Jr. of Industrial Pollution Control 31(2)(2015) pp 135-141

www.envirobiotechjournals.com

IMPACT ASSESSMENT OF AMBIENT AIR QUALITY BY OIL REFINERY: A CASE STUDY IN KUWAIT

AYED RADI KHANFAR *

Environmental Specialist, National Petroleum Services Co., Kuwait

(Received 10 May, 2015; accepted 12 June, 2015)

Key words : Ambient Air Quality, Pollutants, Oil refinery Pollution, Impact assessment, Kuwait.

ABSTRACT

This study reviewed and evaluated measurement approaches and methods are to judge the compliance with and/or progress made towards meeting Kuwait Environment Public Authority's Ambient Air Quality Standards. By carrying out a continuous ambient air quality monitoring study in the company premises, the effectiveness of existing emission control measures can be easily assessed and adequate measures can be taken to improve the environmental commitment of the Kuwait National Petroleum Company. This paper presents predictions of air pollution (PM_{10}, NO_X, NO_2, NH_3, SO_2, H_2S, O_3, CO, THC and NMHC along with meteorological data of Wind Speed, Wind Direction, Temperature, Relative Humidity, Solar Radiation and Rainfall) emitted from a modern refinery plant at Mina Abdullah Refinery area. Our findings indicate that the ambient air quality parameters were well within the limit of the permissible Kuwaiti Standards for ambient air quality. Therefore, the Mina Abdullah Refinery activities are not likely to have any significant adverse impact on the air environment in the vicinity of the Refinery.

INTRODUCTION

Since the establishment of new rules and regulations governing all environment-affecting industries emerged in the state of Kuwait back in 2001 (KEPA, 2001), there has been a growing concern about air quality in urban areas. To improve urban air quality, policy makers express widespread interest in controlling major airborne pollutants such as PM_{10}, NO_X, NO_2, NH_3, SO_2, H_2S, O_3, CO, THC and NMHC.

Oil refineries are complex process plants, which convert crude oil into variety of products. Refining operation is associated with the emission of various volatile organic compounds (VOCs) into the atmosphere, mainly originating from production processes, storage tanks, distribution terminals and wastewater treatment areas (Harrison, 1998). The transportation, distribution and marketing of refined products involve many distinct operations, each of which represents a potential source of evaporation, loss and occupational exposure problem for the workers.

The fugitive emissions from oil refineries add millions of pounds of harmful pollutants to the atmosphere each year, including over 80 million pounds

* **Corresponding author's email :** akhanfar@napesco.com

of volatile organic compounds (VOCs) and over 15 million pounds of toxic pollutants (Kalabokas et al., 2000). But there is a lack of data on exposure to these fugitive emissions. The atmospheric behavior of VOCs is governed to a large extent by their life time. In the process of long-range transport, BTEX are among other VOCs that react with other pollutants such as NOx and produce secondary pollutants with different reaction rates (Atkinson, 2000; Pandya, 2006). The wide range of VOCs released at petroleum refineries may have significant impacts on health of the workers depending on the levels of exposure. Assessment of human exposure to a complex array of such volatile compounds is a key factor in quantifying the relationship between environmental factors and human diseases. Deleterious effects on human health (Brunekreef and Holgate, 2002), injury to plants (Saitanis *et al.*, 2001; Agrawal, 2000) and reduction of crop yield (Nali *et al.*, 2002; Aihara, 1996) are known to be caused by increased levels of these pollutants. Besides, elevated levels of VOCs and ground level O3, measured across regional air sheds are known to affect human health (Seinfeld and Pandis, 1998; Al-Salem and Bouhamrah, 2006; Al-Salem and Al-Fadhlee, 2007). In many countries across Asia, North America and Europe, the air quality has been improved over the last two decades. Air pollution continues to receive a great deal of interest worldwide due to its negative impacts on human health and welfare. Several studies reported significant correlations between air pollution and certain diseases including shortness of breath, sore throat, chest pain, nausea, asthma, bronchitis and lung cancer (Dockery and Pope, 1994).

