Original Article

Traffic Air Quality Health Index in a Selected Street, Alexandria

Eman M. Abd El-Latef, Gehan R. Zaki [¥], Ahmed I. Issa

Department of Occupational Health and Air Pollution, High Institute of Public Health, Alexandria University, Egypt

Abstract

Background: Air Quality Health Index (AQHI) is a scale, which was designed in Canada to help people to understand how the air quality affects their health. It measures the relationship between the air quality and health on a scale from 1 to 10+.
Aim: The aim of this study was to assess traffic AQHI on one street in Alexandria, Egypt at different seasonal conditions.
Methods: This was a time-series study that was conducted during the period from January 1 to December 31, 2016 at Ibrahim Sherif Street. It was accomplished by three-hour air sampling of respirable particulates (PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and ground-level ozone (O_3), during the morning rush hours. A total of 156 samples for each pollutant covered all seasonal variations and activities. After laboratory analysis, the added health risks (%AR) and AQHI were calculated using the Hong Kong equation.
Results: The uppermost median value of %AR was during April [72.9 (23.4)] and the minimum was during January [32.2 (10.0)]. The traffic AQHIs in the study setting were of the serious category 10+ in almost all sampling days. The maximum %AR was during spring [70.0 (19.7)], and the minimum was during winter [40.6 (19.0)].
Conclusion: From the results of the present study, we can conclude that; the highest %AR was during April, and the minimum was during January. The traffic AQHIs in the study setting were of the serious category 10+ in almost all sampling days. The most dominating pollutant affecting the %AR and AQHI was the PM10.

Keywords: Added Health Risk, Rush Hours, Traffic Air Pollution, Traffic Air Quality Health Index

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¥*Correspondence*
Email: gehanra17@gmail.com

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INTRODUCTION

Traffic is the largest source of air pollution followed by power plants and factories that continue to make an important contribution.(1-5) The pollution caused by traffic is very dangerous and has deleterious effects on public health due to the obligatory doses, to which people are exposed to during their daily activities.(1-4) Virtually, most of the road vehicles are powered by gasoline and diesel engines that burn petroleum to release energy. As a result, engines' exhausts contain many kinds of pollution, notably particulates (soot of various sizes), unburned hydrocarbons, carbon monoxide (CO, a poisonous gas), nitrogen oxides (NO_x), volatile organic compounds (VOCs), sulfur dioxide (SO_2) (produced from diesel fuel) and lead—and indirectly produce ozone. The low car speed (idling) is attributed to the higher pollutants' emissions. The old cars of poor maintenance have decreased the fuel-burning efficiency, which much increasing in the pollution caused by vehicles.(1-4) Air pollution is a major risk factor for Non-Communicable Diseases (NCDs), causing cardiovascular disease, stroke, chronic obstructive pulmonary disease and lung cancer, as well as increasing the risks for acute respiratory infections.(6) The World Health Organization (WHO) report indicated that in 2012, around seven million premature people died, of which one out of eight was due to air pollution exposure. This indicates that air pollution is one of the world's largest environmental health risks.(7,8) Moreover, a Japanese study in 2013 observed an increase in cardiopulmonary and cancer mortality among individuals chronically exposed to high levels of traffic-related air pollution.(9) In Poland, cases with chronic obstructive pulmonary disease (COPD) among nonsmokers were four times greater in urban than in rural areas due to high-traffic air pollution levels.(10) In Drammen, Norway, the observed increases in the daily hospital admission due to acute respiratory diseases were observed in urban areas with heavy-traffic pollutants.(9, 11)

Air Quality Health Index (AQHI) is a scale, which is designed in Canada to help people to understand how the air quality affects their health.[12] It measures the relationship between the air quality and health on a scale from 1 up to 10+. The higher the number is, the greater the health risks. AQHI is a health protection tool that was designed to help people to decide about safe guarding their health by limiting short-term exposure to air pollution and adjusting their activities during the increased levels. The AQHI is divided into four categories that describe the level of health risk associated with the index reading (e.g. 'low' (1-3), 'moderate' (4-6), 'high' (7-9) and 'very high' (10+)). Each category is provided by health messages for both the general and at-risk population.[12] It also provides advice on how they can improve the quality of the breathed air. Moreover, a time-series study of 12 major cities in Canada, AQHI directly makes use of the exposure-response relationship between air pollution and health. Using an assumption that the combined health effect of PM2.5, NO_2, and O_3 is of additive type. The AQHI is calculated as the sum of excess mortality risk associated with the three pollutants, adjusted to a (1-10+) scale, which is subdivided into four categories. The Canadian AQHI incorporates PM2.5, O_3, and NO_2.[13]

