Bull. Environ. Contam. Toxicol. (2006) 77:274–281

DOI: 10.1007/s00128-006-1060-5

Bulletin of Environmental Contamination and Toxicology

Atmospheric Concentrations of Sulphur Dioxide in and Around a Typical Indian Petroleum Refinery

P. S. Rao, M. F. Ansari, C. P. Gajrani, A. Kumar, P. Nema, S. Devotta

Air Pollution Control Division, National Environmental Engineering Research Institute (NEERI), Nehru Marg, Nagpur 440 020, India

Received: 28 November 2005/Accepted: 6 June 2006

Petroleum refineries are large industrial installations that are responsible for the emission of several pollutants into the atmosphere. For most refineries, the numbers of products are limited and fairly well defined, however, the volumes may be different. There are refineries that make specialty products such as lubricants and solvents. On a macro scale, the crude oils vary only to a certain extent in their composition. Consequently refinery emissions are mainly related to the raising of energy for the different processes and type of emissions are well defined, viz. CO_2, SO_2, VOCs and NOx. However, the major air emission from petroleum refinery is SO_2 since it is evolved in almost every refinery process.

Appropriate field data are required in evaluating the exposure of population in urban and roadside environments (K. H. Kim et al, 2002). In this communication the ambient air concentrations of Sulphur dioxide and meteorological parameters were measured at several sites around a petroleum refinery in India, while conducting Environmental Audit in 2003. The temporal and spatial variations of the ambient air concentrations of Sulphur dioxide were investigated and analyzed. The contribution of the refinery to the measured atmospheric levels of Sulphur dioxide was also estimated. This study primarily aimed at determining compliance to National Standards and further demonstrating the effect of wind regime on dispersion of SO_2 vis-à-vis possible health risk to the nearby population. The results suggested that there was no health risk due to SO_2 emissions from the refinery.

MATERIALS AND METHODS

The refinery is located in industrial area of Vadodara city on the west coast of Gujarat state in India. It has the refining capacity of 13.5 MMTPA (NEERI Environmental Audit report 2002). It process both domestic and international crude. It has proximity to both natural resources and the main consumers. The refinery complex includes the process units, pipelines, tank farm, and treatment plants, Gas turbine, TPS etc. Figure 1 depicts neighborhood of the refinery. The refinery township is located 150 m to its south and other residential areas 100m west and east of the refinery. These residential areas could be at potential risk from the refinery emissions. Other large industries like petrochemical, fertilizer,

Correspondence to: P. S. Rao

agrochemical, glass etc are situated within around 7 km radius of the refinery. The air emissions are mainly due to the quantities of fuel gas/ fuel oil burned in the process. Percentage contribution of flue gas from refinery stacks (CORINAIR, 2000) is presented in Table 1 & Figure 2. In order to establish the Indian scenario, the refinery plant area was divided into 200 x 200 m grid and 6 sites whereas around the refinery, it was divided into 1000 x 1000 m grid and 12 sites, mainly in the downwind side, for monitoring ambient air quality during winter 2003. Stack emissions were monitored twice every month and ambient air quality twice a week. Meteorological parameters were also monitored at one site. The IS: 5182 and National Ambient Air Quality Guidelines (CPCB, APHA 1977) were followed for carrying out stack emissions and ambient air quality monitoring respectively. US EPA air pollution dispersion model ISCST-3 was used to depict spatial and temporal distribution of ground level concentration of SO_2.

RESULTS AND DISCUSSION

The average ambient air concentration of SO_2 in and around the refinery was in the range of 4 – 28 $\mu g/m^3$ that is within the limit of National Ambient Air Quality Standard. However, the SO_2 concentrations outside the refinery were found to be 5 to 6 times higher than the inside levels, which could be attributed to contribution from various other point and area sources around the refinery. The SO_2 emission load from the refinery as presented in Table 2 was less than 1360 $Kghr^{-1}$, the maximum limit stipulated by CPCB for the refinery. The ground level concentration contours in Figures 3a and 3b also show that the SO_2 concentration was expected within the NAAQS. The Indian refineries are mostly located in and around the urban areas (figure 1 and CPCB, 1995) and air quality in terms of SO_2 in these areas is improving (NEERI report 2000-2003). This may be due to various effective air pollution control measures taken up by the refinery (P.S. Rao et al, 2005) in their process operation and stringent product specifications. The compliance status of other Indian refineries is shown in Table 3. The limit is different for different refineries and is based upon their capacity.

