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Oil Refineries Emissions: Source and Impact: A Study using AERMOD

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Abstract**—**The main objectives of this paper are to measure pollutants concentrations in the oil refinery area in Kuwait over three periods during one year, obtain recent emission inventory for the three refineries of Kuwait, use AERMOD and the emission inventory to predict pollutants concentrations and distribution, compare model predictions against measured data, and perform numerical experiments to determine conditions at which emission rates and the resulting pollutant dispersion is below maximum allowable limits.

Keywords**—**Emissions, ISCST3 model, Modeling, Pollutants, Refinery

I. Introduction

A number of studies have been conducted on air pollution in Kuwait and around the world. Air quality data were assessed by Ettouney et al. [1] from two monitoring stations in Kuwait named as Al-Jahra and Umm-Alhyman. The data were covered a period of four years and was analyzed for annual hourly and 1-h maxima. Concentrations of CO, CO_2, MHC, NMHC, NO_X, SO_2, O_3, and PM_{10} were considered. Moreover, meteorological parameters were included. It was concluded that all data are within the air quality standards except for PM_{10} due to short rain season. Also, it was observed that the NO_X concentrations increase because of increasing in industrial activities and vehicles.

Ettouney et al. [2] estimated the emission inventory of SO_2, CO and NO_X in Kuwait. The emission sources were power plants, motor vehicles, oil fields and oil refineries. In addition, pollutants data base for 2003 in Al-Jahra was simulated using ISCST dispersion model. Furthermore, ozone concentration was forecasted by using two feed forward artificial neural network (ANN). The emission inventory showed that the major sources of SO_2, CO and NO_X are power plants, motor vehicles and oilfields. Also, the predictions of the ISCST model and the data base were nearly the same for the hourly average but a difference was observed for the hourly maxima.

Al-Alawi et al. [3] developed models to predict concentrations of ozone in Kuwait at lower atmosphere. The data was collected in summer. Mobile air pollution laboratory was located in residential area with high traffic influence.

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Seven pollutant concentrations were measured CH_4, NMHC, CO, CO_2, NO, NO_2 and O_3. Wind speed, wind direction, temperature, relative humidity and solar radiation were monitored. Three models were used named as Principle Component regression (PRC), Artificial Neural Network (ANN), and combing of PRC and ANN. The results showed that combining method improves the forecast accuracy for ozone concentration levels in 24 hours period followed by ANN and PCR model respectively.

Gilham et al. [4] analyzed particulate matter by using x-ray photoelectron spectroscopy (XPS) to determine the ratio of elemental carbon to total carbon. All types of particulate matter were considered in this study. Furthermore, results of XPS method were compared with results from standard method. Samples were collected with quartz filter during a period of 24 hr on 6 Oct, 2006. It was observed that XPS is better to use in determine particles composition while the standard method will give a good results in studying the chemistry of the particles.

Monteiro et al. [5] used the CHIMERE Chemistry-transport model to make air quality assessment for Portugal. Data were applied for one year (2001). The model results were compared with air quality data from local monitoring stations. It was observed that NO_2 concentrations were above the air quality standards in two urban areas due to vehicles emissions. Also, there was exceeding in SO_2 concentrations in industrial areas.

II. Measurements And Locations

Air pollution measurements were taken for sixteen days over three periods in different areas as shown in Fig.1. The first period was in Fahaheel residential area from 21/12/2010 to 5/01/2011. The second period was in Umm Alhyman residential area from 10/04/2011 to 25/04/2011. The third period was in Ahmadi residential area from 25/06/2011 to 10/07/2011. Mobile laboratory was rented from local company and used to collect data. Pollutants and meteorological parameters were measured at five minutes intervals for 24 hours a day. The pollutants were included CO, CO_2, SO_2, NO, NO_2, O_3, PM_{10}, H_2S, NH_3, CH_4, NMHC and THC. The recorded meteorological conditions are relative humidity, wind speed, wind direction, ambient temperature and solar intensity. Details of the measuring instruments can be found in [1].