The Hong Kong AQHI equation[14] is used to calculate the added health risk of the combined pollutants' concentrations. It was developed based on the Canadian experience, but comprises the main four pollutants of petro-diesel combustion products; particulate matter (PM10), nitrogen dioxide (NO_2), ground-level ozone (O_3), and sulfur dioxide (SO_2).

Alexandria is the second-largest city in Egypt. It is a coastal city that contains many industrial, agricultural, commercial and tourism activities. So, it is one of the major economic centers in Egypt. According to the annual report of population estimates of the Central Agency for Mobilization and Statistics in January 2016, its population is about 5,009,816 representing 5.4% of the Egyptian population, with population density of 1,870 pop/Km^2.[15] The unlimited increase of private cars' licensing intensifies their number within the streets. The number of licensed vehicles in Egypt is about 8.6 million in 2015, of which about 752.9 thousands in Alexandria, which represent 8.7% of the total number of vehicles in Egypt.[15] Moreover, the seasonal population increase during summer elevates the number of on road vehicles, and dramatically enhances the traffic pollutants, especially during rush hours.[16]

Many countries as Canada, Hong Kong and China used air quality health index (AQHI) to monitor the air pollution and protect the public health.[12,17] Unfortunately, it is not used in Egypt. Therefore, it is essential to assess traffic air quality health index (AQHI) to test its applicability on one of the Alexandria streets. The aim of the present study was to assess and shed to light on the traffic air quality health index on the selected street in Alexandria, Egypt using Hong Kong equation at different seasonal conditions.

METHODS

Study Setting: A time-series study was conducted during the period from January 1, 2016 to December 31, 2016. The study was carried out at Ibrahim Sherif Street, which was selected for conducting this study due to its heavy traffic character, with a relatively high-average traffic flow (2,300 vehicles/ hour). It is the pathway leading to El-Mehwar Highway connecting the west of Alexandria. It connects Smouha area with Abo Qir Street (Mustafa Kamel area). It contains different human activities, including many schools, the public bus garage, Smouha Sporting Club, the railway train and restaurants.[18]

Sampling: The sampling was carried out based on simultaneous three-hour periods of respirable particulates (PM10), nitrogen Dioxide (NO_2), sulfur Dioxide (SO_2) and ground-level ozone (O_3) during the morning rush hours (worst conditions). Sampling and analysis of gases NO_2, SO_2 and O_3 were according to the NIOSH standard methods at a rate of 0.7-1.0 L/minutes.[19] The sampling system consisted of diaphragm pumps (rocker 300), and standard bubblers, in addition to air flow meter and air flow controller. Regarding **ground-level Ozone (O_3)**, sampling was conducted by suction of air through 1% alkaline potassium iodide solution buffered at PH 6.8±0.2. After sampling, the media was sealed, and analyzed for the produced tri-iodide ion using "potassium iodide spectrophotometric method" at 352 nm. **Sulfur Dioxide (SO_2)** was sampled and analyzed using "Improved West and Gaeke Method" (IS 5182 Part 2 Method of Measurement of Air Pollution: Sulphur dioxide). The air containing SO_2 was absorbed through the sampling solution of potassium tetrachloromercurate (TCM) forming a dichlorosulphitomercurate complex, which was induced to react with para-rosaniline and formaldehyde to form an intensely colored pararosaniline methylsulphonic acid solution that can be measured spectrophotometrically at 560nm. **Nitrogen Dioxide (NO_2)** was sampled and analyzed using Modified Jacobs & Hochheiser Method (IS 5182 Part 6 Methods for Measurement of Air Pollution: Oxides of nitrogen). It was collected by bubbling air in a solution of sodium hydroxide and sodium arsenite. The produced nitrite ion was determined by reaction with phosphoric acid, sulfanilamide, and N-(1-naphthyl) - ethylenediamine di-hydrochloride (NEDA), and measuring the absorbance spectrophotometrically at 540 nm. **Respirable particulate matter (PM_{10})** was collected using sampling system consisted of standard PM10 high volume sampler (Tisch Environmental, Inc, USA). Air was dragged through a size selector inlet (Cyclones), and through 8×10-inch filter at a rate 1132