Figure 3a and 3b shows the ground level concentration contours of SO_2 for different seasons during 2003. Despite the complexity in these figures identified regimes of uniform dispersion patterns were observed. During monsoon (June – August), it was observed that wind direction was from northeast side and the highest concentration of SO_2 was found in southwest direction, while during post monsoon (September- October), the wind direction was from southeast and the maximum ground level concentrations of SO_2 were found in northwest. During summer (Feb -May), the wind direction was from north east and the highest concentration of SO_2 was in south west and during winter season (November – January2003) the wind direction was from west and the concentration of SO_2 was found highest in east. Overall scenario suggests that, the wind profile governed the air quality contours indicating uniform dispersion patterns. The major refinery processes are heating hydrocarbons for processing, physical separation and purification, chemical conversion such as residue upgrading, cooling of the products, storage of crude oil and products (P.S Rao et al, 2005).

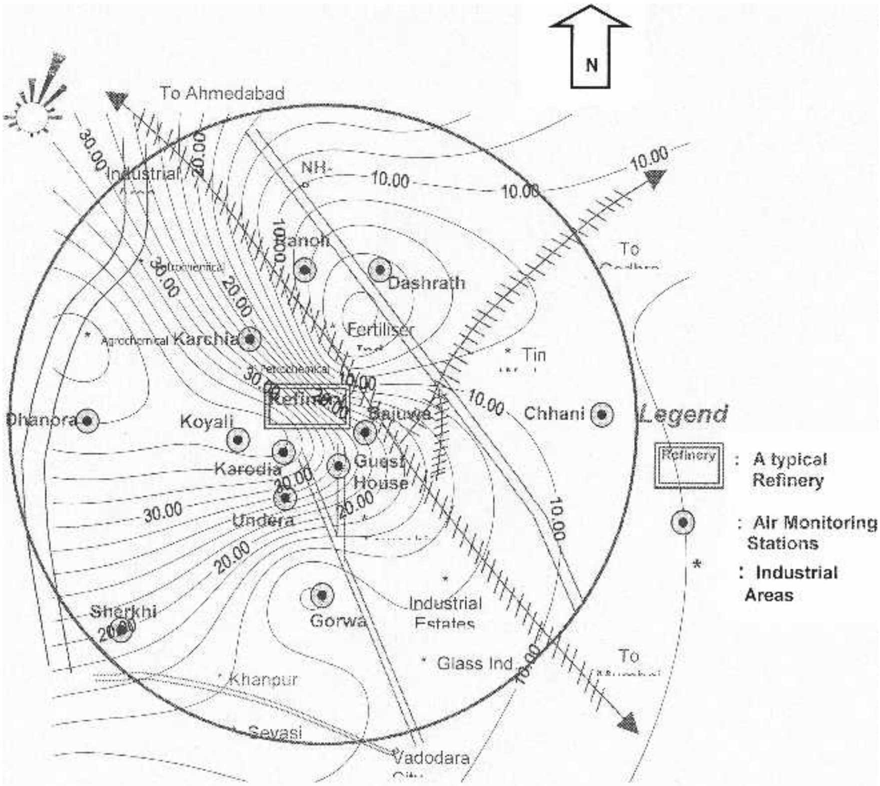


Figure 1. Map showing study area around a typical Indian petroleum refinery.