Extreme effects of air pollution include high blood pressure and Cardiovascular problems (Pope *et al.*, 2002; Sanjay, 2008). Correlations between air pollution and increased morbidity and mortality rates were reported (Pope *et al.*, 1995; Laden *et al.*, 2000). The World Health Organization states that Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide in 2012. (WHO, 2014). Epidemiological studies have shown a strong correlation between pneumonia related deaths and air pollution from motor vehicles in UK (Knox, 2008). In addition to its negative health impacts, air pollution is known to cause injuries to animals, forests and vegetation, and aquatic ecosystems. Its impacts on metals, structures, leather, rubber, and fabrics include cracks, soiling, deterioration, and erosion (Boubel *et al.*, 1994).

At present, the database for Ambient Air Quality in and around an oil refinery regarding exposures of the workers and the village inhabitants is rather sparse in the international literature. In general, a main problem in linking the environmental pollution to health effects is the current lack of data about the actual exposure to hazardous pollutants (Garriazo *et al.*, 2005).

Many attempts have been made by scientists to monitor and control such gaseous pollutants. Khan and Al-Salem (2007a) have studied airborne pollutants in an urban area in Kuwait in order to assess the ambient air quality and its suitability for urban living development. With data collected for three years it was discovered that hydrogen sulfide (H2S) was the pollutant with the major annual increase due to the abundant sources surrounding the area under investigation. Major violations against the KEPA were recorded in that study. A strict strategy was proposed to monitor urban area air quality in Kuwait, with constant monitoring tools and methods.

Khan and Al-Salem (2007b) have selected three pollutants (methane (n-CH_4), benzene (C_6H_6) and NOx) to be seasonally monitored and studied for a period of three years in an urban estate in Kuwait. The elevated temperatures and strong winds of the summer seasons over the study period affected methane levels drastically due to the increase of dust levels in the summer periods in Kuwait. Dust adsorption effect and break down of methane particles all resulted in low levels of methane gas in the summer seasons.

STUDY AREAS

The company premises and Mina Abdullah Refinery area (Al-Ahmadi governorate, state of Kuwait) are characterized by prolonged sunny hot periods from late spring to autumn. Fig.1 shows both study areas with respect to the coastline of Kuwait. The image also shows Fahaheel highway, which is considered one of the two busiest highways in Kuwait, used by work commuters and travelers to other Gulf Council Countries (GCC). The highway is also used by Al-Ahmadi governorate residents to commute to their work places or Kuwait city. Fahaheel highway passes through both study areas.

DATA AND METHODS

The Ambient Air Quality monitoring was carried out from 10th August to 31st August 2014 in KNPC MA Refinery. A fleet of mobile laboratories deployed with full real time Meteorological Monitoring capabilities

