Outdoor air quality data analysis of Al-Mansoriah residential area (Kuwait): air quality indices results

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Abstract

Environmental awareness is of growing concern in the state of Kuwait, especially after the recognition of Kuwait Environment Public Authority (KUEPA) as a separate entity with legal power back in 2001. In this communication, the outdoor air quality data collected over the period of five years (2000-2004) were analyzed for Al-Mansoriah residential area in Al-Asemah "Capital" Governorate (Kuwait). Data points were in two different time spans; five minute original data points and hourly mean averages. Air Quality Indices (AQI) based on the following pollutants: SO_2, CO, O_3 and NO_2 were calculated. Based on CO and SO_2, the AQI was determined "good" ranging between an annual mean of 0.06-0.15. Based on ground level ozone and nitrogen dioxide AQI resulted in the "moderate" category for the period of study.
Keywords: KUEPA, SO_2, CO, O_3, NO_2, AQI.

1 Introduction

Many Gulf Council Countries (GCC) suffer from air pollution health effects especially when it comes to respiratory system chronic diseases and cancers associated with such airborne pollutants [1]. Kuwait is no exception, being a petroleum industry oriented country. Many pollution sources are linked with the

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downstream/upstream industry in the state but yet still little action is taken by the concerned parties. One way of monitoring such pollution levels is what has become a standard approach of Air Quality Indices (AQI) calculation. Each Air Quality Index is a standardized indicator of the air quality in a given location. It measures mainly ground-level ozone and particulates (except the pollen count), but may also include sulphur dioxide, and nitrogen dioxide. Various agencies around the world measure such indices, though definitions may vary between places. In the US, EPA calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health. Ground-level ozone and airborne particles are the two pollutants that pose the greatest threat to human health in US.

Many scientists have devoted their work towards air pollution monitoring and standardizing rules and regulations governing cities around the world. This could be determined by literature available regarding the matter. An air quality monitoring methodology was presented by Landulfo et al. [2], by employing an elastic backscattering Lidar, sunphotometer data, air quality indexing and meteorological data in the city of São Paulo, Brazil, a typical Urban Area. This procedure was made aiming to gather information from different optical atmospheric techniques and add this information to the air quality data provided regularly by the environmental agencies in the city. The parameters obtained by the Lidar system, such as planetary boundary layer height, aerosol optical thickness and aerosol extinction and backscattering aerosol coefficients are correlated with air quality indexes/reports provided by state environmental control agencies in order to extend the database information concerning pollution assessment and abate policies.

In India [3], the measured 24 h average criteria pollutants such as sulfur dioxide, oxides of nitrogen, respirable suspended particulate matter and suspended particulate matter for the period from 1997 to 2005 at three air quality monitoring stations were used for the development of AQIs. The results indicated that the air pollution at all the three air quality monitoring stations can be characterized as ‘good’ and ‘moderate’ for SO_2 and NO_x concentrations for all days from 1997 to 2004. The Pollution Standards Index (PSI) was initially established in response to a dramatic increase in the number of people suffering respiratory irritation due to the deteriorating air quality. The PSI was subsequently revised and implemented by the USEPA in 1999, and became known as the (AQI) that includes data relating to particle suspension, $PM_{2.5}$, and a selective options of either 8-hour or 1-hour ozone concentration during increased O_3 periods. This was discussed in the publication of Cheng et al. [4]. An aggregate AQI based on the combined effects of five criteria pollutants (CO, SO_2, NO_2, O_3 and PM_{10}) taking into account the European standards was developed previously [5]. An evaluation was carried out for each monitoring station and for the whole area of Athens, Greece. A comparison was made with a modified version of Environmental Protection Agency/USA (USEPA) maximum value AQI model adjusted for European conditions. Hourly data of air pollutants from 4 monitoring stations, available during 1983–1999, were analyzed for the development of the proposed index.

The objective of this communication is to investigate the ambient air quality of Al-Mansoriah residential area using standard AQI calculations with respect to four airborne pollutants. These pollutants are: sulfur dioxide (SO_2), carbon monoxide (CO), ground level ozone (O_3) and nitrogen dioxide (NO_2). No previous attempts (to the authors knowledge) have been initiated or published regarding this matter in Kuwait.

2 Investigated area description

Al-Mansoriah residential area hosts Kuwaiti residents of mid/high class and could be considered a posh area. Fig.1 shows the area from satellite imagery, indicating main locations including Al-Arabi sports club, Cairo St. and receptor point (i.e. area's polyclinic).