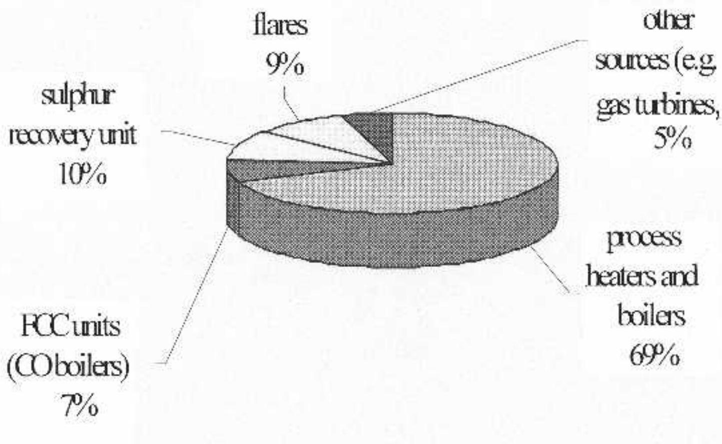
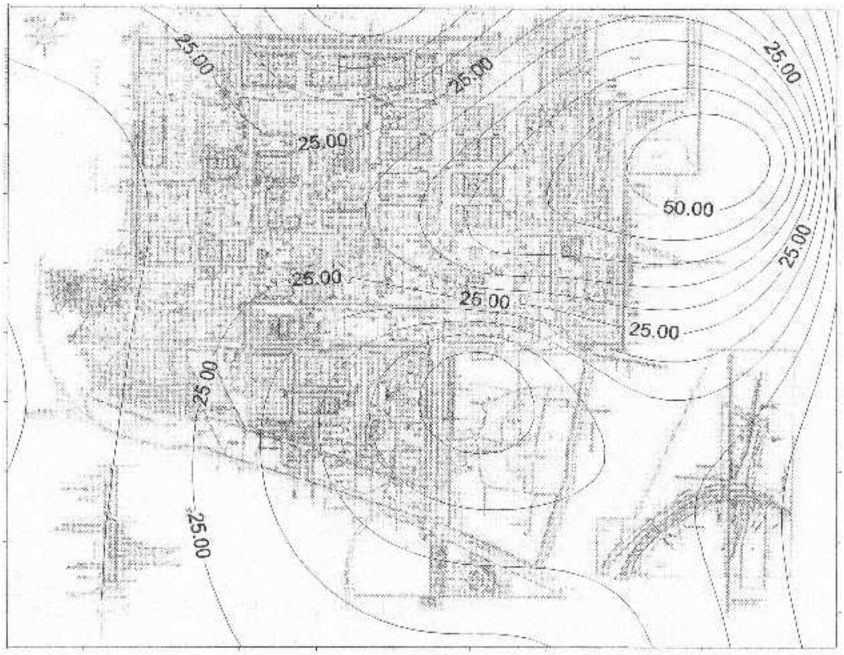
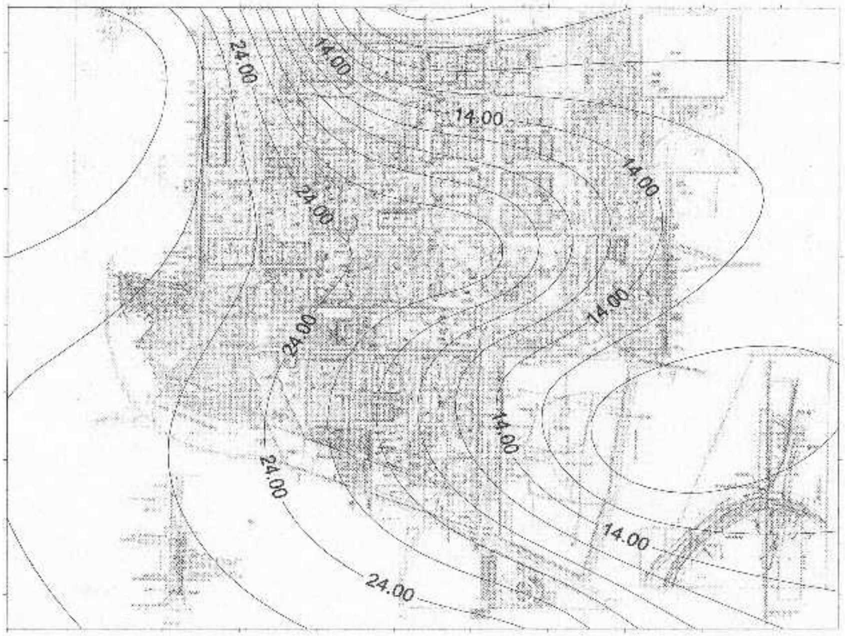


Figure 2. Contribution of sulphur dioxide from different sources.