L/minute. Particles with an aerodynamic diameter less than 10µ were collected on the filter and determined gravimetrically.[19] Quality control (QC) affects the precision, accuracy, and validity of the measurements. The QC activities included selecting the standard operating procedure (SOPS) to be followed during sampling, chemical analysis, [19] and data processing. In addition, the air sampling systems, equipment and spare parts were maintained and calibrated monthly according to the Florida Department of Environmental Regulations Quality Assurance Section.[19]

Application of Hong Kong equation: The daily added health risks (AR %) was calculated using Hong Kong equation, [20] and then the Air-Quality Health Index (AQHI) was calculated and categorized according to Table (1).

$$\% \text{ AR (Added health risk)} = ([e^{(0.0004462559 \times C\ (NO_2))} - 1] + [e^{(0.0001393235 \times C\ (SO_2))} - 1] + [e^{(0.0005116328 \times C\ (O_3))} - 1] + [e^{(0.0002821751 \times C\ (PM10))} - 1]) * 100$$ [20]

Table 1: Hong Kong AQHI categories[14]

Health Risk Category	The label	AQHI	Added Health Risk (%AR)	Remarks
Low	低 LOW	1	0-1.88	
		2	>1.88-3.76	
		3	>3.76-5.64	
Moderate	中 MODERATE	4	>5.64-7.52	% AR of 5.64:.5x threshold for people who are sensitive to air pollution (%AR of 11.29) to take precautionary actions
		5	>7.52-9.41	
		6	>9.41-11.29	
High	高 HIGH	7	>11.29-12.91	%AR of 11.29 for people who are sensitive to air pollution to take precautionary actions
Very high	甚高 VERY HIGH	8	>12.91-15.07	% AR of 12.91 thresholds for general public to take precautionary actions.
		9	>15.07-17.22	
		10	>17.22-19.37	
Serious	嚴重 SERIOUS	10+	>19.37	% AR of 19.37: 1.5 X thresholds (% AR of 12.91) for general public to take precautionary actions.

Using the table (1) the values of added health risks were converted to the air-quality health index (AQHI) with the same color codes, and remarks.[20]

The data were entered and analyzed using the Statistical Package for the Social Sciences (IBM SPSS Statistics-21). The added health risk and pollutants' concentrations were checked for normality using Kolmogorov-Smirnov Z Test. The data were expressed as [median (Interquartile Range)]. Kruskal-Wallis Test was used to inspect the significance of variation at different months and seasons. The Mann-Whitney Test was used to examine the significance of variation between each two months or seasons.

Ethical Considerations

The study was approved by the Institutional Review Board and the Ethics Committee of High Institute of Public Health. The study conformed to the principles of Helsinki declaration (2013) and the international ethics guidelines. Permissions from the management of the Eastern District of Alexandria and from the Dean of High Institute of Public Health were obtained. Confidentiality of collected information was ensured.