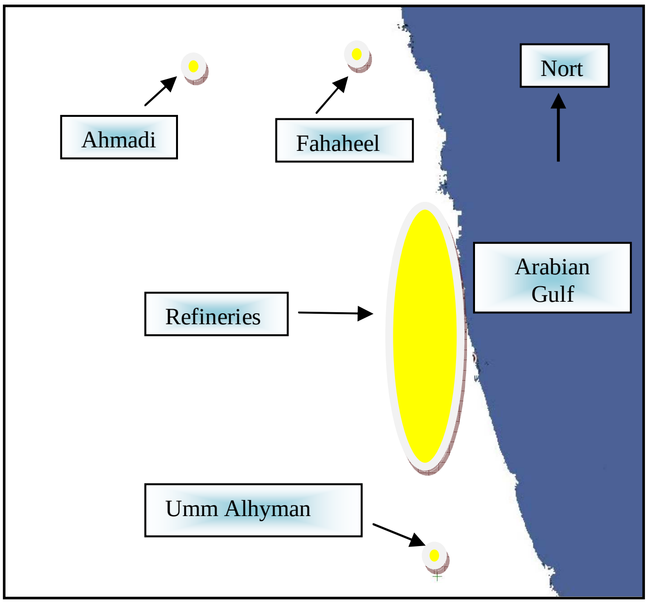


Fig. 1 Location of the oil refineries and residential areas

III. EMISSION INVENTORY

Emission inventory of oil refineries in Kuwait was collected for four flares in Ahmadi refinery, two flares in Shuaiba refinery, and six flares in Abdullah refinery during 2007.

Data were measured continuously at an interval of 10 minutes. The measured data were averaged on monthly basis. Data included SO_2, VOCs, NO, CO and CO_2.

IV. ISCST3 MODEL AND PARAMETERS

Industrial Source Complex Short Term Model (ISCST3) provides options to model emissions from five basic sources, which include point, volume, area, line and open pit sources.

In this paper the (ISCST3) model was used to predict the measured data of SO_2, NO, CO and VOCs. The calculations were based on the hourly averages of the measured data over a 24 hours period per day. The ISCST3 model requires information on source, meteorological data, and receptor [6].

V. DATA ANALYSIS

Measured data were analyzed over three periods. Fig.2 represents wind rose graphs for a period of sixteen days from 21/12/2010 to 5/01/2011, 10/04/2011 to 25/04/2011 and 25/06/2011 to 10/07/2011 respectively. As shown wind is blowing from North West direction during the first period, from nearly all directions during the second period and from West, North West and South West directions during the third period of measuring data.

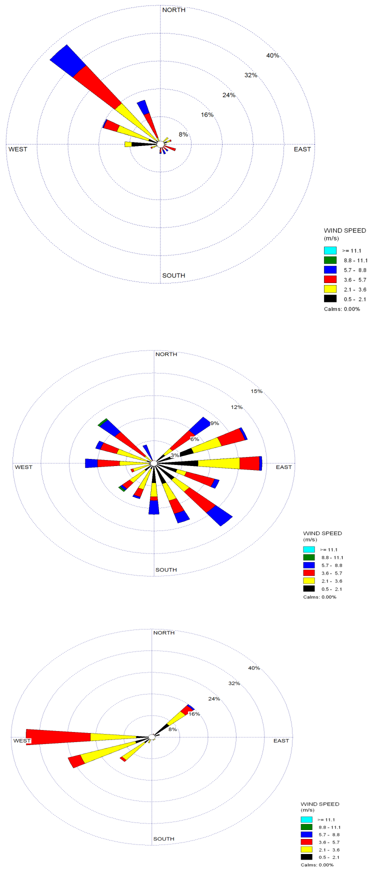
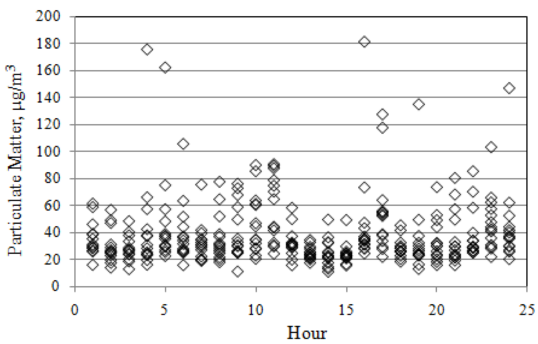