The receptor point of the area was the polyclinic of Al-Mansoriah situated near the area's Co-Op, which associated with restaurant and human related pollution emissions. These pollutants include n-CH_4 (resulting from restaurants), NOx and CO (emissions of automobile and other burning sources) and VOCs from the gas and gasoline dispensing station. On the other hand, Al-Arabi sports

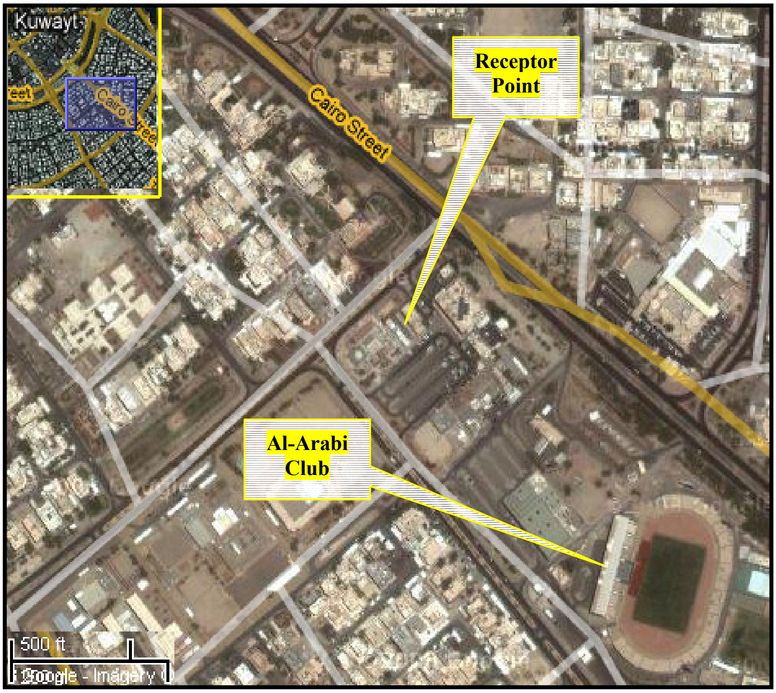

Figure 1: Al-Mansoriah residential area adapted from Google earth imagery. Main area locations are indicated.

club is considered one of the largest sports and family functions facility in Kuwait, in terms of children entertainment lounges and other function spaces. All of these sections in the club are always adjacent to a food court or lounges which also emit gases through vents and other outlets.

Cairo St. is situated to the north side of the receptor point. It is one of the busiest streets of Kuwait especially when it comes to school time linking three main residential areas together in the governorate, i.e. Al-Mansoriah, Al-Qadisiah and Al-Daeiah. Automobile vehicles operated with gasoline are the main source of pollution associated with it. Rush hours are usually between 7:30 am to 9:00 am (weekdays); and 8:00 pm to 9:30 pm (weekends).

3 Data collection and methods

The data used in this study were secured form the Kuwait Environment Public Authority (KUEPA), more precisely Al-Mansoriah monitoring station covering the period from Jan 1^{st} 2000 – Dec 31^{st} 2004. The station is operated with a number of air sampling devices and analyzers with a tolerance of 1%. Air probe was approximately 15 m above sea level. All data were stored and manipulated with *EnviDas* data acquisition software which did store up to three months worth of data points. Pollutants collected by the station included the following: CH_4 (ppm), n-MHC (ppm), CO (ppm), CO_2 (ppm), NO (ppb), NO_2 (ppb), NOx (ppb), VOCs (ppb), mp-Xylenes (ppb), NH_3 (ppb), H_2S (ppb) and O_3 (ppb). Metrological conditions were collected via a fixed weathering station recording the following: wind speed (ms^{-1}) and direction (^{0}), relative humidity (%) and ambient temperature (^{0}C).

Data points were treated and filtered before performing any analysis. Filtration procedure was performed as indicated by [6-11]. NOx, NO_2 and NO points exceeding 200 ppb were deleted from the spreadsheets, in order to eliminate any automobile point source effect on data collection. CH_4 levels below 1.3 ppm were also deleted to avoid ion presence and instrumentation chocking points. Calibration and span check points were also deleted.

The AQIs were calculated using standards USEPA methodology. The purpose of the AQI is to help you understand what local air quality means to health. To make it easier to understand, the AQI is divided into six categories (Table 1).

Table 1: Air Quality Index (AQI) category in accordance with the USEPA.

AQI Value Range	AQI Conditions	Audience Color
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

The AQI is calculated every hour for each air quality parameter using the formulas indicated below (Table 2). The highest number calculated for a specific hour is used as the AQI for that hour. Four pollutants were chosen to be studied which were: SO_2, CO, NO_2 and O_3.

Table 2: Air Quality Index (AQI) Calculation formulas in accordance to the USEPA.

Parameter Name	Concentration	Units	Formula
Carbon Monoxide	If <= 13	ppm	AQI = 1.92 x Concentration
	If > 13	ppm	AQI = (1.47 x Concentration) + 5.88
O_3	If <= 0.05	ppm	AQI = 500 x Concentration
	If > .05 <= 0.08	ppm	AQI = (833 x Concentration) - 16.67
	If > 0.08	ppm	AQI = (714 x Concentration) - 7.14
SO_2	All	ppm	AQI = 147.06 x Concentration
Nitrogen Dioxide	If <= 0.21	ppm	AQI = 238.09 x Concentration
	If > 0.21	ppm	AQI = (156.24 x Concentration) + 17.19
$PM_{2.5}$	If <= 30	ugm^{-3}	AQI = 0.8333 x Concentration
	If > 30	ug/m^{-3}	AQI = (0.5 x Concentration) + 10

4 Results and discussion

Based on the standard USEPA methodology the AQIs of the pollutants SO_2, CO, NO_2 and O_3, were calculated. Table 3 shows the results obtained by the running calculations of AQI for the five years period based on yearly averages.