RESULTS

This study lasted for 12 months from January 1, 2016 to December 31, 2016. There were 156 samples for each of respirable particulates (PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and ozone (O_3) to represent all seasonal variations and activities. Kolmogorov-Smirov Z Test indicated that some numeric variables were non-parametric. The data were expressed as [Median (Interquartile Range)]. The highest PM10 concentrations were during August [1429.9 (159.3) µg/m3], and the minimum were during January [504.5 (200.6) µg/m3]. Furthermore, the uppermost concentration of NO2 was during March as a relatively cold month [578.1 (740.0) µg/m3], and the lowest was during July as a warm [277.5 (75.2) µg/m3]. The peak SO_2 concentration was during February [4.3 (0.9) µg/m3] as one of the cold months and the minimum was during September [2.3 (1.7) µg/m3] as a hot month. The maximum level of O_3 was during July [96.3 (19.8) µg/m3], and the minimum was during February [29.0 (34.7) µg/m3]. Application of the Hong Kong equation revealed that in the present study, the highest value for added health risk (%AR) was during April [72.9 (23.4)], and the minimum was during January [32.2 (10.0)] (Table (2) and Figure (1)). It is also obvious that there were highly significant monthly variations of %AR according to Kruskal-Wallis followed by Mann-Whitney tests ($P<0.05$, C.I. 95%). The added health risks (AR%) had strong significant Spearman's rho correlation coefficient with PM10 (0.901). It was directly correlated with each of UV-Index and temperature, besides; it is inversely correlated with RH% (Figure 2).

The traffic Air Quality Health Indexes in the study setting were of the highest category 10+ (serious) in almost all sampling days. So, the general public must be notified to take precautionary actions like to limit their outdoor activities. The maximum value for %AR was during spring [70.968 (19.674)], and the minimum value was during winter [40.616 (19.012)] (Table (3) and Figure (3)). It is also obvious that there is a highly significant seasonal variation in the added health-risk value according to Kruskal -Wallis test ($P<0.05$, C.I. 95). Further analysis using Mann-Whitney test revealed significant %AR variations between winter and each of spring, summer and fall. Moreover, it was significantly varied between fall and each of spring and summer.

Table 2: Monthly Added Health Risk (%AR) and Traffic Air Quality Health Index during the period from January, 2016 to December, 2016 at Ibrahim Sherif Street, Mostafa Kamel, Alexandria, Egypt

	Month	N[A]	Median AR%	AQHI[B]	IQR.[C]	Minimum	Maximum	Sig.[D]
	January	19	32.156	10+	10.044	14.5	46.1	
Cold Months	February	14	52.272	10+	25.234	32.8	78.8	
	March	11	63.183	10+	43.303	31.2	100.4	
	April	6	72.875	10+	23.357	46.2	84.5	
	May	14	70.860	10+	16.641	44.8	78.6	
	June	12	60.169	10+	20.629	41.4	74.5	<0.05
Hot Months	July	9	66.903	10+	5.893	57.0	74.6	
	August	12	70.992	10+	7.816	58.3	74.3	
	September	12	61.655	10+	21.027	42.9	77.4	
	October	13	49.795	10+	14.048	38.5	67.1	
Cold Months	November	19	46.707	10+	4.672	32.5	54.3	
	December	15	43.819	10+	10.696	30.1	60.2	

A Number of measurement days
B Air Quality Health Index
C Interquartile range
D P-value using Kruskal Wallis Test

