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Impact Assessment of Respirable Suspended Particulate Matter from Diesel Generator Sets Used for Pumping Station

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Abstract Prediction of respirable suspended particulate matter impacts of diesel generator sets used for pumping station has been made using meteorological data, information on stack characteristics and emission rate, baseline ambient particulate matter and Industrial Source Complex Short Term (ISCST-3) model. It is observed that particulate matter emission from pumping station-S workplace diesel generator sets ranged from 2.4 to 436.5 mg Nm^{-3} and while at pumping station-C, it ranged from 23.2 to 186.5 $mgNm^{-3}$. The predicted and ambient respirable suspended particulate matter concentrations are below the national air quality standard for respirable suspended particulate matter in a mixed industrial area. Metals contents in respirable suspended particulate matter indicate the origin of crustal and mobile sources. Therefore, the impact of diesel generator sets used for pumping of crude oil on local air quality would be acceptable.

Keywords RSPM · Metals · DG sets · ISCST-3 model

In recent years the shortage of power coupled with unreliable and poor quality of the power supply has resulted in a proliferation of captive generator sets, run with diesel, petrol or kerosene, as an alternate source of power. This is happening, particularly, in urban areas where the need is greater. Diesel engines move a large portion of the world's goods, power much of the world's equipment, and generate electricity more economically than any other device in their size range (Lloyd and Thomas 2001). Despite its many advantages; the diesel engine is inherently dirty. Particulate matter (PM) emissions from diesel combustion contribute to urban and regional hazes. Nitrogen oxides (NO_x) and hydrocarbons (HCs) are precursors for O_3 and PM. Some components of HC and PM emissions have been identified as toxic substances with the potential for adverse health effects. Diesel is produced from a fossil fuel and engines using it as fuel produce air pollution and high sulfur levels. Diesel fuel also creates a distinct smell and exposure to diesel engine exhaust can also lead to health hazards. Particulate matter in diesel exhaust is primarily composed of carbonaceous material (Shah et al. 2004; Schauer et al. 1999) containing different mixtures of elemental and organic carbon, which vary according to engine operating conditions (Lough et al. 2007). Elemental carbon (EC) is often used as a marker for particulate diesel exhaust in the atmosphere (Schauer 2003). Diesel engines produce submicron soot particles that are believed to mediate several of the observed adverse effects. It has been estimated that the particulate emission from diesel engines per travelled distance is over 10 times higher than the emission from petrol engines (Zweidinger et al. 1990).

It is well established that high levels of ambient particulate matter (PM) are significantly associated with adverse health effects, ecosystem damage and degraded visibility (Goswami et al. 2002). The concentrations of heavy metals in the atmospheric particulate matter have been widely determined and studied (Wang et al. 2001; Ye et al. 2003; Ho et al. 2003; Xie et al. 2006; Deng et al. 2006; Li et al. 2008). A particular fraction of the particulate matter (PM) which is known to exert toxic effects is metals, such as Fe, Zn, and Cu which may release free radicals in lung fluid via the Fenton reaction, and are hypothesized to cause cellular inflammation (Birmili et al. 2006). Heavy

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metals are present in the atmosphere in ever increasing levels as a result of anthropogenic and natural emissions (Suzuki 2006). Frequently, anthropogenic emissions cause the levels of metal in suspended particles to be well above natural background levels (Finlayson-Pitts and Pitts 2000; Quiterio et al. 2004). Present study was undertaken for monitoring the air quality with respect to respirable suspended particulate matter (RSPM) in and around workplace of pumping station at Western Region, transports crude oil/petroleum to and from refineries across India through a network of pipelines and uses high capacity diesel engine pumps. Present study focused on assessment of impact of high capacity diesel engine pumps activities on ambient air quality with respect to particulate matter along with associate trace metals and GLC prediction of particulate matter.

Materials and Methods

Air quality monitoring with respect to respirable suspended particulate matter (RSPM) was carried out continuously for 6 days in summer season using standard procedures at two pumping station namely at pumping station-C and at pumping station-S to establish the existing air quality status from operations of booster pump. Respirable dust samplers were used for measurement of particulates matter (Katz 1977). Samples for RSPM was collected on glass fiber filter paper used to determine the toxic metals which includes copper (Cu), iron (Fe), lead (Pb), manganese (Mn), and nickel (Ni) by Inductively coupled plasma optical emission spectrometry, (ICP-OES), model–optima 4100 DV, Perkin Elmer. Meteorological data collected on wind speed, wind direction, mixing height and stability class is used for prediction exercise. Stack emission studies were carried out as per standard methods (Brenchley et al. 1974). Particulate matter was determined by gravimetric methods. Modeling exercise was carried out for prediction of ground level concentration (GLC) influence by PM emissions released from pipeline work station using air pollution dispersion model. Number of Gaussian dispersion models is available to predict the GLC (U.S.E.P.A. 1987). One of such model, Industrial Source Complex Short Term (ISCST-3) model was used for the prediction of 24-hourly average GLCs of air pollutant around the pipeline station.