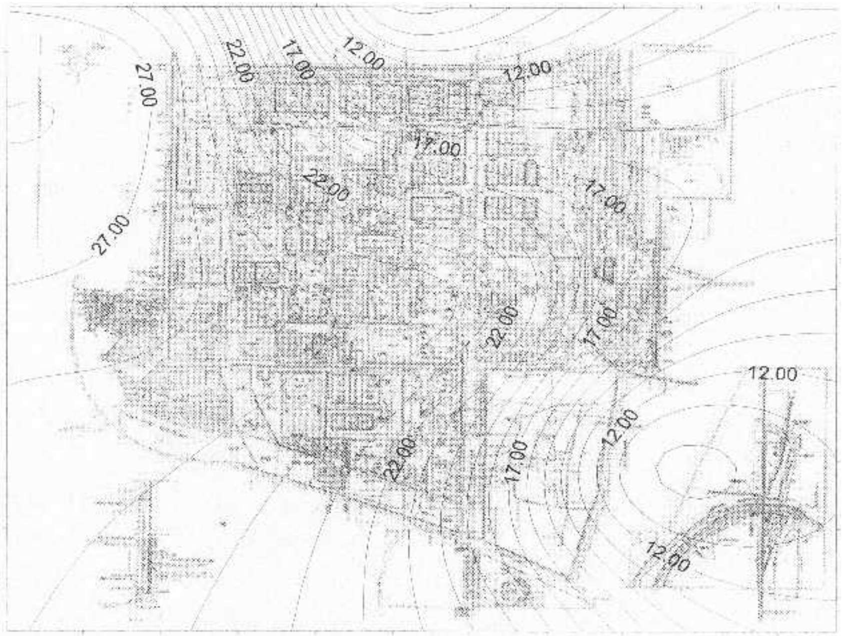


Monsoon

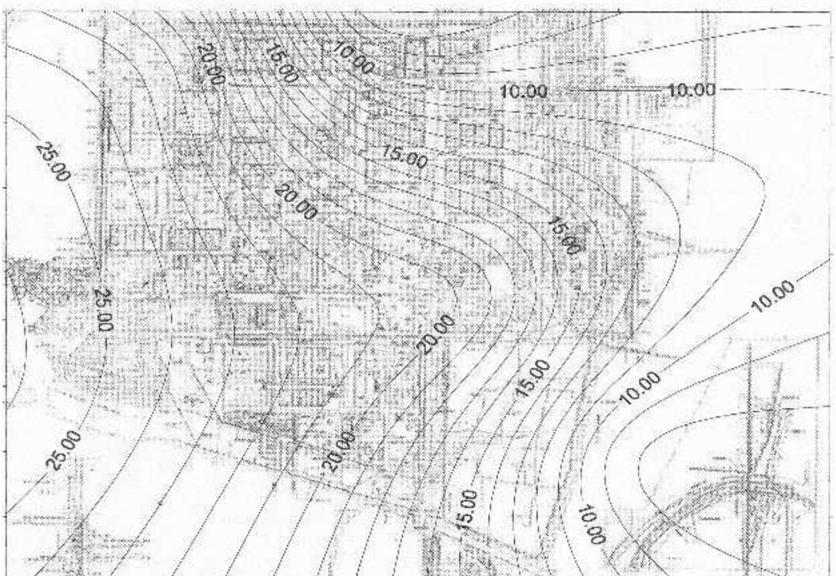


Post Monsoon

Figure 3a. Ground level concentration contours of sulphur dioxide inside in Indian petroleum refinery, 2003.



Winter



Summer

Figure 3b. Ground level concentration contours of sulphur dioxide inside Indian petroleum refinery, 2003.

Table 1. Contribution of SO_2 emissions in a refinery

Sr. No.	Percentage SO_2 of total Refinery Emissions from refineries	%
1.	Process heaters and boilers	69
2.	FCC units (CO boilers)	7
3.	Sulphur recovery unit	10
4.	Flares	9
5.	Other sources (e.g. gas turbines,	5
	Total	**100**

Source: CORINAIR W-Europe (2000)

Table 2. SO_2 emissions from refinery stacks

Sr. No	Unit	Stack	SO_2 Kg/hr) Avg. 2002	SO_2 (Kg/hr) Avg. 2003	SO_2 (Kg/hr) Avg. 2004
1.	AU-I	F1-F5	51.9	51.29	43.71
2.	AU-II	F1-F5	48.66	56.81	22.06
3.	AU-	F1-F3	61.46	70.01	39.67
4.	TPS	Boiler	200	26	38.26
5.	GRE	CDU E&W, VBU, VDU, BBU 1 & 2	156.76	149	75.6
6.	CRU	Old Heater, 21F1 -F2, 22F1	15.2	18.93	22.93
7.	FCC U	CH. HTR/CO-BLR	303.83	304.38	288
8.	GHP-CPP	GTI, GT2, GT3, FPU-II, H2U, HCU, SRU, DHDS Stack	282	237.74 80.61	284.5
9.	AU-5	--	62.15	52.20	48.8
	LAB	--	82.5	80.15	79.0
		Total	**1264.46**	**1127.12**	**936.5**

Source: Environmental Audit NEERI report (2002-2004)

Table 3. Compliance status of total SO_2 emission limits of various Indian refineries.