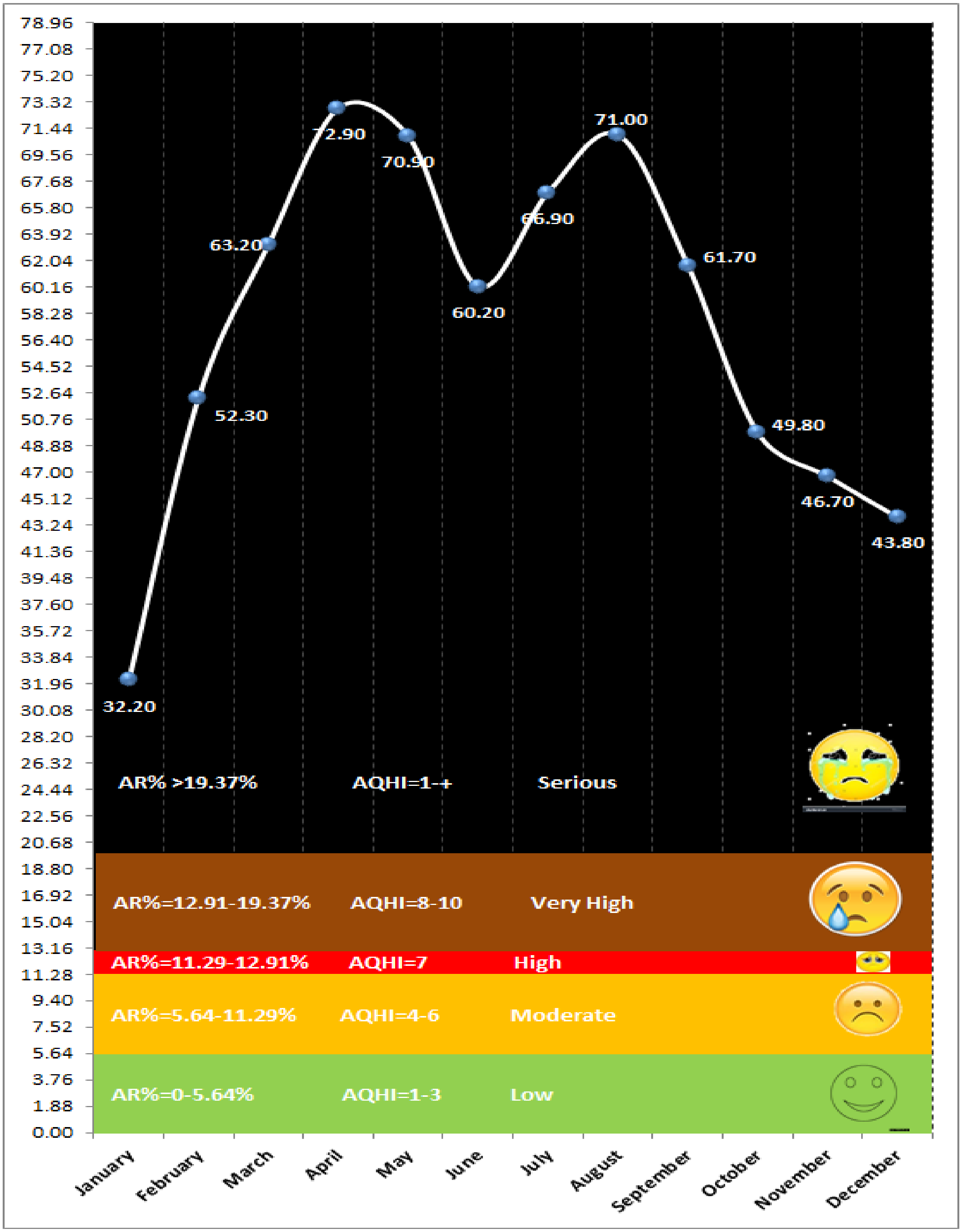

Figure 1: Monthly Added Health Risk (%AR) and Traffic Air Quality Health Index during the period from January, 2016 to December, 2016 at Ibrahim Sherif Street, Mostafa kamel, Alexandria, Egypt