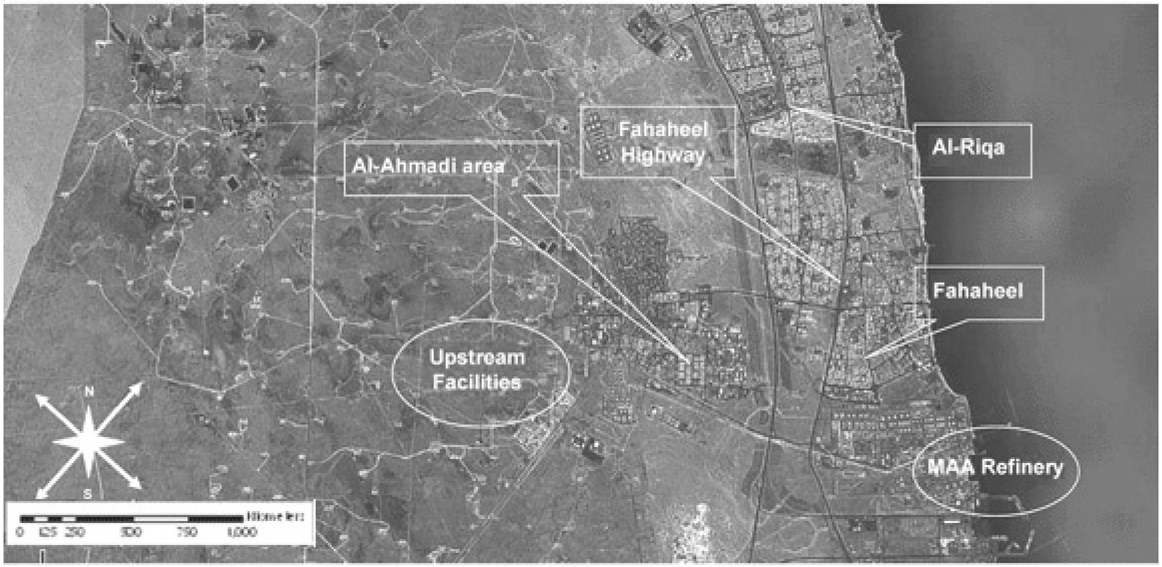

Fig. 1 Aerial View of Mina Abdullah Refinery area

and Continuous Ambient Air Monitoring System (CAMS). The CAMS were fitted with State of Art automated Analyzers of Technology viz., NOx-Chemiluminescent, CO-NDIR, SO_2-UV Fluorescent, SPM-Beta Attenuation Mass, THC/NMHC/VOC-GC FID/PID etc.,. Detailed and Summarized Ambient Air Quality and Meteorological data is presented in this paper.

Methodology

Mobile Air Monitoring Lab (Environment SA, France) has been deployed during the above-mentioned period. The monitoring has been carried out for criteria Parameters viz. PM_{10}, NO_X, NO_2, NH_3, SO_2, H_2S, O_3, CO, THC and NMHC along with meteorological data of Wind Speed, Wind Direction, Temperature, Relative Humidity, Solar Radiation and Rainfall.

Test Methods

Ambient Air Quality Monitoring has been carried out using the Continuous Ambient Air Monitoring System, equipped with the analyzers of make Environment SA, France. These analyzers are designated by USEPA as Automated Test Methods of 40 CFR 53. The Meteorological data was generated using meteorological data-logging sensors mounted on them. These sensors are conforms the ASTM Test requirements and were installed as per he guidelines of World Met Organisation (WMO).

Quality Assurance and Quality Control

All the analyzers were calibrated prior to installation of the Mobile Laboratory on site. Standard traceable calibration gases were used to calibrate the analyzers. Periodical ZERO and ZERO REFERENCE checks were conducted automatically for better performance of the analyzers.

RESULTS AND DISCUSSION

In order to assess the air quality in the two areas of the company premises and Mina Abdullah Refinery, measured concentration values of the pollutants were analyzed and compared with the limits and guidelines specified by the latest regulations (Law 210/2001) of the Kuwait Environment Public Authority (KEPA, 2001).

Daily Meteorological and Ambient Air Quality Data

Hourly concentrations of the pollutants monitored were compared with the limits specified by KEPA. For the protection of human health, the KEPA sets a limit of 80 ppb as an hourly rolling average for ground level O_3. Inhabitants of both areas in our study were exposed to O_3 levels above the limit.

Ambient air quality monitoring of Mina Abdullah Refinery area has been carried out during the month of August 2014. The average temperature recorded is 340 Celsius. The average wind speed is 2.4 m/s during the study period. Predominant wind direction was blowing from north westerly (as evident from wind rose) direction. During the monitoring period August 2014, it was observed that the ambient air

Table 1. Parameters and Specifications

S.No.	Parameter	Units	Principle/Method	Measuring range	Test Method
1.	Non Methane Hydrocarbon (NMHC)	PPM	Flame Ionization Detector	0-1000	40 CFR 53
2.	Total Hydrocarbon (THC)	PPM		0-1000	40 CFR 53
3.	Methane (CH_4)	PPM		0-1000	40 CFR 53
4.	Nitrogen Dioxide (NO_2)	PPB	Chemiluminescence	0-50000	40 CFR 53
5.	Nitrogen Oxides (NO_x)	PPB		0-50000	40 CFR 53
6.	Ammonia (NH_3)	PPB		0- 50000	40 CFR 53
7.	Sulphur Dioxide (SO_2)	PPB	UV Fluorescent	0-10000	40 CFR 53
8.	Hydrogen Sulphide (H_2S)	PPB		0-10000	40 CFR 53
9.	Carbon monoxide (CO)	PPM	IR Gas Filter Correlation	0-200	40 CFR 53
10.	Particulate Matter(PM_{10})	μg/m3	Beta Gauge	0-10000	40 CFR 53
11.	Ozone (O_3)	PPB	UV Photometric	0-10000	40 CFR 53

quality parameters were well within the limit (where ever the standard available, a comparison is made) of KEPA standards for industrial areas. Daily Summary for the Month of August 2014 shown in the following table (Table 2).

