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Estimation of health effects (morbidity and mortality) attributed to PM10 and PM2.5 exposure using an Air Quality model in Bukan city, from 2015-2016 exposure using air quality model

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Abstract
Background: Air Quality software is a useful tool for assessing the health risks associated with air pollutants. Quantifying the effects of exposure to air pollutants in terms of public health has become a critical component of policy discussion. The present study purposed to quantify the health effects of particulate matters on mortality and morbidity in a Bukan city hospital from 2015-2016.
Methods: Information regarding coordinates, exposed population, number of stations used in profiling, mean and maximum concentrations (annual, winter, and summer), annual 98th percentile, baseline incidence (BI) per 100 000 per year, and relative risk was needed for use with the software.
Results: The average particulate matter concentration was higher in summer than in winter. The concentrations of PM_{10} in summer and winter were 84.37 and 74.86 µg m^{-3}, respectively. The Air Quality model predicted that total mortality rates related to PM10 and PM2.5 were 33.3 and 49.8 deaths, respectively. As a result, 3.79% of the total mortality was due to PM_{10}. In Bukan city, 2.004% of total deaths were due to cardiovascular mortality. The Air Quality model predicted that the deaths of 92.2 people were related to hospital admissions for respiratory disease.
Conclusion: The continual evaluation of air quality data is necessary for investigating the effect of pollutants on human health.
Keywords: Air pollution, Bukan, Morbidity, Particulate matter, Software, Public health
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Introduction

A dust storm is defined as air turbulence which spreads a large mass of dust in the atmosphere and reduces horizontal visibility to less than a thousand meters (1). Dust storms carry a lot of various materials. Annually, dust storms transport particulate matter approximately 800 trillion grams to Asia (2). The frequent occurrence of dust storms due to drought in the Middle East is causing environmental and health problems (3,4). Particulate matter is one of the most important compounds in the atmosphere. It comprises microscopic solids or liquid matters suspended in the atmosphere (5). Furthermore, it consists of complex mixtures that may contain biological, metal, toxic, and/or acid materials (6). Sources of particulate matter can be man-made or natural (7). Particulate matter impacts climate and precipitation, has harmful effects on human health, animal health, and the environment (8-10), and constitutes the most important issues and challenges associated with air pollution (11,12). PM_{10} and $PM_{2.5}$ have average aerodynamic diameters of less than 10 and 2.5 microns, respectively (13,14). Studies show that particulate matter can be associated with increased hospital admissions, physiological changes in the body, and different diseases, especially of the respiratory (15) and cardiovascular (16) system, asthma, and lung cancer mortality (17). According to a report by the World Health Organization (WHO), particulate matter contributes to approximately 800 000 premature deaths each year (6). The report also estimated that 1.5% of deaths in the world are caused by air pollution (18).

Air Quality (or Air Q) software is a useful tool for assessing the health risks associated with air pollutants. Quantifying the effects on public health of exposure to air pollution has become a critical component in policy discussion. WHO/Europe's software tool Air Q performs calculations that allow the quantification of the health effects of exposure to air pollutants, including estimations of the reduction in life expectancy. Air Q has two main parts. In the first part, the short-term effects of changes in air pollution (based on risk estimates from time-series studies) are estimated. In the second part, the long-term effects of exposure (using life-tables approach and based on risk estimates from cohort studies) are estimated (19).

Iran is a dry country, and drought has exacerbated its dryness in the past two decades. Soil erosion, uncontrolled increases in agricultural land, uncontrolled exploitation of groundwater, and the desiccation of rivers have caused an increase in dust storms. Lake Urmia is located in northwestern Iran and is one of the largest saline lakes in not only Iran, but also the world (20). Moreover, it is the largest lake in the Middle East (21,22). Bukan city is located south of Lake Urmia. Currently, most parts of the lake have dried up because of drought. In addition to dust storms, salt storms are also on the rise. Both salt storms and salty dust storms can increase the negative health effects of exposure to them. The present study aimed to quantify the health effects of particulate matter on mortality and morbidity in a hospital in Bukan city.

Methods

Location data

Bukan city is situated in West Azerbaijan province at northwest of Iran (36° 32' N, 46° 13' E). Figure 1 shows the location of the city and the nearby air quality monitoring station. At present, there is only one air quality monitoring station there. Bukan city has an area of 306.2541 km^2. According to the latest census in Iran, the city's population is 224 628 persons.