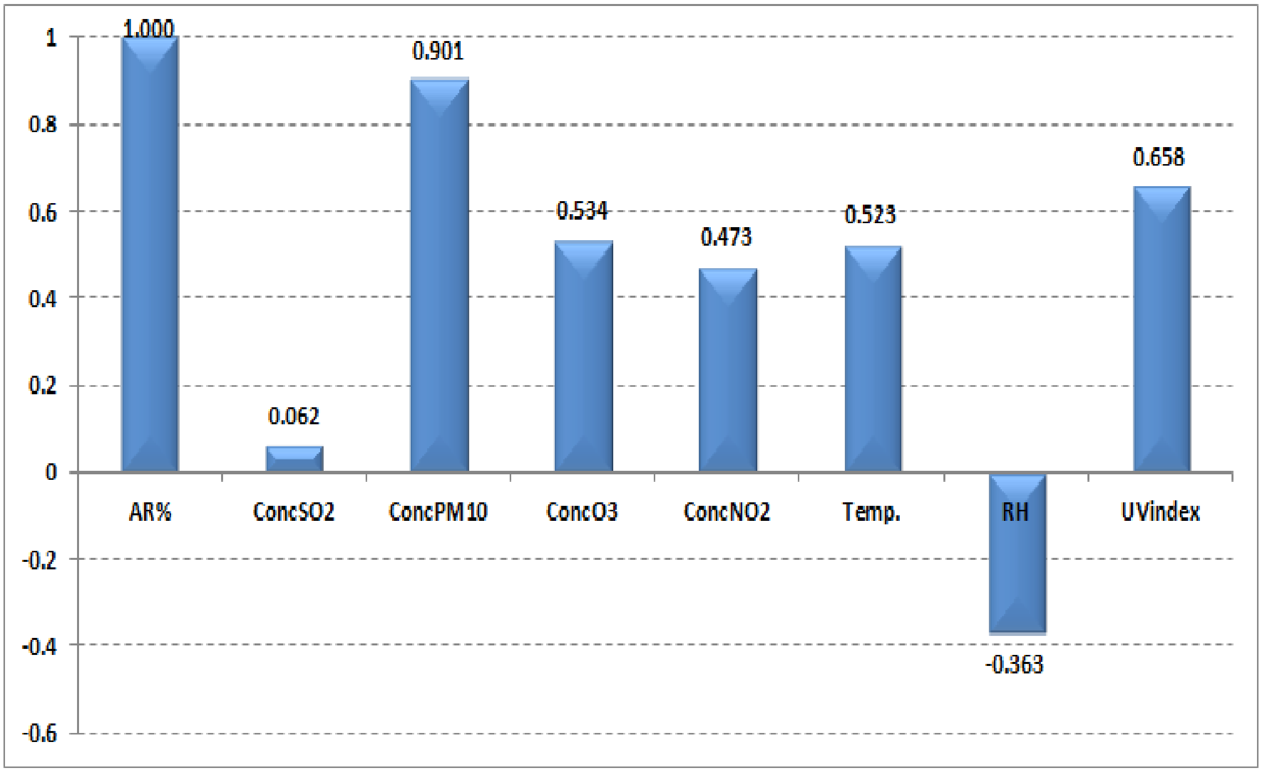

Figure 2: Spearman's rho Correlation Coefficients of Added Health Risk with some contributing factors during the period from January 2016 to December 2016 at Ibrahim Sherif Street, Mostafa Kamel, Alexandria, Egypt

Table 3: Seasonal Added Health Risk (%AR) and Traffic Air Quality Health Index during the period from January, 2016 to December, 2016 at Ibrahim Sherif Street, Mostafa kamel, Alexandria, Egypt

		N[A]	Median AR%	AQHI[B]	IQR.[C]	Minimum	Maximum	Sig.[D]
Cold Seasons	Winter	42	40.616	10+	19.012	14.5	78.8	<0.05
	Spring	34	70.968	10+	19.674	41.4	100.4	
Hot Seasons	Summer	33	68.925	10+	9.533	47.4	77.4	
	Fall	47	47.537	10+	8.936	32.5	77.1	

A Number of measurement days
B Air Quality Health Index
C Interquartile range
D P-value using Kruskal Wallis Test