Fig.2: Wind rose graphs

Variations in the particulate matter are shown in Fig.3 during the measured periods respectively. The measured data during the first period ranged between 20 to 60 μg/m^3. Examining wind speed data does not show any stormy or adverse conditions. Therefore, these concentrations were caused by localized field or site construction. On the other hand, the measured data during the second and third periods show high concentrations of particulate matter ranged between 100 to 600 μg/m^3. This can be related to wind speed with wind direction in addition to localized field or site construction



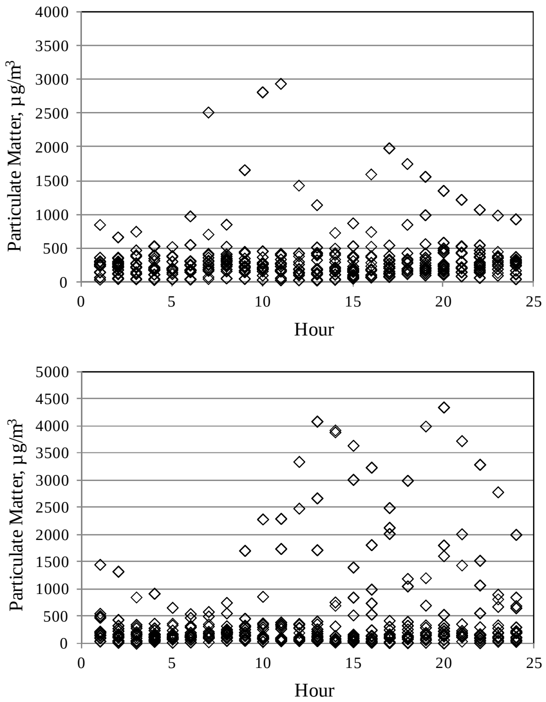
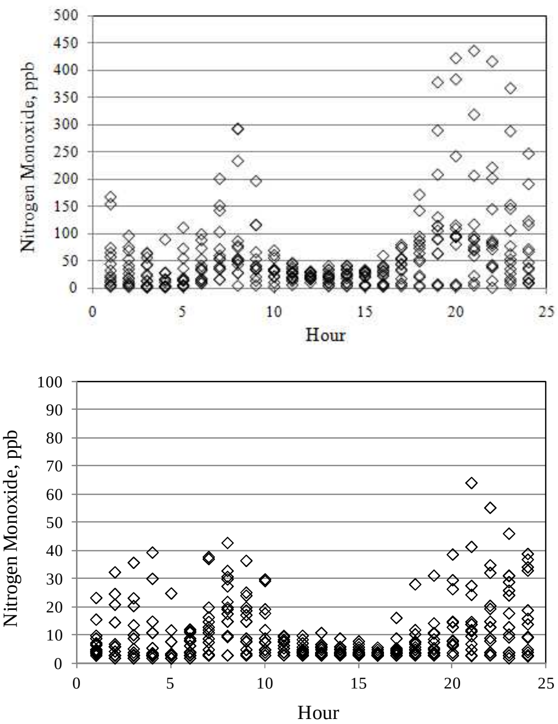


Fig. 3 Variation in measured particulate matter

The measured data of nitrogen monoxide (NO) are shown in Fig.4. The daily pattern for this pollutant is in the same range during day hours except at early morning and evening. The reason for this high values is attributed to increase in traffic volume or heavy use of construction vehicles. This result is consistent with carbon monoxide data