Data collection and information processing

In this work, PM_{10} data was obtained from the Bukan Environmental Department. Study stages were classified into 4 steps, shown in Figure 2. In Step 1 (data collection from monitoring station), data regarding hourly PM_{10} and $PM_{2.5}$ concentrations (2015-2016) was received from the Bukan Environmental Department in a Microsoft Office Excel spreadsheet. In Step 2, the information was processed with MS Excel using the following procedure:

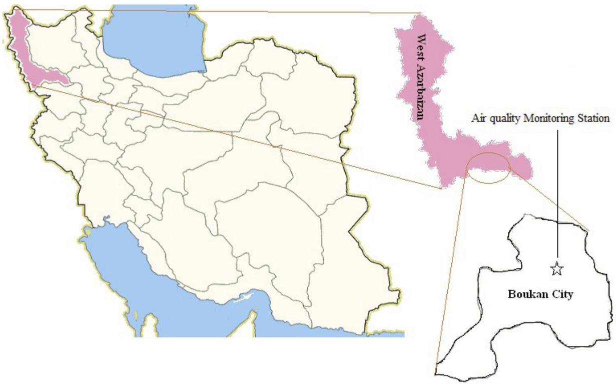

Figure 1. Location of the study area in Bukan City, West Azerbaijan, Iran.

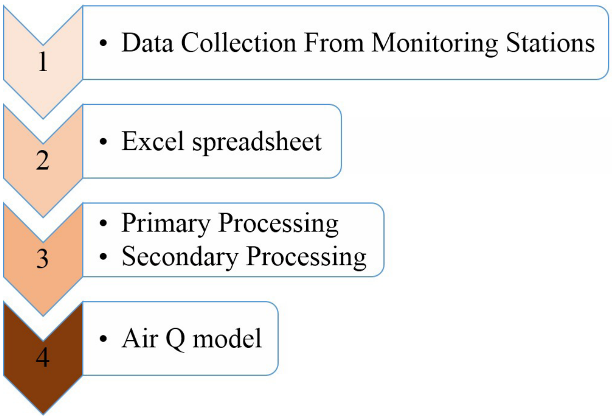

Figure 2. Flowchart of use of Air Q software (4 steps).

primary processing (removing, sheeting, integration time), secondary processing (code writing in Excel, calculating PM_{10} and $PM_{2.5}$ means, primary and secondary filtering of data). In this work, the interval of 10 $\mu g\ m^{-3}$ was selected for assessing short-term health impacts. After data classification based on the interval of 10 $\mu g\ m^{-3}$, the results were entered into the software.

Air Quality software

Air Q is a software that quantifies air pollution data. This work employed Air Q software, version 2.2.3. When working with the software, one air pollutant had to be selected for the assessment of its effect on health, and the data regarding population exposure to this pollutant was entered in the program. The data entered included coordinates (latitude and longitude), exposed population, number of stations used for profiling, mean and maximum concentrations (annual, winter, and summer), annual 98th percentile, baseline incidence (BI) per 100 000 per year, and relative risk (RR) (mean, lower, and upper). For the predefined health outcomes, two options were given when calculating the health impact: to use WHO default values for BI and RR (95% CI), the level of scientific certainty of which is given according to the available epidemiological evidence, or to replace the WHO default values with estimates for BI and RR obtained from local

Table 1. Particle concentrations of PM_{10} and $PM_{2.5}$ in different seasons of the year

PM_{10} (μg m^{-3})						
Average			**Maximum**			**98th Percentile**
Annual	Summer	Winter	Annual	Summer	Winter	
79.6	84.37	74.86	395.95	395.95	261.57	237.39
$PM_{2.5}$ (μg m^{-3})						
Average			**Maximum**			**98th Percentile**
Annual	Summer	Winter	Annual	Summer	Winter	
33.01	34.95	31.07	180.41	180.41	85.32	94.88

epidemiological studies. In cases of the second option, the scientific uncertainty will be set to unknown by the program. In this research, the BI and RR values were selected based on similar studies (23,24).

Results

Table 1 shows a descriptive analysis of PM_{10} and $PM_{2.5}$ concentrations in the various seasons of 2015-2106. Table 2 shows the hourly average concentrations (μg m^{-3}) of PM_{10} and $PM_{2.5}$ at Bukan city from 2014 to 2015. Table 3 presents the RR with a 95% CI; this figure was used for the health effect estimates of PM_{10} and $PM_{2.5}$ particles. The correlation between PM_{10} and $PM_{2.5}$ concentrations and the percentage of estimated AP (attributed proportion, RR, and estimated number of excess cases [persons]) are shown in Table 4. Figure 3 shows the correlation between cumulative excess and PM_{10} concentration, including total mortality, cardiovascular mortality, respiratory mortality, hospital admissions (HA) for respiratory disease, and HA for cardiovascular disease.

