Bull. Environ. Contam. Toxicol. (2002) 68:839–844

DOI: 10.1007/s00128-002-0031-8

Bulletin of Environmental Contamination and Toxicology

Identification of Inplant Ambient Air Quality Monitoring Stations Using a Prediction Model

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Received: 12 March 2001/Accepted: 17 April 2002

Stack emissions in petroleum refineries effects considerably ambient air quality. The sources of emissions from refineries comprise crude furnaces, FCCU charge heaters, gas turbine units, SRU unit, CO boiler, waste heat recovery unit, utility boilers, flare and captive power units. The major pollutants, which are emitted through stacks, are SO_2, NO_x, HC, CO, H_2S and particulates. Ashar (1985) provided pollutant regulation and monitoring techniques for undertaking emission survey in a refinery. A detailed emission characterization study alongwith ambient air quality monitoring in and around a typical 10 MMTPA refinery was conducted at Vadodara, India. The impact of emissions on air quality was predicted by using a mathematical model. Inputs to this model include emissions data, source details, receptor locations and meteorology. The findings from the model were used to identify inplant ambient air quality monitoring stations. Based on modeling exercise and ambient air quality monitoring results, additional monitoring stations have been suggested.

MATERIALS AND METHODS

Detailed stack emission characterisation of major units and ambient air quality studies were carried out to obtain a comprehensive status of air pollution and their contribution in and around the refinery premises. A 10 MMTPA petroleum refinery in the western region of India was chosen for the study. The stack gas characterization and ambient air quality studies were carried out as per BIS (1990) and CPCB (1995) standards respectively.

In order to predict the cumulative effect of SO_2 emissions from all the stacks together, ISCST-2 model of USEPA was used. The short-term ground level concentrations (GLCs) at multiple receptors resulting from multiple point sources for flat and hilly terrain are estimated assuming constant emissions from sources throughout the simulation period. It is also assumed that if short-term predictions do not exceed stipulated limits, then long-term predictions are also not expected to exceed the limits.

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Various options available with this model can be utilized to simulate actual physical conditions at the sources. It also offers greater flexibility in meteorological data input compared to models being used at screening levels. The micrometeorological data recorded at the project site are essential inputs to air quality models as these parameters regulate the transport and dispersion of air pollution emissions. The hourly meteorological data collected at the site was first converted to monthly mean hourly parameters for one day and then used for predictions. With hourly meteorological data available for the study period, impact prediction can be made on hourly, daily, weekly, monthly and seasonal basis. ISCST model has flexibility in specifying the receptor locations. Receptors can be either in Cartesian or Polar coordinate system. Data requirement for this model includes:

Pollutant Emission rate (g/s), Stack height (m), Stack top inner diameter, (m), Flue gas exit velocity, (m/s), Flue gas exit temperature, (K), Source coordinates, x and y axis, (m)

Wind speed (m/s), Wind direction (towards), Ambient temperature, (K), Pasquill-Gifford stability class, Hourly mixing height, (m)

Scaled receptor coordinates, Height of receptor

The impact on ambient air quality was predicted with respect to SO_2 emissions. The prediction was made using the meteorological data with a suitable grid of 5x5 km pattern surrounding the site. In order to obtain a blowup view of concentration profile within the refinery boundary, a refined grid of 1x1 km pattern was chosen for critical pollutant viz. SO_2.

RESULTS & DISCUSSION

The total SO_2 emission from all the stacks was 7400 kg/day as represented in Table 1. These emissions are 32 % of the total gaseous emissions. The average fuel consumption was about 5.6% of the crude throughput. The sulphur content in these fuels ranged from 0.1 to 3.3% with weighted average of fuel mix as 1.7%. Accordingly the overall SO_2 emission was 0.02% of crude throughput. Ahnell & Leany (1977) reported that SO_2 was 46% of the total gaseous emissions in a European refinery. Studies carried out by CONCAWE (1994), suggested that the average fuel consumption in European refineries is about 4.8 percent of crude throughput. The sulphur content in these fuels (oil/gas) varied in the range of 1-5% with weighted average of fuel mix as 1.7%. It was estimated that overall SO_2 emissions from a refinery is 0.16% of crude throughput.

The maximum ambient SO_2 concentration observed was 55 μg/m^3, NE of the refinery and is presented in Table 2. The ground level estimates are presented in Table 3. The GLC of SO_2 was observed as 40.1 μg/m^3 in the SE sector for 1 km grid representing inplant concentration and it was 44.0 μg/m^3 in the SE sector for 5 km grid, which is surrounding of the refinery.

Based on the study, four ambient air quality-monitoring stations were suggested inside the plant, to project impact of background, downwind and crosswind emissions on inplant ambient air. These locations were identified as in Table 4 on the basis of meteorological conditions, predicted GLCs, ambient air quality status and space constraint of the industry. Out of the four AAQM station's the stations 'A' and 'B' represents the impact of refinery emissions while 'C' & 'D' provides impact of storage tanks and process units respectively. The inplant air quality stations provide the occupational exposure status in the work zone. These results further suggest that the emissions from the refinery can be mitigated through process control as well as by use of natural gas for firing heaters / boilers and other combustion units. Continuous ambient air monitoring in these stations would provide sufficient database for effective management of air quality inside the refinery premises.