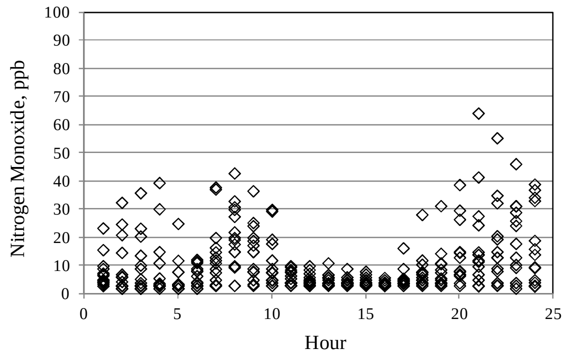


Fig. 4 Variation in measured nitrogen monoxide

VI. Measured and Predicted Data

The contour maps were generated by the ISCST3 model. Examining these figures show that the pollutants distribution patterns are uniformly distributed and there is strong dependence on the wind direction as illustrated in the wind rose graphs. Fig.5 shows contour map of SO_2 concentration from 10/04/2011 to 25/04/2011 using emission rates of all refineries together. As shown, the three residential areas are affected by Ahmadi, Shuaiba and Abdullah refineries for the case of simulating the three refineries emissions together. This is due to wind direction as discussed which was nearly blowing from all directions during the second period of measured data. Table I shows predicted concentrations of SO_2, NO, CO and VOCs generated from AERMOD model during the three measuring periods for the case of simulating emissions from Ahmadi, Shuaiba and Abdullah refinery one by one as well as all the three refineries were simulating together.

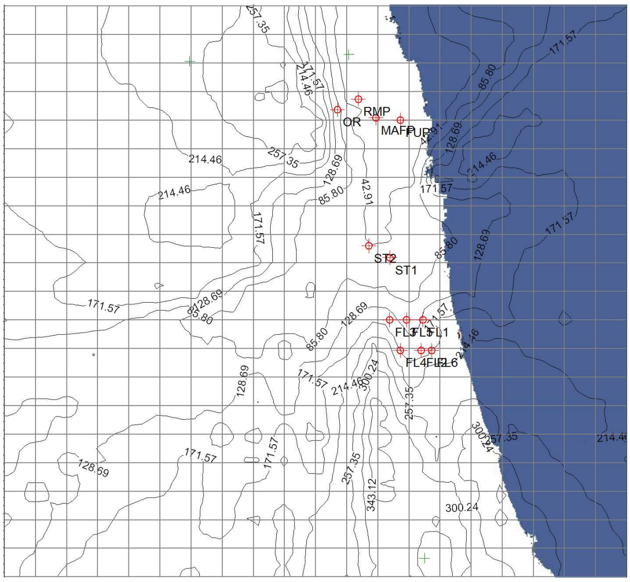


Fig. 5 Contour map of SO_2 concentration

TABLE I
PREDICTED CONCENTRATIONS OF POLLUTANTS IN THREE RESIDENTIAL AREAS IN KUWAIT DURING THREE PERIODS, PPM

Receptor	Pollutants	Ahmadi Refinery	Shuaiba Refinery	Abdullah Refinery	All Refineries
Fahaheel residential area (21/12/2010-5/01/2011)	SO_2	2.50×10^{-4}	1.60×10^{-3}	3.28×10^{-6}	2.00×10^{-3}
	NO	1.64×10^{-6}	1.40×10^{-4}	2.70×10^{-5}	2.00×10^{-4}
	CO	6.16×10^{-5}	6.30x10-2	2.00×10^{-3}	6.50×10^{-2}
	VOCs	1.54×10^{-5}	2.10×10^{-2}	2.60×10^{-3}	2.34×10^{-2}
Ahmadi residential area (25/06/2011-10/07/2011)	SO_2	5.80×10^{-4}	0.00	0.00	6.80×10^{-4}
	NO	1.57×10^{-2}	0.00	0.00	2.30×10^{-2}
	CO	2.50×10^{-2}	0.00	0.00	2.50×10^{-2}
	VOCs	0.00	0.00	0.00	3.11×10^{-1}
Umm Alhyman residential area (10/04/2011-25/04/2011)	SO_2	2.40×10^{-3}	1.52×10^{-2}	5.50×10^{-4}	6.50×10^{-3}
	NO	2.12×10^{-3}	4.37×10^{-4}	8.58×10^{-4}	2.20×10^{-3}
	CO	9.50×10^{-2}	1.29×10^{-1}	5.29×10^{-1}	8.20×10^{-1}
	VOCs	3.10×10^{-2}	0.75	8.90×10^{-1}	1.57×10^{-1}