Variation in Ambient Air Quality

Wind Speed

Average wind speed of the study area during the study period ranges between 2.1-2.9 m/s.

Temperature

Observed average temperature during the study period was 33.8 ^{o}C. The recorded temperature was from 29 ^{o}C to 38.9^{o}C for the month of August 2014.

PM_{10}

The ambient air quality standard prescribed by KEPA for PM_{10} is 350μg/m3. It is observed that the recorded daily average PM10 concentrations were in the ranges of 119.1 to 297.5μg/m3.

NO_x

NOx is a prime parameter, causing global warming. Rise in NOx is of prime concern due to this reason. It was observed that the daily average value of NO_x was within the range of 17 to 21 ppb.

NO_2

Due to this prime focus, ambient air standards and guidelines are given exclusively for NO_2 concentrations by most countries and environmental organizations. It was observed that the daily average value of NO_2 was around 12.2 ppb at the project area and it is well within the stipulated limit of KEPA which is 50 ppb.

SO_2

It was observed that the daily average concentration of SO_2 at the project area is well and within the stipulated limit of KEPA which is 200 ppb.

NH_3

The average value of NH_3 during study period is in the range of 11-18.6 ppb. No KEPA standard is available for this Parameter.

H_2S

The Daily Average KEPA limit for H2S is 130ppb. The observed range of average 24 hour concentration for H_2S during the month of August 2014 was between 8.5-14 ppb. Refer below table 2 for daily variation.

O_3

The prescribed Hourly Average limit by KEPA for Ozone is 80ppb. The observed range of average 24 hour concentration for O_3 during the month of August 2014 was between 8-14.5 ppb. Refer below Table 2 for daily variation.

CO

The prescribed Daily Average limit by KEPA for Carbon monoxide is 8ppb. The observed range of average 24 hour concentration for CO during the month of August 2014 was between 0.89 to 1.09 ppb. Refer below table 2 for daily variation.