Discussion

The average concentration of particulate matter was higher in summer than in winter. The concentrations of PM_{10} in summer and winter were 84.37 and 74.86 μg m^{-3}, respectively. The maximum concentration of PM_{10} was greater in summer (395.95 μg m^{-3}). The concentrations of $PM_{2.5}$ in summer and winter were 34.95 and 31.07 μg m^{-3}, respectively (Table 1). The maximum concentration of $PM_{2.5}$ was greater in summer (180.41 μg m^{-3}). The results reported in Table 1 show that neither the PM_{10} nor the $PM_{2.5}$ concentration changed significantly with seasonal variations; they were nearly constant. In recent years, dust storms have been the main causes of high PM_{10} and $PM_{2.5}$ concentrations in summer compared with other seasons (1). In Iran, dust storms have both internal and external sources. The external sources of dust storms are the countries of Iraq, Jordan, and Saudi Arabia, and the internal sources are the provinces of Khuzestan, Kerman, and Sistan-Baluchistan. The reasons for the increase in dust storms in Iran include drought, lack of suitable vegetation, reduced rainfall and moisture in the air, destruction of forest and grasslands in Iraq, changes in air

Table 2. Hourly average concentrations (μg m-3) of PM_{10} and $PM_{2.5}$ particles in Bukan City from 2015 to 2016

		Maximum (μg m^{-3})	Minimum (μg m^{-3})	Mean (μg m^{-3})
January	PM_{10}	261.57	12.07	53.81
	$PM_{2.5}$	49.7	4.74	29.62
February	PM_{10}	230.72	19.92	75.33
	$PM_{2.5}$	66.52	16.61	27.66
March	PM_{10}	204.83	11.13	74.51
	$PM_{2.5}$	85.32	19.17	32.7
April	PM_{10}	179.11	19.31	62.48
	$PM_{2.5}$	54.18	6.75	19.55
May	PM_{10}	225.4	24.45	78.35
	$PM_{2.5}$	27.45	7.33	27.45
June	PM_{10}	395.95	6.92	97.5
	$PM_{2.5}$	164.98	7.71	40.08
July	PM_{10}	233.74	18.75	69.2
	$PM_{2.5}$	140	5.93	27.67
August	PM_{10}	144.99	17.05	62.55
	$PM_{2.5}$	180.41	1.83	38.85
September	PM_{10}	175.66	31.18	71.56
	$PM_{2.5}$	99.91	1.25	32.49
October	PM_{10}	248.99	3.16	75.05
	$PM_{2.5}$	81.44	1.55	32.76
November	PM_{10}	103.07	2.38	56.76
	$PM_{2.5}$	64.26	8.33	23.66
December	PM_{10}	116.62	3.02	49.54
	$PM_{2.5}$	51.43	0.87	35.26

Table 3. Relative risk with 95% confidence interval and corresponding reference

Health effects		Baseline Incidence	Relative risk per 10 μg m^{-3}		
			Low	Medium	High
Mortality	Total	543.5	1.004	1.006	1.008
	Cardiovascular	231	1.005	1.009	1.013
	Respiratory	48.8	1.005	1.020	1.013
Morbidity	HA Respiratory Disease	1260	1.005	1.008	1.011
	HA Cardiovascular Disease	436	1.006	1.009	1.013

Table 4. Health effects, relative risks, estimated AP, and estimated numbers of excess cases due to short-term exposure to PM10 levels above 10 μg m-3

Health effects	RR (Medium)	Estimated AP (%)	Estimated number of excess cases (persons)
Total Mortality	Central	4.0332	49.3
	Lower	2.7254	33.3
	Upper	5.3062	64.9
Cardiovascular mortality	Central	5.9302	30.8
	Lower	3.3837	17.6
	Upper	8.3458	43.4
Respiratory mortality	Central	8.3458	9.2
	Lower	3.3837	3.7
	Upper	12.2876	13.5
HA respiratory disease	Central	5.3062	150.4
	Lower	3.2528	92.2
	Upper	7.2743	206.2
HA cardiovascular disease	Central	5.9302	58.2
	Lower	4.0332	39.6
	Upper	8.3458	81.9