Quality assurance/Quality control (QA/QC) protocol is undertaken for precise measurement of particulate matter by calibrating the air flow measurement device using top load calibrator prior to sampling and air flow is corrected at standard temperature and pressure. Blank test background contamination was monitored by using operational blanks (unexposed filter) which were processed simultaneously with field samples. Blanks were cleaned and prepared with the same procedures applied to the actual samples. Concentration of particulate matter was determined by gravimetrically using calibrated balance (Mettler AE 163). Analysis of trace metals were carried out using ICP-OES. High quality glass wares were preferred, throughout the sampling, digression and analysis steps, to prevent any metal contamination. The filter paper were digested with concentrated nitric acid (Merck) in Teflon vessel in a microwave digestion chamber (ETHOS make-milestone, Italy). The sample was digested for 20 min and then filtered through Whatman 42 filters into properly cleaned volumetric flask. Samples are analyzed by spiking with a known amount of metals to calculate recovery efficiencies. The analysis procedure for the recovery test is the same as that described for the field samples. The recovery tests of trace metals were 106.5%, 98.0%, 94.5%, 98.0%, and 93.0% for Fe, Pb, Ni, Mn and Cu, respectively. The range of recovery efficiency varies between 93% and 106% and the relative standard deviation is smaller than 5.23%. The reproducibility test indicates the stability of the instruments. Analysis of metals of the same concentration standard solution is repeated for many times. The standard solution of 0.5 ppm was repeated and reproducibility of results indicates that 96.61%, 99.40%, 97.24%, 98.62%, 94.4%, for Fe, Pb, Ni, Mn and Cu, respectively was observed. The reproducibility varied between 94.4% and 99.61%, and the mean relative standard deviation is 1.9%.

Results and Discussion

Meteorological parameters play very crucial role in transport and dispersion of pollutants in the atmosphere. Therefore, micrometeorology data with respect to wind speed and direction during the study period was collected from Indian Meteorological Department (IMD). The predominant wind directions (blowing from) were S: 12% and

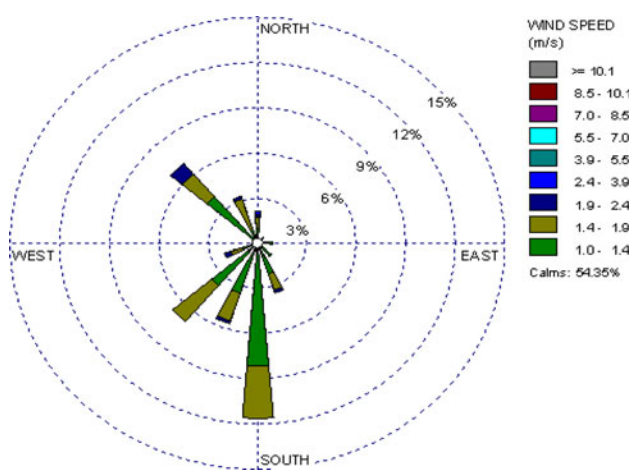

Fig. 1 Windrose diagram

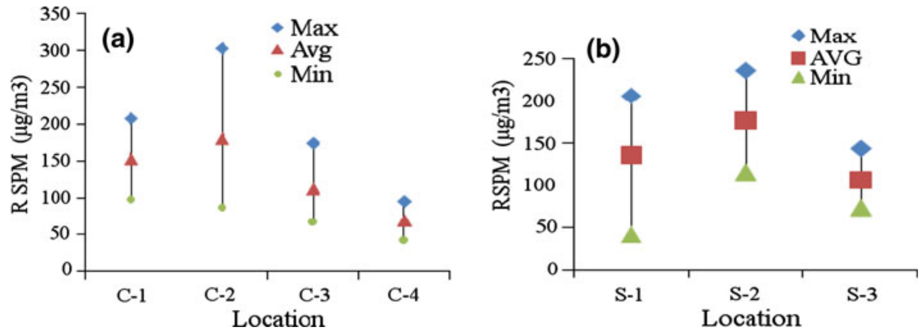

Fig. 2 **a**, **b** Variation in respirable suspended particulate matter concentration at pumping station-C and pumping station-S location

SSW: 8%, with 54.35% falling under calm condition. The average wind speed was 0.74 m/s with a maximum of 2.7 m/s (Fig. 1).