Total Hydrocarbons

There is no prescribed KEPA standard is available for

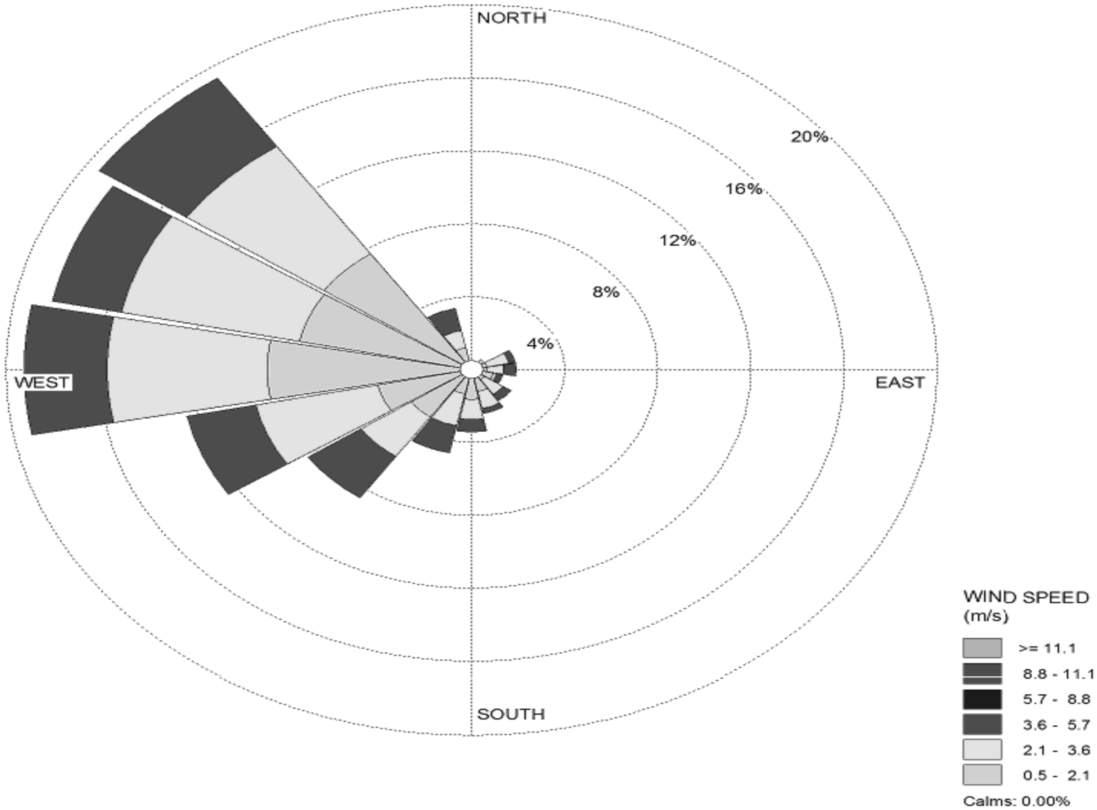

Fig. 2 Wind speed and wind direction during the Study

total hydrocarbon levels in ambient air. The observed range of average 24 hour concentration for THC during the month of August 2014 was between 2.7 to 3.6 ppm. Refer below Table 2 for daily variation.

Non Methane Hydrocarbons

KEPA has not yet set a limit for non methane hydrocarbons level in ambient air. The maximum concentration among daily average of NMHC in the study area was observed less than 1.13 ppm.

Wind Direction

The predominant wind direction during the study period was blowing from north westerly; strong wind was also observed which was blowing from north westerly direction. Average wind speed observed was 2.44 m/sec. Wind speed and wind direction were plotted in the format of wind rose diagram for the study area.

Rainfall

Rainfall was not observed during the monitoring period (month of August 2014).

CONCLUSION

The ambient air quality monitoring was carried out for KNPC, Mina Abdullah Refinery area for the month of August 2014. It is evident from the above data that, the average concentrations of the Criteria Parameters are well within the stipulated standards of Ambient Air Quality for Industrial areas prescribed by Kuwait EPA.

The data of this study would be useful for future comparisons. It is obvious that, for future air quality management strategies, the development of accurate, temporally and spatially resolved day-of-the-week emission inventories. Regarding the role of local agencies involved in making air quality conditions better in urban living locations, the Kuwait Environment Public Authority (KEPA) must enforce their rules and regulations of the industrial sectors around urban areas.

Emissions from upstream and downstream industries cause a number of problems in the general popu-