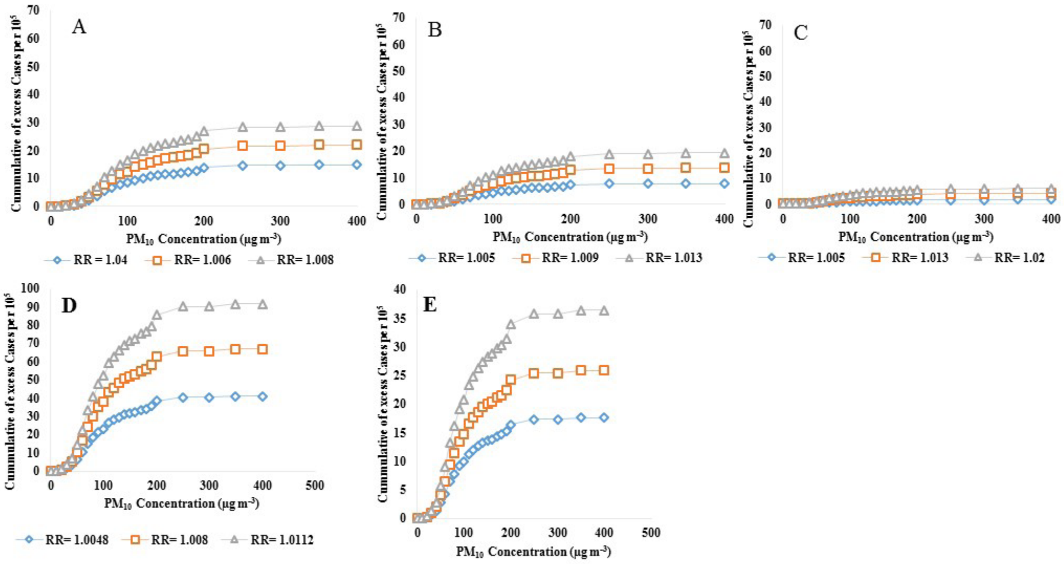

Figure 3. Cumulative excess of case related to PM_{10} concentration: **A**: total mortality, **B**: cardiovascular mortality, **C**: respiratory mortality, **D**: HA for respiratory disease, **E**: HA for cardiovascular disease.

pressure, and strong winds from the deserts of Iraq and Saudi Arabia. The WHO guidelines for PM_{10} and $PM_{2.5}$ particles are 50 and 25 μg m^{-3}, respectively (25). As shown in Table 2, the PM_{10} and $PM_{2.5}$ concentrations measured in this study were higher than WHO guidelines in most months of the year.

The values shown in Table 3 were extracted from similar studies in Iran (24,26). Illustrated in Table 3 are the health effects of PM_{10} particles that can be calculated in mortality, such as total mortality, cardiovascular mortality, respiratory mortality, and morbidity such as HA for respiratory disease and HA for cardiovascular disease. As illustrated in Table 4, the Air Q model predicted that the means of total mortality relative to PM_{10} and $PM_{2.5}$ particles were 33.3 and 49.8 deaths, respectively. Figure 3, Part A shows the cumulative excess cases per 100 000 related to total mortality (lower, mean, and upper). In 2015-2016, there were 935 deaths, 57 of which were due to driving accidents. In other words, 878 people suffered a non-accidental death. As a result, 3.79% of total mortality was due to PM_{10} particles. Similar studies have shown that the effects of PM_{10} on total mortality were responsible for 2194 deaths in the city of Tehran in 2012 (24). Other studies have shown that the highest number of deaths caused by air pollution was related to PM_{10} particles (100 deaths) (27). The Air Q model predicted that 17.6 deaths (mean), or 2.004% of total mortality in Bukan City were related to cardiovascular mortality. Figure 3, Part B shows the cumulative excess of cases per 100 000 related to cardiovascular mortality (lower, mean, and upper). Motalleby and colleagues' results showed that the effects of PM10 were responsible for 66 cardiovascular deaths in the city of Kashan in 2011 (27). The Air Q model predicted that 3.7 deaths from respiratory disease (mean) were related to the effects of PM_{10}. As a result, 0.42% of the total mortality in Bukan City was due to respiratory mortality. Figure 3, Part C shows the cumulative excess of cases per 100 000 related to cardiovascular mortality (lower, mean, and upper). The Air Q model predicted that 92.2 deaths (mean) were related to HA respiratory disease morbidity. Figure 3, Part D shows the cumulative excess of cases per 100 000 related to cardiovascular mortality (lower, mean, and upper). The Air Q model predicted that 39.6 deaths (mean) were related to HA cardiovascular disease. Figure 3, Part E shows the cumulative excess of cases per 100 000 related to cardiovascular mortality (lower, mean and upper). The continual evaluation of air quality data is necessary to investigate the effects of air pollution on human health.

Conclusion

This work used Air Quality software to assess the health risks of particulate matter. The health effects associated with particulate matter, such as total mortality, cardiovascular mortality, respiratory mortality, HA for respiratory disease morbidity, and HA for cardiovascular disease, were calculated.

This model can be useful in aiding data collection about the health effects of pollutants on exposed population.

Authors' contributions

All authors contributed equally and were involved in the study design, data collection, and article approval.

Competing interests

The authors of this article declare that they have no competing interests.

Ethical issues

The authors confirm that the research is their original study. It has not been published, nor is it under review in another journal, and it is not being submitted for publication elsewhere.

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