The air quality status of RSPM at the chosen four locations around pumping station-C is presented in Fig. 2a. The 24-hourly average concentration of RSPM at all the four locations ranged from 69 to 180 μg/m^3, respectively. The maximum RSPM concentration at pumping station-C was found to be 303 μg/m^3 at C-2 location and minimum 42 μg/m^3 at C-4 location. Air quality status with respect to RSPM is also carried out around another pumping station-S and summary has been presented in Fig. 2b.

The average concentration of RSPM ranged from 106 to 176 μg/m^3, respectively. The maximum RSPM concentration at pumping station-S was found to be 236 μg/m^3 at S-2 location and minimum 42 μg/m^3 at S-1 location. Comparison of RSPM data of past 5 year along with latest present study was presented in Fig. 3. In pursue of figure indicate the concentration of RSPM increases in subsequent year.

Profile of metals at sampling location in pumping station-S and pumping station-C anlysis are shown in Figs. 4 and 5. The levels indicate that metals were marginally significant. It is experienced that the toxic metals, which are oftenly, associated with particulate matter even at low level causes more serious health problems. At pumping station-C location, Fe concentrations were higher at C-2 site.

Fe ranged from 3.82 to 1.47 μg/m^3. Cu were higher at C-4 site, Cu ranged from 0.16 to 0.06 μg/m^3, Mn ranged

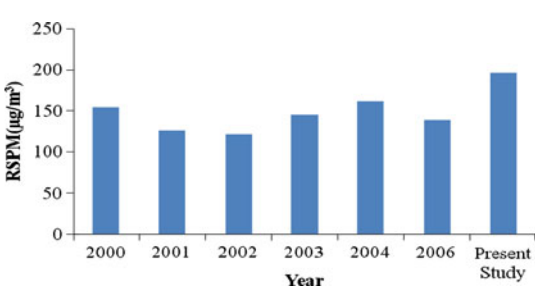

Fig. 3 Comparison with present and past status of respirable suspended particulate matter

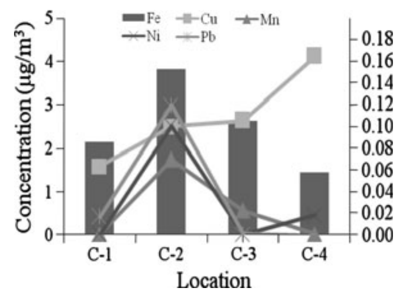

Fig. 4 Trace metals concentration in various location at pumping station-C

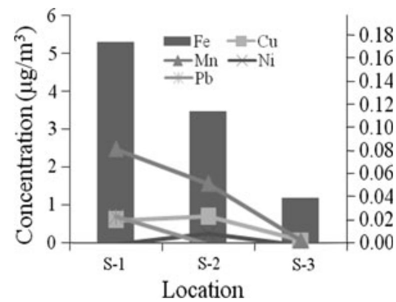

Fig. 5 Trace metals concentration in various location at pumping station-S

from 0.070 to 0.0016 μg/m^3, and Ni 0.10–0.0011 μg/m^3, Pb were ranged from 0.12 to 0.0016 μg/m^3. Ni and Pb were insignificant because there is no combustion activities. Fe concentration was found to be higher at S-1 site around pumping station-S.

Fe concentration ranged from 5.31 to 1.17 μg/m^3. The Cu concentration ranged from 0.6 to 0.056 μg/m^3 and Mn concentration was ranged from 0.08 to 0.004 μg/m^3. Ni was very low 0.010 μg/m^3 and Pb varied from 0.03 to 0.0015 μg/m^3. Ni and Pb were ND in S-3 site. Fe and Mn are generally from the crustal origin. Cu comes from the vehicular activities. The levels indicate that metals were marginally significant. It is experienced that the toxic metals, which are oftenly, associated with particulate matter even at low level causes more serious health problems. The Fe concentration was found to be higher at S-1 site around pumping station-S. Fe concentration ranged

Table 1 Stack emission characteristic of the diesel generator set at pumping station-C and pumping station-S

Location	Stack	Stack height (m)	Stack diameter (m)	Exit gas velocity (m/s)	Exit gas temperature (K)	Particulate matter emission (mg Nm^{-3})
Pumping station- S	MP1	0.4	7.3	19	621	109
	MP2	0.4	5.7	18.6	589	98
	FFE1	0.1	2.3	23.7	719	85
	FFE2	0.1	6.7	56.5	606	–
	DG A1	0.15	–	20	489	115
	DG B1	0.15	3.7	20.3	481	–
Pumping station- C	MP1	6.6	0.4	25.7	680	105
	MP2	6.9	0.4	20.2	695	102
	MP3	6.4	0.4	16.5	585	106
	MP4	8.6	0.4	27.9	667	100
	MP6	5	0.4	31	705	109
	FFE1	5	0.25	24.2	753	110
	FFE2	4.9	0.25	32.5	776	60
	FFE3	–	0.25	31.9	747	70
	DG1	3.6	0.2	29.1	726	120
	DG2	–	0.2	29	719	102