VII. COMPARISON AGAINST EPA STANDARDS

Table II shows measured concentrations in Fahaheel, Umm Alhyman and Ahmadi residential areas during measured periods. This shows that these areas are affected by other sources of emissions in addition to the oil refineries. Comparing measured concentrations in Fahaheel area during the first period of measuring with international standards given by US-EPA illustrates that only CO concentration is below EPA limits due to limited number of motors and high ambient temperature in Kuwait while SO_2 and NO concentrations are higher than standards. On the other hand, it is shown that SO_2, NO and CO measured concentrations during second and third periods of collecting data in Umm Alhyman and Ahmadi areas are lower than international standards. However, measured data show that VOCs concentration is out of the scale in Fahaheel, Umm Alhyman and Ahmadi residential areas which indicates that there are other sources of VOC emissions which should be included in the next study.

TABLE II
MEASURED CONCENTRATIONS OF POLLUTANTS IN THREE RESIDENTIAL AREAS

Receptor	Pollutants	Measured ppm	EPA ppm
Fahaheel residential area (21/12/2010-5/01/2011)	SO_2	0.21	0.14
	NO	0.44	0.15
	CO	6.80	35
	VOCs	5.80	0.24
Ahmadi residential area (25/06/2011-10/07/2011)	SO_2	0.045	0.14
	NO	0.05	0.15
	CO	2.04	35
	VOCs	7.14	0.24
Umm Alhyman residential area (10-25/04/2011)	SO_2	0.04	0.14
	NO	0.064	0.15
	CO	1.60	35
	VOCs	2.91	0.24

VIII. CONCLUSION

This study continues previous efforts on assessment and analysis of air pollution in Kuwait. Emission inventory was obtained during 2007 for all flares in the three refineries of Kuwait, Ahmadi, Shuaiba, and Abdullah. Air pollution measurements were made in three residential areas in Kuwait, Fahaheel, Umm Alhyman and Ahmadi. Measured data included pollutants concentrations and meteorological parameters. Pollutant dispersion was simulated using the ISCST3 of AERMOD. Comparison was made between US-EPA standards and measured concentrations of CO, NO, SO_2, and VOCs. For the Fhaheel area, the comparison showed that all pollutants exceeded the international limits, except for CO. This is because of low traffic volume and high ambient temperature in Kuwait. On the other hand, it is shown that SO_2, NO and CO measured concentrations during second and third periods of collecting data in Umm Alhyman and Ahmadi areas are lower than international standards. However, measured data show that VOCs concentration is out of the scale in Fahaheel, Umm Alhyman and Ahmadi residential areas. This is caused by emissions from several small scale industrial sites, which are poorly regulated and utilize little or no method of treatment for their emissions.

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REFERENCES

[1] R. S. Ettouney, J. G. Zaki, M. A. El-Rifai, and H. M. Ettouney, “An assessment of the air pollution data from two monitoring stations in Kuwait,” *Toxicological & Environmental Chemistry.*, vol. 92, Aug. 2010, pp. 655–668.

[2] R. S. Ettouney, S. Abdul-wahab, and A. S. Elkilani, “Emissions inventory, iscst, and neural network: modeling of air pollution in Kuwait,” *International Journal of Environmental Studies.*, vol. 66, Aug. 2009, pp. 181–194.

[3] S. M. Al-Alawi, S. A. Abdul-Wahab, C. S. Bakheit, "Combining principal component regression and artificial neural networks for more accurate predictions of ground-level ozone," *Environmental Modeling & Software.*, vol. 23, Aug. 2008, pp. 396–403.
[4] J. Gilham, et al., "On the applicability of xps for quantitative total organic and elemental carbon analysis of airborne particulate matter," *Atmospheric Environment.*, vol. 42, Aug. 2008, pp. 3888–3891.
[5] A. Monteiro, et al, "Air Quality Assessment for Portugal," *Science of the Total Environment.*, vol. 373, Aug. 2006, pp. 22–31.
[6] C. A. Borrego, and C.A. Brebbia, *Air Pollution XV.* Belmont, WITPRESS, UK, 2007, pp. 15–113.