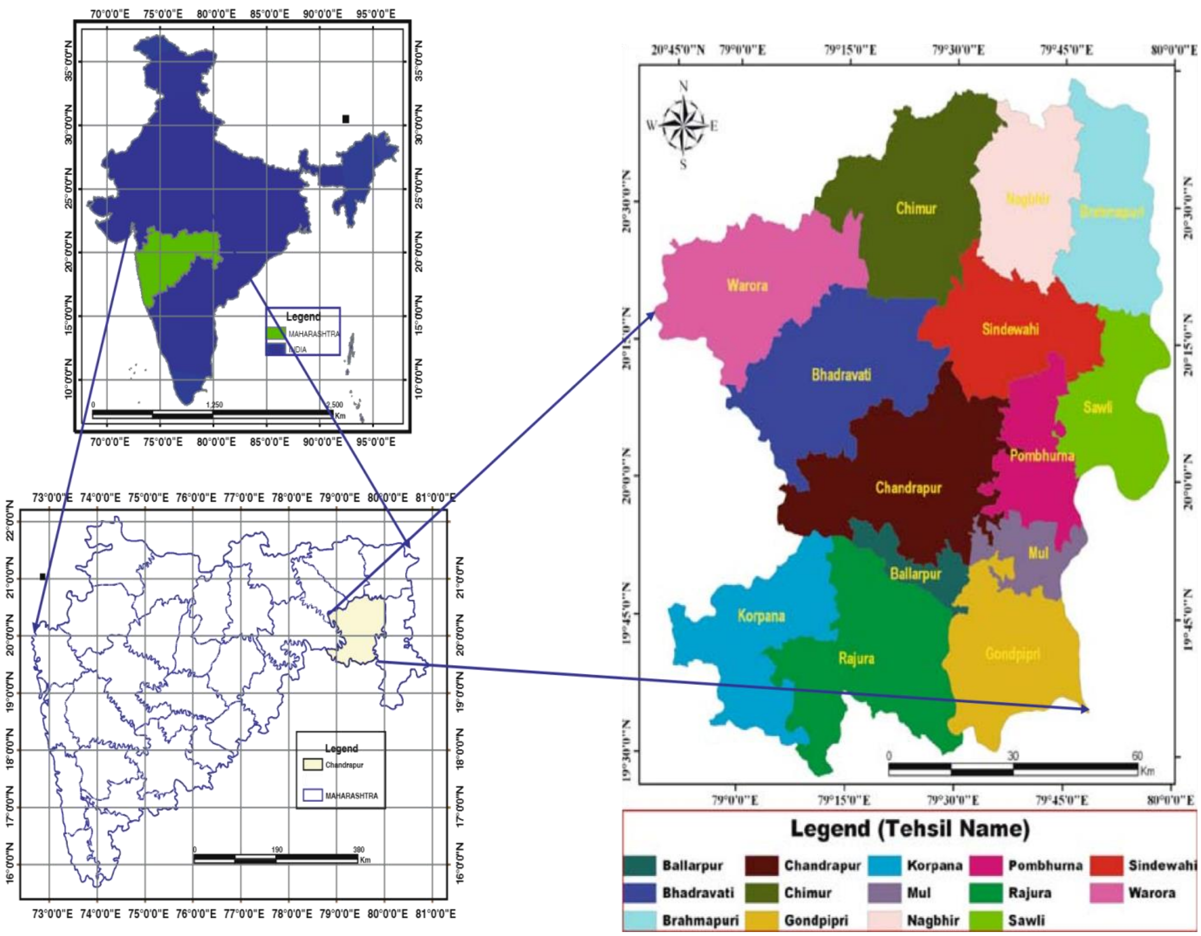

Figure 1: Chandrapur district in central India (Satapathy, 2009)

The city is at southeast direction from Nagpur city, on the Delhi-Chennai railway route. The area of the city is about 70.02 sq km (Figure 1). Physiographically the district is situated within the Wainganga and Wardha river basins, respectively, flowing on the eastern and western boundaries of the district that are the tributaries of Godavari river (Gazetteer of India-Chandrapur, 1973). It had a population of 20,71,101 of which 32.11 % were urban as of 2001. Chandrapur industrial cluster includes MIDC (Maharashtra Industrial Development Corporation) Chandrapur, Ballarpur, Tadali and Ghuggus area. Chandrapur city is famous for its super thermal power station (2340 MW)–one of the largest in Asia and vast reserve of coal. Chandrapur also has large reservoirs of limestone. The abundance lime and coal supplied to many cement industries like L&T, Gujrath Ambuja and Manikgad in the district. The mammoth coal mines in an around the city also contribute to the heavy industrialization of the city. The city also boasts of having the largest paper-manufacturing unit of Ballarpur Industries Limited (BILT), largest manufacturer and exporter of paper in India, in the adjoining Ballarpur city. The city houses various cement factories in the vicinity. Various other major industries include a ferro-manganese and silico-managanese plant of Steel Authority of India. About 700 small and large-scale industries are located at Chandrapur district. Around 120 industries from Chandrapur district are categorized in red, 178 in orange and around 400 in green category (MPCB, 2006). The industrial classification from the study area is presented in table 1 (MPCB, 2010).