Table 2. Daily Summary for the Month of August 2014

Date	Wind Speed m/s	Wind Direction degrees	Temperature ºC	Relative Humidity %	Solar Radiation Watts/m2	Rainfall mm	PM_{10} µg/m3	NO_x ppb	NO_2 ppb	NH_3 ppb µg/m3	SO_2 ppb	H_2S ppb	O_3 ppb	CO ppm	THC ppm	NM-HC ppm	Chlorine µg/m3	Lead (Pb) µg/m3
KEPA 24-Hour Std.	-	-	-	-	-	-	350	-	50	-	200	130	-	8	-	-	-	-
01 Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
02-Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
03-Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
04-Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
05-Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06-Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
07-Aug.-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
08-Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09-Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-Aug.	2.3	204	38.9	50.2	257.4	0.00	150.2	18.12	11.42	11.26	12.28	13.62	14.27	0.93	3.21	1.05	0.06	0.007
11-Aug.	2.1	275	36.4	47.8	194.9	0.00	155.0	18.58	11.19	11.45	13.78	8.90	11.97	0.97	3.11	0.97	0.06	0.007
12-Aug.	2.5	226	36.9	49.4	190.7	0.00	164.7	17.47	10.93	11.74	14.95	9.02	12.61	0.89	3.22	1.09	0.05	0.008
13-Aug.	2.4	278	37.2	48.9	180.1	0.00	127.2	18.00	11.63	11.33	11.66	8.95	14.23	1.01	3.31	0.82	0.07	0.009
14-Aug.	2.2	261	35.8	51.7	195.7	0.00	177.5	18.59	11.49	14.84	13.19	8.79	12.08	0.91	3.24	0.78	0.05	0.01
15-Aug.	2.6	262	35.1	45.7	193.2	0.00	188.7	19.24	11.98	14.26	14.58	8.98	11.73	1.09	3.24	0.82	0.07	0.009
16-Aug.	2.4	243	32.8	46.7	197.0	0.00	148.4	18.59	12.07	10.99	15.06	8.98	12.65	1.01	3.32	0.84	0.05	0.006
17-Aug.	2.2	265	32.7	48.8	195.6	0.00	212.6	21.34	11.42	14.13	13.32	8.87	12.47	0.93	3.08	1.00	0.07	0.008
18-Aug.	2.1	255	32.6	45.9	197.4	0.00	297.5	18.13	11.81	11.51	13.56	9.01	12.45	0.93	3.24	0.95	0.06	0.008
19-Aug.	2.4	276	32.7	46.6	193.8	0.00	160.2	18.31	18.29	12.93	15.46	8.92	11.93	0.92	3.32	1.4	0.06	0.01
20-Aug.	2.1	280	32.9	49.0	196.7	0.00	168.9	18.45	18.21	13.66	14.24	8.80	13.39	1.03	3.52	0.87	0.06	0.009
21-Aug.	2.5	245	32.6	47.8	191.6	0.00	218.9	18.05	11.56	13.06	14.05	8.91	11.81	0.96	3.58	1.00	0.07	0.011
22-Aug.	2.9	287	32.5	49.5	191.1	0.00	185.5	19.38	11.64	11.03	14.51	8.86	12.62	0.98	3.21	1.00	0.05	0.006
23-Aug.	2.5	246	32.9	48.0	196.2	0.00	119.1	18.74	11.11	14.64	12.59	8.96	12.73	0.99	3.19	0.88	0.06	0.008
24-Aug.	2.1	227	32.4	50.8	196.5	0.00	226.5	17.40	11.63	14.63	13.37	8.93	12.42	1.05	3.47	0.85	0.06	0.008
25-Aug.	2.5	277	32.8	49.1	200.5	0.00	192.9	18.16	11.29	18.61	15.23	9.11	12.24	0.99	3.10	0.98	0.05	0.009
26-Aug.	2.4	279	32.6	51.9	198.1	0.00	191.1	18.70	11.69	12.64	13.66	8.83	12.07	1.08	3.28	0.85	0.06	0.009
27-Aug.	2.4	275	32.6	51.0	182.5	0.00	126.2	19.03	11.66	13.99	14.67	9.10	12.13	1.02	3.51	0.67	0.06	0.008
28-Aug.	2.6	265	32.5	48.4	197.7	0.00	206.7	18.14	11.47	11.74	14.25	8.93	12.58	0.95	3.42	0.98	0.06	0.008
29-Aug.	2.4	244	29.0	48.0	71.1	0.00	231.8	18.72	12.34	15.10	13.76	8.99	7.90	1.00	2.70	0.98	0.06	0.009
30-Aug.	2.5	240	35.2	82.9	187.2	0.00	278.9	19.05	11.30	13.49	17.18	13.85	14.40	1.08	3.29	1.07	0.05	0.007
31-Aug.	2.7	265	36.1	83.6	194.0	0.00	199.1	19.03	11.39	14.44	20.97	8.79	11.81	1.06	3.62	1.25	0.07	0.009
Maximum	2.9	287.0	38.9	82.9	257.4	0.00	383.4	21.3	12.34	18.61	17.18	15.28	14.40	1.09	3.58	1.40	-	-
Average	2.4	257.7	33.8	50.4	190.7	0.00	215.5	18.6	11.35	13.19	14.06	14.10	12.36	0.99	3.26	0.95	0.06	0.008
Minimum	2.1	204.2	29.0	45.7	71.1	0.00	119.1	17.4	8.75	10.99	11.66	13.03	7.90	0.89	2.70	0.67	-	-

lation regarding human health and welfare. The Kuwait Public Authority of Industry (KPAI), must monitor the activities of small industries and their role in contributing to the general pollution load around urban areas in the state.

REFERENCES

Agrawal, M. 2000. Researches on air pollution effects on vegetation in India. A review. *The Botanica.* 50 : 75-83.

Aihara, K. 1996. Evaluation of air pollution using indictor plants. *Kankya Gijustu*. 25 : 674-680.

Al-Salem, S. and Al-Fadhlee, A. 2007. Ambient levels of primary and secondary pollutants in a residential area: population risk and hazard index calculation over a three years study period. *American Journal of Environmental Sciences.* 3 : 244.

Al-Salem, S.M. and Bouhamrah, W.S. 2006. Ambient concentrations of benzene and other VOC's At typical industrial sites in Kuwait and their cancer risk assessment. *Research Journal of Chemistry and Environment.* 10 : 42.

