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THE STATISTICAL ANALYSIS OF SEASONAL AND TIME VARIATIONS ON TREND OF IMPORTANT AIR POLLUTANTS (SO_2, O_3, NO_X, CO, PM_{10})-IN WESTERN IRAN: A CASE STUDY

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Abstract

Western Iran, for example, Kermanshah, is one of the industrial cities of Iran that due to industrial development and transport development and located in the west side of country, the levels of its air pollutants have a lot of fluctuations. So the aim of this study is to determine the trend of variations in Kermanshah air pollutants (sulfur dioxide, ozone, nitrogen oxides, carbon monoxide and particulates).This is a descriptive - analytical study, so that the data of various air pollutants in Kermanshah city during the period of 5 years (2006-2011) obtained from the Environmental Protection Agency of Kermanshah, then data analysis was attempted using SPSS and Excel software. Results showed that the highest average concentrations of pollutants based on years, season and months were 2010, summer and July for O_3, 2005, autumn and December for NO, 2008, spring and April for NO_2, 2008, summer and July for PM_{10}, 2008, summer and September for SO_2 and 2005, Autumn and June for CO. Increasing the some pollutants such as O3, NO and NO2 from 2006 years onwards is related to increasing the vehicle and industries. Therefore, it is essential to understand the causes of increasing and reducing the emissions is needed to Public education to deal, harm reduction and management measures.

Keywords: Seasonal variations, Air quality, Air pollutants, Western Iran

Introduction

Nowadays; the air quality in urban areas is one of the most important issues in the urban areas. A broad spectrum of adverse health endpoints due to exposure to air pollutants, at levels usually experienced by urban populations have been recorded throughout the world (1-3). Moreover, in recent years, even though pollution due to combustion fuels has decreased considerably, some contaminants such as O_3 and NO_2, and variations in the composition and size distribution of PM, have become important in the health endpoints of air pollution (4). Spectrum of health endpoints from growth occurrence of pneumonia and asthma intensification of chronic obstructive pulmonary diseases increased respiratory symptoms and decreased lung function, to an increased cardiovascular mortality rate (4-7). However, in developing countries with investments and new technologies great progress has been obtained in the field of local pollution control, but developing countries still has a serious challenge in this regard.

Kermanshah (fig 1) is one of the major western cities of Iran that is near to Iraq, Saudi Arabia and Kuwait, the main origins of dust storms in this area. Particularly, the air quality of Kermanshah seems to be affected by north wind, northwesterly wind that frequently occurs in the spring and carries high levels of particles from southern areas of Iraq (8, 9). Moreover the abovementioned source, this city with a population of more than one million people, is one of the industrial cities and has a huge number of vehicles that can degrade its air quality. This city has been experiencing large quantities of air pollutants originating from the mentioned sources, especially since 2004. Thus, this research has produced a sought to evaluate the air pollutant (SO_2, O_3, NO_X, CO, PM) concentrations during five years period in Kermanshah from 2006 to 2011.The aim of the study is to determine the general trend of air pollutant concentrations to extract the patterns of diurnal variation of air pollutant. The findings of this study can represent information of the significance and impacts of air pollution in the study area. This awareness could help responsible authorities to design integrated management of air pollution control plans and sachems.

Fig1. Study area.

Materials and methods

In this study, we have tried to statistically analyze of seasonal and time variations on trend of most important parameter air quality changes in Kermanshah city, Iran. To do so, the pollutants selected were PM_{10}, CO, SO_2, NO_2 and O_3.We used the air quality data from the permanent monitoring stationsof Kermanshah environmental protection organization from 2006 to 2011 years. For all the pollutants, the measured units by monitoring stations were µg/m^3, but for CO was ppm. So for correction the unit of CO, raw data were converted into data based on temperature and pressure by writing the appropriate program (according to Table 1).

Table-1: Correction of CO data units based on temperature and pressure.