Table 1. Industrial classification in Chandrapur industrial cluster (MPCB, 2010)

Name of industrial area	Highly polluting industries	Red category industry	Orange /Green category industry	Grossly polluting industry
MIDC Chandrapur	02	08	24	02
Ghuggus	01	03	Nil	Nil
MIDC Tadali	Nil	05	Nil	Nil
Ballarpur	01	12	18	01

Meteorology

The micrometeorological data was recorded with the help of mechanical weather monitoring station placed at a height of 10 m above ground surface to collect wind speed and wind direction data during the study period.

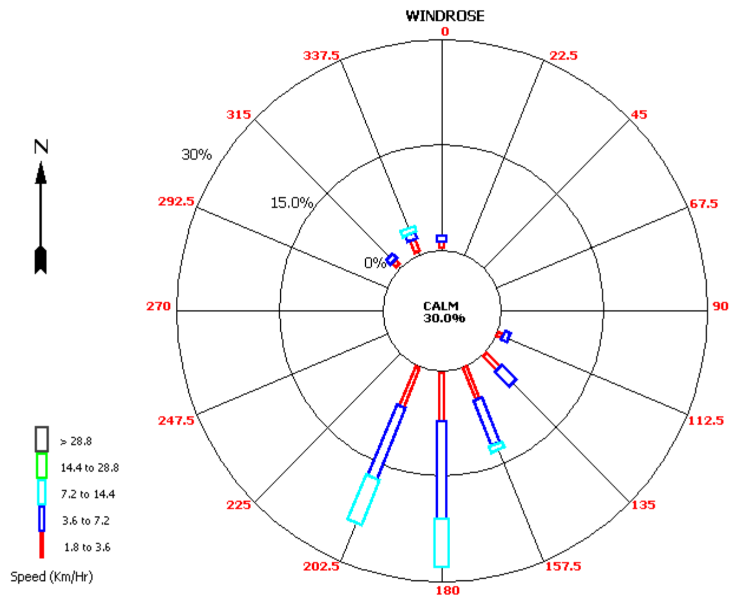

Figure 2a. Wind rose from study area (December 2014)

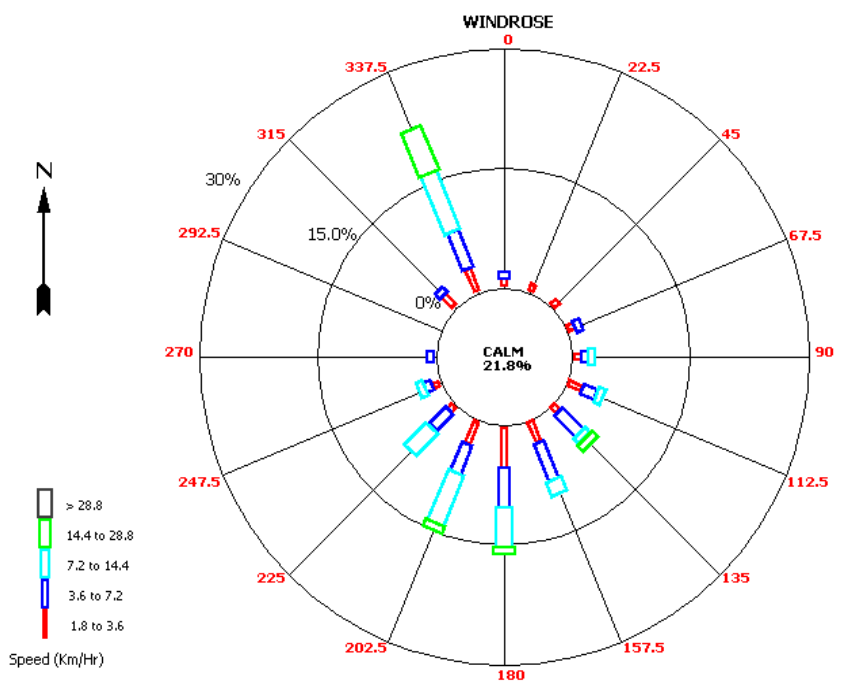

Figure 2b. Wind rose from study area (January 2015)