In terms of SO_2 and CO, good air quality resulted from the calculations based on the standards calculations and annual mean. Both pollutants recorded a minimum in the last two years of study (2003 and 2004). Maximum SO_2 AQI calculated was in the year 2002 recording an AQI of 71.77. In terms of NO_2, moderate air quality was characterized for Al-Mansoriah with a maximum value for the first year of study of 160.46. Moderate air quality is also characterized for O_3 in the period of study.

Fig.2 shows the scatter left by the points of average AQI vs. years of study. A clear increase in the CO AQI, when comparing the 2000 (AQI=6.8) and 2004 (AQI=14.2) values. AQI of CO has increased by more than 100% in the period of study. In terms of ground level ozone (O_3), there was a general decrease in the annual average trend. Unlike the case of SO_2, where there was a general decrease but a shooting off point does exist in the middle range. NO_2 had also a general decrease in the trend. AQI in 2000 was equal to 37.46 while in 2004 it was 31.8.

Table 3: Air Quality Index (AQI) calculated for Al-Mansoriah residential area in the time of the study (2000-2004).

Year	Pollutant	Avg. AQI	Min. AQI	Max. AQI	Category
2000	SO_2	1.84	0.15	47.06	Good
	CO	6.80	0.06	26.53	Good
	NO_2	37.46	0.24	160.46	Moderate
	O_3	37.72	0.50	391.99	Moderate
2001	SO_2	2.73	0.15	37.94	Good
	CO	1.93	0.06	17.53	Good
	NO_2	31.40	0.24	133.75	Moderate
	O_3	38.26	1.0	84.24	Moderate
2002	SO_2	3.97	0.147	71.77	Good
	CO	18.52	0.50	25.0	Good
	NO_2	37.45	0.23	168.58	Moderate
	O_3	36.56	0.50	80.65	Moderate
2003	SO_2	4.9	0.1	68.2	Good
	CO	14.85	0.1	27.6	Good
	NO_2	34.6	0.2	105.9	Moderate
	O_3	33.31	0.5	65	Moderate
2004	SO_2	3.2	0.1	52.2	Good
	CO	14.2	0.1	27.6	Good
	NO_2	31.8	0.5	93.6	Moderate
	O_3	33.10	0.5	79.3	Moderate

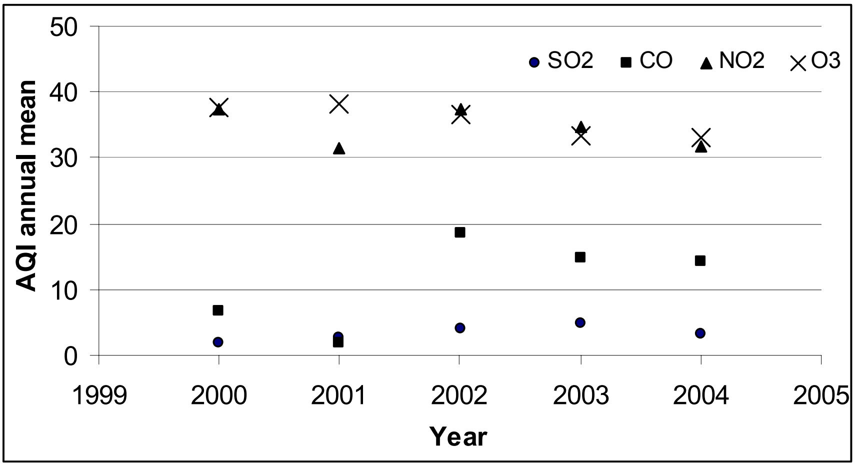

Figure 2: Average Air Quality Index for the studied pollutants in the period of study.

5 Conclusion

A general decrease was witnessed in the AQI values along the period of study. The four pollutants studied (*i.e.* SO_2, CO, NO_2 and O_3) resulted in a “good” and “moderate” ambient air quality. This leads to the understanding that Al-Mansoriah residential area exhibited a moderate air quality during the five years of investigation. In terms of SO_2 and CO, both pollutants recorded a minimum in the last two years of study (2003 and 2004). Maximum SO_2 AQI calculated was in the year 2002 recording an AQI of 71.77. For NO_2, moderate air quality was characterized for Al-Mansoriah with a maximum value for the first year of study of 160.46. Moderate air quality is also characterized for O_3 in the period of study. A clear increase in the CO AQI, when comparing the 2000 (AQI=6.8) and 2004 (AQI=14.2) values. AQI of CO has increased by more than 100% in the period of study. KUEPA has no records of any AQI running investigation in their current plan. More strict regulations should be applied for monitored area in the state of Kuwait.

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