Atkinson, R. 2000. Atmospheric chemistry of VOCs and NOx. *Atmos. Environ.* 34 (12-14) : 2063-2101.

Boubel, R.W., Fox, D.L., Turner, D.B. and Stern, A.C. 1994. *Effects on Materials and Structures, Fundamentals of Air Pollution*, 3rd ed. Academic Press, New York.

Brunekreef B. and Holtage S.T. 2002. Air pollution and health. *The Lancet*. 360 : 1233.

Burchett, M., Rachid, M. and Jane, T. 2002. *Air Pollution and Plant Biotechnology.* 16 : 61-91.

Dockery, D.W. and Pope, C.A. 1994. Acute respiratory effects of particulate air pollution. *Auun. Rev. Publ. Health.* 15 : 107–132.

Finlayson-Pitts, B.J. and Pitts, J.N. 1997. Tropospheric air pollution: Ozone, airborne toxics, polycyclic aromatic hydrocarbons and particles. *Science.* 276 : 1045–1051.

Garriazo, C., Pelliccioni, A., Filipo D., Sallusti, F, Cecinato, A. 2005. Monitoring & analysis of volatile organic compounds around an oil refinery. *Water, Air & Soil Poll.* 16 (7-1-4) : 17-38.

Harrison, R.M. 1998. Setting health-based air quality standards, In: Air Pollution and health, Issues in *Environmental Sciences and Technology*, 10 (Cambridge: The Royal Society of Chemistry), pp. 57-73.

Kalabokas, P.D., Hatzaianestris, J., Bartzis, J.G., Papagiannakopoulis, P. 2000. Atmospheric concentrations of saturated and aromatic hydrocarbons around a Greek refinery. *Atmos. Environ.* 3 (14) : 2545-2555.

KEPA Rules and Regulations, Kuwait Al-Youm, 2001. Appendix 533, KWT Gov. Press, law 210/2001.

Khan, A. and Al-Salem, S. 2007a. Primary and secondary pollutants monitoring around an urban area in the state of Kuwait: A three years study. *Research Journal of Chemistry and Environment.* 11 : 77.

Khan, A. and Al-Salem, S. 2007b. Seasonal variation effect on airborne pollutants in an urban area of the state of Kuwait. *Journal of Environmental Research and Development*. 1 : 215.

Knox, G. 2008. Atmospheric pollutants and mortalities in english local authority areas. *J. Epidemiol. Community Health.* 62 : 42–447.

Laden, F., Neas, L.M., Dockery, D.W. and Schwartz, J. 2000. Association of fine particulate matter from different sources with daily mortality in six U.S. cities. *Environ. Health Perspect*. 108 : 941–947.

Nali, C., Pucciariello, C., Lorenzini, G. 2002. Ozone distribution in central Italy and its effects on crops productivity, Agriculture Ecosystem and the Environment, 90 : 277.

Pandya, G.H. 2006. Concentration of volatile organic compounds (VOCs) at an oil refinery. *International J. Environ. Studies*. 6 (3) : 337-351.

Pope, C.A., Thun, M.J., Namboodira, M., Dockery, D.W., Evans, J.S., Speizer, F.E. and Health Jr., C.W. 1995. Particulate air pollution as a predictor of mortality in a prospective study of US adults. *Am. J. Respir. Crit. Care Med*. 151 : 669–674.

Pope, C.A, Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K. and Thurston, G.D. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *J. Am. Med. Assoc*. 287: 1132–1141.

Saitanis, C.J., Riga-Karandinos, A.N., Karandinos, M.G. 2001. Effects of ozone on chlorophyll and quantum yield of tobacco (*Nicotiana tabacum* L.) varieties. *Chemosphere*. 42 : 945.

Sanjay, R. 2008. Exposure to Bad Air Raises Blood Pressure, Study Shows, Science Daily, Ohio State University, http://www.sciencedaily.com/releases.

Seinfeld, J. and Pandis, S. 1998. *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*, Wiley Intersciences, 1st edition, New York.

World Health Organization 2014. Ambient (outdoor) air quality and health, Fact sheet N°313, Updated March 2014. http://www.who.int/mediacentre/factsheets/fs313/en/.