Unit	Actual (Kg/hr)	Standard (Kg/hr)
Guwahati	NA	50-100
Barauni	768	220
Gujarat	1360	1050
Haldia	1240	1050
Mathura	450	260
AOD	NA	7-10
Panipat	1000	875

Source: CPCB Report (2000)

Air pollutants from refineries mainly originate from process furnaces, boilers, gas turbines, Fluidized Catalytic Cracking (FCC) regenerators, flare systems, incinerators, Sulphur recovery units (SRU), coke/plants, storage and handling facilities, oil/water separation systems, fugitive emissions from flanges, etc. and vents (P.S. Rao et al, 2005).

Awareness of air pollution has led to numerous studies on ambient air pollutants (CPCB, 2000). Air pollutants adversely influence many atmospheric processes including cloud formation, visibility, solar radiation, and precipitation and play a major role in acidification of clouds, rain and fog (Hong et al., 2002; Fang et al., 2002). Sulphur dioxide gases contribute to the deterioration of air quality, vegetation, animal world and valuable monuments. Several epidemiological studies have demonstrated a direct association between atmospheric inhalable Sulphur dioxide and respiratory diseases, pulmonary damage and mortality among population (Mayer, 1999). Atmospheric chemical reactions transform primary pollutants into secondary air pollutants (Khoder, 2002). Atmospheric releases of acidic pollutants, which include sulphur and compounds in both gaseous and aerosol species, can cause adverse health effects and have the potential to cause other environmental damage (Gupta, 2003). Low source height and relatively high dry deposition velocity has resulted in substantial fraction (20-40%) deposition near its source (Gupta, 2003). In India, pollution has become a great topic of debate at all levels and especially the air pollution because of the enhanced anthropogenic activities (Goyal and Sidhartha, 2002).

Acknowledgements. The cooperation and support provided by the refinery personnel during the course of the study is gratefully acknowledged

REFERENCES

Carmichael GR, Ferm M, Thongboonchoo N, Woo JH, Chan LY, Murano K, Viet PH, Mossberg C, Bala R, Boonjawat J, (2003). Measurements of sulfur dioxide, ozone and ammonia concentrations in Asia, Africa, and South America using passive samplers. Atmos Environ 37: 1293-1308

CPCB (2000) Air Quality status and trends in India. NAAQMS/14/(1999-2000), Central Pollution Control Board, Delhi. pp 20-22

CONCAWE Report (1997), Regulatory guidelines of environmental concern to the oil industry in western Europe, pp 30-161

Fang GC, Chang CN, Wu YS, Fu PP, Yang CJ, Chen CD, Chang SC, (2002). Ambient suspended particulate matters and related chemical species study in Taiwan, Taichung during 1998-2001 Atmos Environ 36: 1921-1928

Goyal SK, Sidhartha P (2002) Effect of winds on SO_2 and SPM concentrations in Delhi. Atmos Environ 36: 2925-2930

Gupta AK, Patil RS, Gupta SK (2003). A long-term study of oxides of nitrogen, Environ Sci Health A 38: 2877-2894

GHK International Ltd (2000) Interim status report Delhi 21, Delhi Urban Environment and Infrastructure Improvement Project (DUEIIP), May (2000) for MoEF and GNCTD, GHK International Ltd. In association with operation Research Group, New Delhi

Hong YM, Lee BK, Park KJ, Kang MH, Jung YR, Lee DS, Kim MG, Atmospheric nitrogen and sulfur containing compounds for three sites of South Korea. Atmos Environ 36: 3485-3494

Khoder MI, (2002). Atmospheric conversion of sulfur dioxide to particulate sulfate and nitrogen dioxide to particulate nitrate and gaseous nitric acid in an urban area. Chemosphere 49: 675-684

Kim KH, Lee JH, Jang MS, (2002) Metals in airborne particulate matter from the first and second industrial complex area of Taejon city, Korea. Environ Pollut 118, 41-51

Mayer H, (1999). Air pollution in cities. Atmos Environ 33: 4029-4037.

Rao P, Pandit VI, NEERI Report (2002-2004) Environmental Audit Studies of Gujarat Refinery Vadodara, NEERI Nagpur, India, pp 78

Rao Padma BS, Ansari F, Ankam S, Kumar A, Pandit VI, and Nema P (2005) Estimating Fugitive Emission Budget of Volatile Organic Carbon (VOC) in a Petroleum Refinery. Bulletin of Environ Contaminat and Toxicology Vol. 75: 127-134

Richard A. Dobbins (2003) Environmental guidelines for oil and gas-petroleum refineries COFACE pp 187-298

Suess MJ, 1979. Review paper, an international approach to air quality monitoring. Atmos Environ 13: 211-221