from 5.31 to 1.17 μg/m^3. The Cu concentration ranged from 0.6 to 0.056 μg/m^3 and Mn concentration was ranged from 0.08 to 0.004 μg/m^3. Ni was very low 0.010 μg/m^3 and Pb varied from 0.03 to 0.0015 μg/m^3. Ni and Pb were ND in S-3 site. At pumping station-C, Fe concentrations were higher at C-2 site. Fe ranged from 3.82 to 1.47 μg/m^3. Cu were higher at C-4 site, Cu ranged from 0.16 to 0.06 μg/m^3, Mn ranged from 0.070 to 0.0016 μg/m^3, and Ni 0.10–0.0011 μg/m^3, Pb were ranged from 0.12 to 0.0016 μg/m^3. Ni and Pb were insignificant because there is no combustion activities. Fe and Mn are generally from the crustal origin. Cu comes from the vehicular activities.

The details of stacks characterization at pumping station-S and for pumping station-C is given in Table 1. The profile of the stack emission characteristic reveals that the flue gas velocity in diesel generator (DG) set at pumping station-S varied from 18.6 to 56.5 m s^{-1} and flue gas temperature ranged from 481 to 719 K. At pumping station-C, the average values of flue gas velocity and temperature were 16.5 to 32.5 m s^{-1} and 585 to 776 K, respectively. Stack emission studies for PM were carried out in selected area of workplace at pumping station-C and pumping station-S. PM concentration from pumping station-S workplace DG sets station chimney ranged from 85 to 115 mg Nm^{-3} and while at pumping station-C, concentration ranged from 60 to 120 mg Nm^{-3} which were below the emission standards for particulate matter promulgated by regulatory authority.

As regards to PM concentration, comparison of model result and monitored values shows that predictions were found fairly well in all the stations. However, monitored RSPM values were found higher than the predicted values. This may be due to contribution of PM from unaccountable sources like fugitive dust around the activities and road dust in the study area. The prediction exercise was also carried out to evaluate the impacts of DG sets at two different locations. The results indicate that the impact around DG sets is minimum at both activities. Isopleths of predicted GLCs of PM for both locations are presented in Figs. 6 and 7.

The elevated level of ambient RSPM was observed at all sampling location which may be due to resuspended road dust contributed by movement of vehicles on unpaved road. Metals include Fe, Cu and Mn which are crustal originate attribute in significant concentrations. To arrest the PM pollution in the study area, green belt development around the road side and pumping sites are suggested.

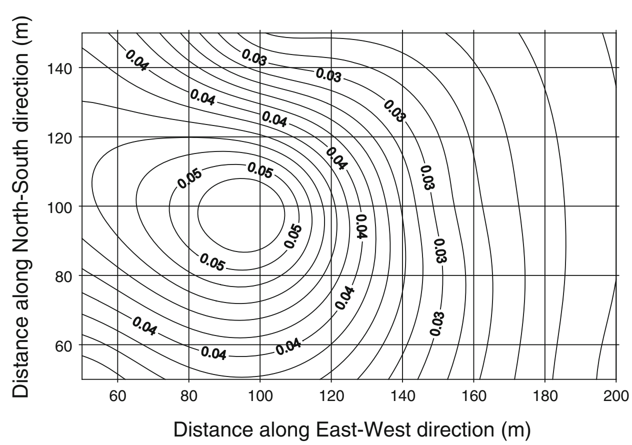

Fig. 6 Isopleths of predicted particulate matter concentration (μg/m^3) at pumping station-S

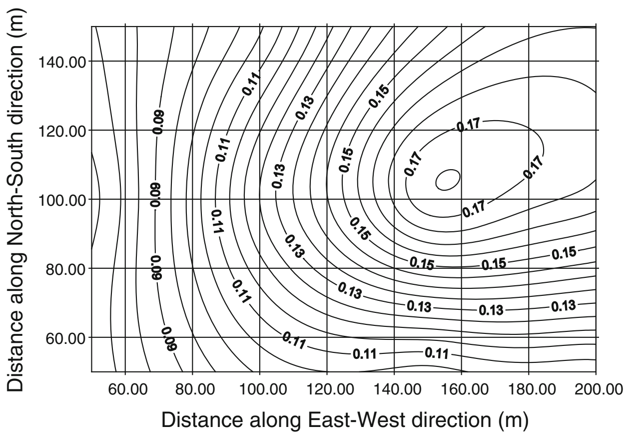

Fig. 7 Isopleths of predicted particulate matter concentration ($\mu g/m^3$) pumping station-C

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