The hourly record of wind speed and wind direction data during study period were used for computing the relative percentage frequencies of occurrence in 16 cardinal directions and 5 wind speed classes. These frequencies were computed on 24 hourly basis for winter season as shown in figures 2a and 2b. The 24 hourly windroses during winter season for December and January shows predominat winds were from S, SSW and SSE directions, with dominant wind speed class of 3.6-7.2 km h^{-1}. Average calm condition was recorded 26 % of time during study period.

Materials and Methods

Sampling sites

Sampling locations for sulphation rate were identified taking into consideration the meteorology of the study area. The predominant upwind directions in the study area were S, SSW and SSE during December 2014 and January 2015 (winter season). To have a clear idea of distribution of sulphation rate in the study area four sampling locations were selected. Of four locations, two were in upwind direction and two were in downwind direction. Two sampling locations were nearby road side–state highway and regional road and one sampling location each at industrial site and residential area.

Lead Peroxide Candle Method

Sulphation rate monitoring was carried out by using lead peroxide candle method IS: 5182 (Part VIII)-1976 (Reaffirmed in 2009) (IS: 5182-1976, 2009). Sampling was carried out in December 2014-January 2015 (winter season). The lead peroxide candle static collector is an inexpensive method for measuring the relative "sulphation" of the atmosphere. Sulphur dioxide collection efficiency depends upon ambient air temperature, relative humidity, wind speed, atmospheric concentration of sulphur dioxide and the length of exposure period. Sulphation rate is the method of measurement of sulphation rate in air, using lead peroxide as one of the reagents. Lead peroxide, due to its oxidizing power, converts other compounds such as mercaptons and hydrogen sulphides into sulphates. It also fixes sulphur trioxide and sulphuric acid mist present in the atmosphere. It converts oxides of nitrogen into nitrates. In this method, ambient air was exposed to lead peroxide candle and sulphur dioxide in air forms lead sulphate, which was estimated by various analytical methods (Gruber and Jutze, 1976).

Lead peroxide candles were prepared by using tapestry cloth and a paste of lead peroxide was applied on wounded cloth around a plastic cylinder of 10 cm height with a total reactive area of 100 cm^2. These lead peroxide candles were kept in louvered boxes and were exposed to ambient air at a height of 10 m above ground level. The sampling was carried out for a period of 30 days. To know the blank concentration a candle was kept in a desiccator in the laboratory in an unexposed condition for 30 days. After exposure of candles for 30 days, they were brought to the laboratory for estimation of sulphation rate.

Various methods have been developed for analysis of sulphation rate which includes gravimetric, turbidimetry and colorimetric titration method. For estimation of sulphation rate for this study gravimetric method was adopted. The coated exposed fabric was stripped off from the cylinder and treated with 5 g of anhydrous sodium carbonate in 100 mL distilled water in a beaker with occasional stirring for 3 hours. The content was heated nearly to boiling for 30 minutes keeping volume constant by adding additional distilled water. The content was filtered through Whatman No. 41 filter paper with subsequent 4 to 5 washings with hot water. The filtrate was neutralized (pH 3-4) with conc. HCl. The solution was boiled for few minutes and volume was made to 250 mL. Acidity of the solution was adjusted to pH 4.5 to 5 with dilute HCl. Additional 1-5 mL conc. HCl was added and the solution was heated to boiling. After removing the burner and while stirring, warm barium chloride solution was slowly added until precipitation was completed and kept it overnight. The barium sulphate precipitation was filtered in a washed, ignited and pre-weighted Gooch crucible. The crucible was dried with residue and ignited at 800 ^{o}C for 1 hour and sulphation rate was calculated gravimetrically by using standard formula and reported in mg SO_3/100 cm^2/day.

Results and Discussion

From results of study minimum sulphation rate was observed at Tukum (0.68 mg SO_3/100 cm^2/day) followed by Babupeath (1.16 mg SO_3/100 cm^2/day) and maximum at Ballarpur (1.41 mg SO_3/100 cm^2/day) (Table 2). The average sulphation rate in study area was 1.12±0.31 mg SO_3/100 cm^2/day (Table 3). At Tukum sampling site (residential area) minimum sulphation rate was observed. Restricted anthropogenic activities at this sampling site may have contributed to this result. Maximum sulphation rate at Ballarpur can be attributed to pulp and paper mill having CPP, vehicular and anthropogenic activities. The Ballarpur sampling location was adjacent to Ballarpur Industries Limited (BILT) pulp and paper mill. Kraft pulping at BILT uses sulphur to get fibre out of wood. The use of this technology in BILT may have released large quantity of sulphur into atmosphere, which had resulted in such an elevated sulphation rate at this sampling location.