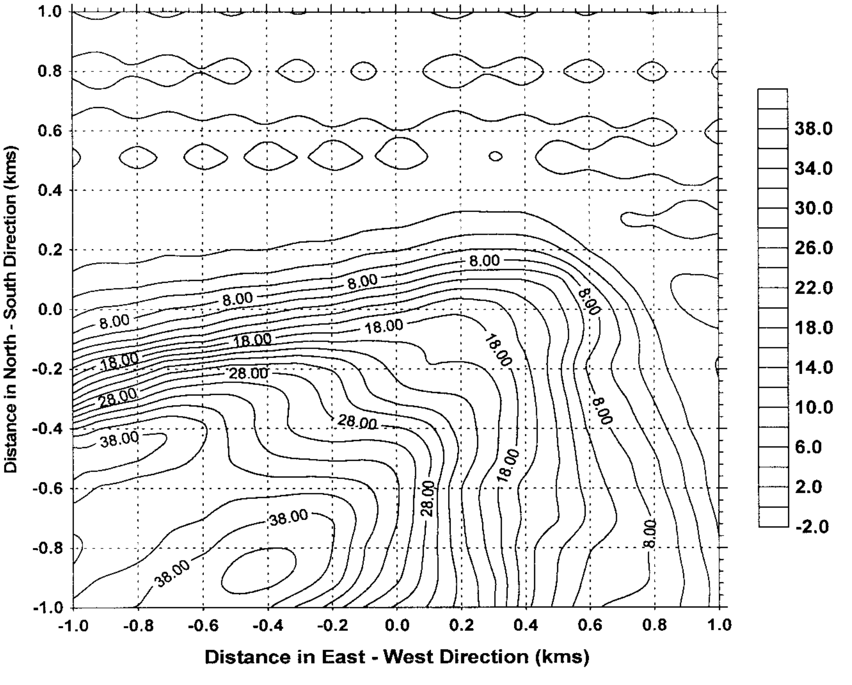
Table 1. Stack emission characterization.

Unit	Stack diameter (m)	Stack gas temp (°C)	Stack gas vel (m/sec)	SPM (mg/ Nm^3)	SO_2 (mg/ Nm^3)	NO_2 (mg/ Nm^3)
AU-1	2.4	225	5.8	10	286	316
TPS	3.0	152	--	--	296	329
CRU	0.8	260	6.6	19.2	32	148
UDEX	1.9	195	--	--	34	42
GRE	1.9	255	9.2	22.5	32	196
FPU	2.3	265	7.2	13.4	59	73
CO-BL	2.6	215	9.6	95.4	156	110
GT-1	3.5	145	4.0	11.5	10	152
FPU	2.7	225	6.0	16.0	53	76
HCU	2.1	260	--	--	40	120
SRU	0.7	282	4.3	17.2	6056	160

Table 2. Ambient air quality monitoring data.

24 hrs avg. unit: μg/m^3

Direction/ Distance (kms)	SO_2 Max	SO_2 Min	SO_2 Avg	NO_2 Max	NO_2 Min	NO_2 Avg	SPM Max	SPM Min	SPM Avg
NE/3	53	6	19	30	5	16	368	150	239
NNW/4	6	6	6	12	4	8	279	114	182
N/5	18	6	10	23	7	12	265	165	202
S/7	54	6	20	61	15	37	282	191	245
SE/3	6	6	6	11	5	7	134	82	108
NNE/7	12	6	8	14	4	10	311	169	244
SE/6	47	6	14	34	8	17	375	170	264
ENE/6	48	6	18	36	5	16	245	172	211
SSE/5	25	6	11	19	12	15	227	129	191
E/5	35	6	19	98	13	40	332	187	247
SE/1	31	6	11	21	7	13	299	104	215
E/2	55	10	29	32	10	20	455	287	343



Source : Refinery Stacks **Average Time :** 24 hours

Unit : μg/m^3 **Pollutant :** SO_2

Figure 1. Isopleths for ground level concentration of SO_2.

Table 3. Ground level concentration of SO_2.

SO_2	Rank	Concentration (GLC, $\mu g/m^3$)	Co-ordinates	
100 in 1 kms	1st	40.1	-400	-800
	2nd	40.0	-400	-900
	3rd	39.4	-500	-800
	4th	39.2	-300	-800
	5th	39.2	-600	-1000
	6th	39.1	-500	-1000
200 in 1 kms	1st	40.1	-400	-800
	2nd	39.2	-600	-1000
	3rd	38.1	-800	-1000
	4th	38.0	-400	-1000
	5th	37.7	-600	-800
	6th	37.7	-200	-800
In 5 kms grid	1st	43.9	-1000	-4000
	2nd	42.5	-1000	-4600
	3rd	40.4	-1000	-3600
	4th	37.4	-1000	-5000
	5th	33.2	-1000	-3500
	6th	32.6	-1000	-2690

Table 4. Location of proposed ambient air quality stations.

Site	Direction	Aerial distance from centre of the plant (km)	Remarks
A	SE	0.6	Representative of refinery emissions
B	NE	0.4	Representative of fugitive emissions
C	S	0.7	Representative of impact mainly due to storage tanks
D	W	0.7	Representative of process emissions

Acknowledgement. We thank Dr. R. N. Singh, Director, NEERI, Nagpur for his encouragement, interest and according permission to publish the paper.

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