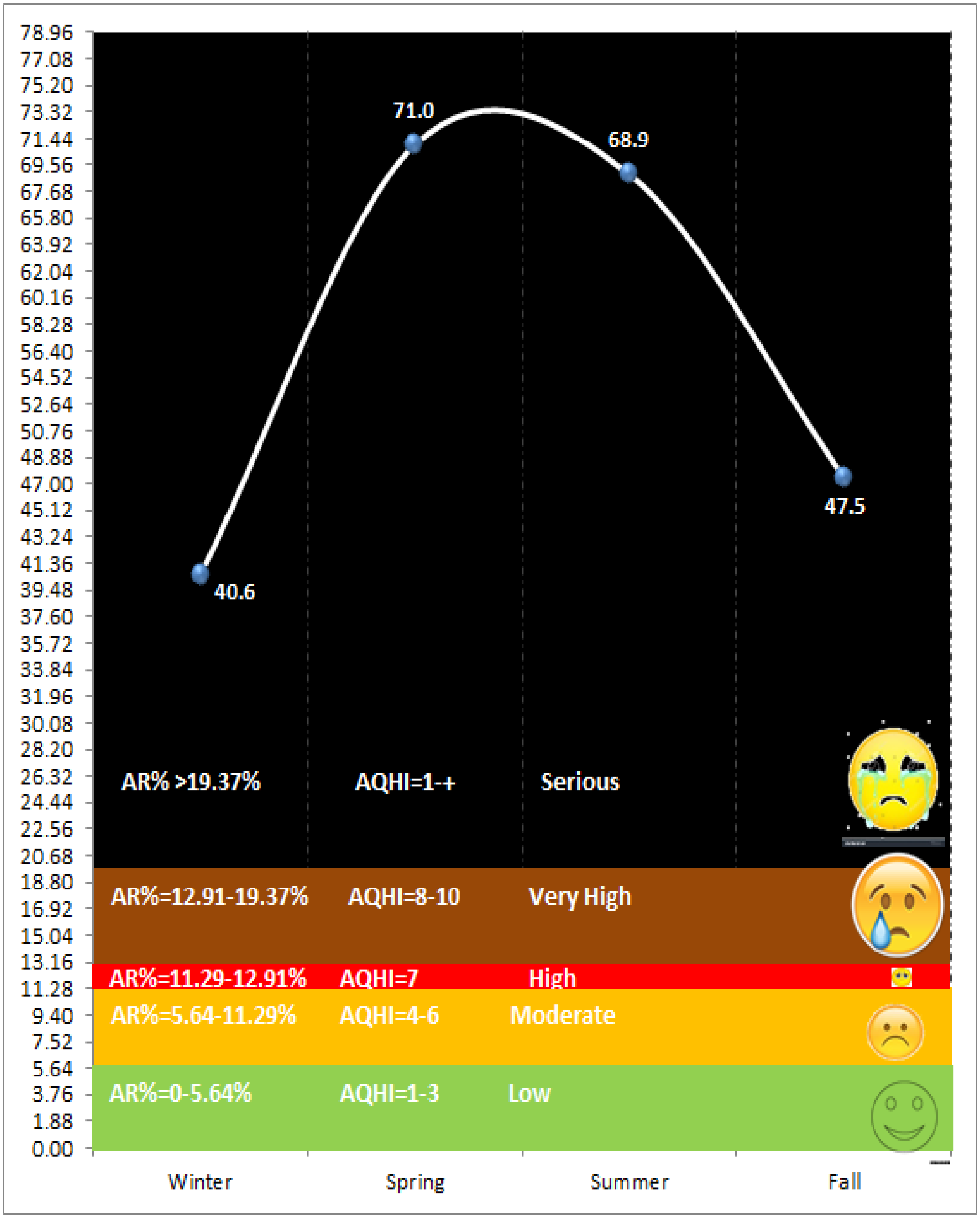

Figure 3: Seasonal Added Health Risk (%AR) and Traffic Air Quality Health Index during the period from January, 2016 to December, 2016 at Ibrahim Sherif Street, Mostafa kamel, Alexandria, Egypt

DISCUSSION

It is important to apply the AQHI in Egypt, which can be used for air quality forecasting and sending health messages to the public. This paper focuses on application of the Hong Kong AQHI to indicate its levels, and the vital role in Egypt, which may be a good motive for the authorities to develop and use Egyptian AQHI. The PM10 levels were higher during hot than cold months. The elevated air temperature during the warm months may result in formation of secondary particles, which increases the PM10 concentrations.(23) During the cold rainy months, the rains and the comparatively high relative humidity initiate the condensation of water vapors on particulates. Thus, this causes settling of particles out of the atmosphere leading to lower concentrations. (23) A study conducted in USA (2005) analyzed the air pollution in relation to the mortality in 100 US Cities. It revealed that the Southern California, Northwest, and Southwest regions had their highest PM10 levels in the cold months, in contrast to our results, while other regions had their highest levels during the hot months similar with the results of the present study.(24)