At sampling location of Babupeath sulphation rate was 1.16 mg SO_3/100 cm^2/day. This sampling location was adjacent to state highway (Chandrapur-Ballarpur highway). Heavy and light motor vehicles ply on this road. The fuel used in these vehicles (diesel) leads to emission of different air pollutants and one of the air pollutants from diesel vehicles is sulphur dioxide which contributes to sulphation rate at this sampling location.

Table 2. Sulphation rate in study area

Sampling location	Type of area	Location w.r.t. wind direction	Sulphation rate (mg SO_3/100 cm^2/day)
Ballarpur	Residential, in BILT colony	Upwind	1.41
Babupeath	Near state highway	Upwind	1.16
Nakoda	Near road side	Downwind	1.23
Tukum	Residential	Downwind	0.68

Table 3. Statical summary of sulphation rate in study area

Particulars	Details
Minimum	0.68 mg SO_3/100 cm^2/day
Maximum	1.41 mg SO_3/100 cm^2/day
Average	1.12 mg SO_3/100 cm^2/day
Range	0.73
SD	±0.31
Variance	0.09

At Nakoda, sulphation rate was 1.23 mg SO_3/100 cm^2/day. Cement industry was located near the sampling site and heavy vehicles plying on the road contribute air pollution into atmosphere. These factors contribute to elevated sulphation rate at this sampling site.

Sulphation rate concentration was more in upwind direction as compared to downwind. The winds from upwind direction (Ballarpur) carries sulphur compounds along with it, which were emitted from Ballarpur industrial area. As wind moves past over Babupeath area concentration of these sulphur compounds becomes relatively reduced may be due to dilution, dispersion and transportation activities in atmosphere. As wind progresses towards downwind direction over Chandrapur city to Tukum, concentration of sulphur compounds from upwind direction reduces significantly. Nakoda and Babupeath sampling locations were adjacent to local road and state highway respectively. On comparison of results obtained for these two sampling locations it has been observed that at Nakoda sulphation rate was 1.23 mg SO_3/100 cm^2/day whereas, at Babupeath 1.16 mg SO_3/100 cm^2/day. Regular heavy vehicular activities and industrial air pollutant emissions contribute significant sulphur emissions into atmosphere at both sampling sites. A gradual increase in sulphation rate was observed from residential area to mixed area to industrial area. The results were in accordance with Tyagi and Tomar (2013).

Conclusion

Sulphation rate was observed in all sampling locations in study area for December 2014-January 2015 (winter season). Maximum sulphation rate was at Ballarpur upwind direction and minimum at Tukum. This maximum sulphation rate can be due to presence of pulp and paper mill in the sampling area whereas at Tukum anthropogenic activities had contributed the observations. At both road side sampling locations of Babupeath and Nakoda significant sulphation rate was observed.

Predominant sources which were contributing sulphur emissions into atmosphere includes domestic coal burning, Multiorganics Ltd. in Chandrapur MIDC area where coal in boiler generates predominantly particulate, SO_2 and NO_X. In Ballarpur, pulp and paper mill with CPP and coal mines were significant contributor whereas, in Tadali and Ghuggus area steel industry complex with sponge iron plants with CPP and steel products, cement industries and coal mines (MPCB, 2010).

Expansion of existing Chandrapur super thermal power station (CSTPS, 2340 MW) by 1000 MW will add additional sulphur emissions into atmosphere in near future that will make the situation more worse. Average calm condition of 26 % during December-January (winter season) in study area may lead to formation of sulphurous smog like conditions in future. The immediate effect can be local acid rain, effects on plants, animals and archaeological monuments in Chandrapur city.

Adaptation of cleaner technologies at source–fuel switching and process modification–which will significantly reduce sulphur emissions into atmosphere as compared with end-of-pipe technology–flue gas desulfurization (FGD)–should be encouraged by industries in this industrial cluster to reduce further consequences of elevated sulphation rate. The future expansion of industries in this industrial cluster should be considered by executing carrying capacity of the region along with regional meteorological conditions into consideration so that minimum impact on environment can be ensured.

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