The concentrations of NO_2 and SO_2 were higher during the cold than hot months. This may be due to consumption of NO_2 in the photochemical oxidation process during the warm season.(25) In addition, the high air temperature during summer enhances gaseous diffusion and reduces the concentrations.(26) In contrary, the low temperature of air near the earth's crust during cold months reduces diffusion and accumulates NO_2 and SO_2.(26) In compliance with the results of the present study, Italian (2018) and Indian (2013) articles indicated the greatest NO_2 concentrations during cold months and minimum during warm.(21, 22) A Chinese (2018) and Indian (2012) researches disclosed the highest SO_2 concentration during winter and minimum during summer, in agreement with this study.(21, 26) The maximum levels of O_3 were during the hot months due to the successive photochemical reactions that induce the O_3 formation. A Chinese study 2018 revealed higher ground-level ozone during hot than during cold months in conformity with our study.(27) A study in Erzurum, Turkey disclosed that O_3 concentration increases with raising wind speed, temperature, relative humidity and previous day's O_3 concentration, which may be due to different lifetimes of atmospheric air pollutants at various prevailing meteorological factors.(28)

Application of the Hong Kong equation on the traffic pollutants of the selected street in the present study revealed that the maximum added health risk (%AR) was during April, and the minimum was during January. The value of %AR depended on the four pollutants' concentrations. It was more sensitive to the levels of PM10. This may be attributed to its relatively high concentrations compared with the other three pollutants. The traffic Air Quality Health indexes in the study setting were of the highest category 10+ (serious) in almost all sampling days. So, the general public must be notified to take precautionary actions like to limit their outdoor activities. A study conducted in Canada during the period between March 2004 and December 2009 declared that in contrast to the present study, the AQHI was higher during cold seasons than during warm. This was explained based on the lower concentrations of pollutants (except O_3) during the warmer than the cooler seasons. Another study in Ontario Canada during the time period from 2003 to 2006 revealed that the highest value of AQHI was during summer [4.07 ±1.43], and the minimum was during fall [3.18 ±1.19].(29) This contradictory behaviors of the index may be due to the variation in meteorological conditions between Canada and Egypt.(30)

A study conducted in Hong Kong (2013) to measure the efficiency of AQHI to communicate air quality to the public and at-risk population disclosed that AQHI was much more efficient than the other air quality indices.(31) A study in Edmonton, Canada (2014) investigated using AQHI as a prediction tool for hospital admission. It found that the AQHIs were positively associated to the number of emergency department visits for ischemic stroke during the warm months in the northern urban Canada center. (32) In 2016, a research tested the correlation between the AQHI and hospital administration for Otitis Media in Windsor, Ontario, Canada for children three years old or younger. The research findings confirm that there is direct correlation between the AQHI and the emergency department visits for Otitis Media.(33)

Application of Hong Kong equation on the selected street in Alexandria, Egypt revealed values AQHI more than 3.5 times higher than that found in China. (20) This necessitates developing an Egyptian equation to enable better justification of the Egyptian situation, and to enhance the decision-making process. The limitation faced this research was due to the absence of Egyptian equation for AQHI that based on the Egyptian morbidity data and conditions. In addition, there was a difficulty to count the number of vehicles passed through the sample point during the sampling time to get the relationship between the traffic density and traffic air pollution.

CONCLUSION AND RECOMMENDATIONS

From the results of the present study, we can conclude that; the supreme concentrations of particulates (PM10), and Ozone (O_3) were during the hot months; and that of nitrogen and sulfur dioxides (NO_2 and SO_2) were during the cold ones. The highest values for %AR (added health risk) were during April and the minimum values were during January. The traffic Air Quality

Health indices in the study setting were of the uppermost category 10+ (serious) in almost all sampling days. The most dominating pollutant affecting the Added Health Risks at the sample point was the respirable particulate matter (PM10) concentrations.

An Egyptian AQHI must be developed to inform the public about the levels of air quality and to facilitate their assimilation of the health messages. In order to decrease the traffic air pollution, it is recommended to conduct periodic maintenance of cars. To reduce the traffic density, it preferred to divide the cars according to their numbers into odd; which are permitted to run during Saturday, Monday, and Wednesday; besides the even cars are allowed to run during Sunday, Tuesday, and Thursday. Both odd and even cars can be allowed to pass during Friday. Additionally, it is recommended to improve the public transportation system. Cleaning and maintenance of the streets must be performed during the late evening in periods to reduce excitation of respirable particulates. Moreover, it is important to specify rewards for the cleanest street and region as a promoting step toward clean environment. Finally, Regulations must be enforced to reduce vehicles' emissions through periodic governmental inspection during the car license update.

Conflict of interest: None to declare.

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