A	B	C	D	E	F	G
NO	Temp(℃)	Temp(K)	Pressure(mbar)	P/P_0	CO(ppm)	CO(mg/m^3)
1	6.8	279.95	941.54	0.93	2.85	2.89
2	6.81	279.96	941.54	0.93	3.63	3.68
3	6.17	279.32	941.18	0.93	3.18	3.23
4	5.57	278.72	94.85	0.93	3.19	3.24

Columns F and B are raw data that obtained from monitoring stations of Kermanshah environmental protection organization and the other columns are calculated through the following equations:

$C_1=271.15+B_1$

$D_1=[1013.25*e^{(-(0.0342*1520)/C_1)}]$

$E_1=D_1/1013.25$

$G_1=[(273.15*E_1)*(1.25*F_1)]/[C_1]$

Finally, the corrected data were analyzed statistically using SPSS ver. 20. Descriptive statistics were used for the presentation of pollutant concentrations. One-sample T-test was used to evaluate the values of each pollutant with standard value and One-Way ANOVA was used to evaluate the values of pollutants in years of study.

Results

The results show that the variation trends of pollutants are significant ($P_{value}<0.0001$) in years, seasons and months of study. Table 2 indicates the variation trends of pollutants of Kermanshah during 2006 to 2011 years based on years of study. Table 3 indicates the variation trends of pollutants of Kermanshah during 2006 to 2011 years based on seasons of study. Table 4 indicates the variation trends of pollutants of Kermanshah during 2006 to 2011 years based on months of study.

Table-2: The variation trends of pollutants in Kermanshah during 2006 to 2011 years based on years of study.

Parameters	year	Sample. no	Mean	SD	Max	Min	P_{value}
O_3	2006	357	17.78	9.65	50.71	2.13	0.001
	2007	363	13.05	12.64	44.88	0.58	
	2008	362	15.41	13.82	119.04	0.00	
	2009	232	24.97	15.64	52.38	2.25	
	2010	363	28.43	13.71	65.67	7.08	
	2011	194	39.34	15.10	158.00	10.00	
	Total	1871	21.60	15.59	158.00	0.00	
NO	2006	357	41.15	24.05	141.75	1.04	0.001
	2007	363	25.86	17.74	93.67	0.17	
	2008	362	20.28	14.89	92.67	1.13	
	2009	232	11.53	6.38	28.42	1.13	
	2010	363	16.95	11.11	73.50	1.42	
	2011	294	16.93	14.91	96.40	2.29	
	Total	1871	23.27	18.94	141.75	0.17	
NO_2	2006	357	26.74	7.15	44.54	4.38	0.001
	2007	363	16.64	9.62	39.50	0.38	
	2008	362	10.33	3.69	23.54	2.83	
	2009	232	6.84	3.65	16.00	0.04	
	2010	363	44.36	13.55	92.94	6.25	
	2011	294	39.02	15.91	107.20	8.83	
	Total	1871	23.83	16.79	277.20	0.38	
PM_{10}	2006	357	89.63	37.51	358.01	9.73	0.001
	2007	363	125.72	94.56	916.80	20.55	
	2008	362	152.63	138.72	1294.94	27.49	
	2009	232	169.05	256.49	2758.60	0.00	
	2010	363	121.05	111.25	1124.60	4.11	
	2011	294	144.59	106.81	1003.20	29.74	
	Total	1871	133.81	137.42	2758.60	0.00	
SO_2	2006	357	22.00	14.69	136.04	0.21	0.001
	2007	363	22.15	4.64	44.00	6.17	
	2008	362	24.06	4.84	36.92	4.96	
	2009	232	43.69	26.03	156.46	5.75	

	2010	363	12.10	8.83	39.33	0.08	
	2011	294	24.62	9.43	88.80	7.92	
	Total	1871	23.47	15.31	156.46	0.08	
CO	2006	357	2.59	1.055	5.65	0.23	0.001
	2007	363	2.27	1.12	8.08	0.20	
	2008	362	1.77	0.80	4.24	0.32	
	2009	232	1.38	0.63	3.66	0.31	
	2010	363	1.07	0.77	4.39	0.21	
	2011	294	0.94	0.50	4.13	0.33	
	Total	1871	1.75	1.06	8.08	0.20	

Table-3: The variation trends of pollutants in Kermanshah during 2006 to 2011 years based on seasons of study.

Parameters	season	Sample no	Mean	SD	Max	Min	P_{value}
O_3	Spring	555	20.27	15.44	119.08	1.75	0.001
	Summer	531	34.99	10.96	69.13	5.00	
	Autumn	432	14.67	13.06	158.00	1.46	
	Winter	353	12.03	10.17	47.46	0.00	
	Totally	1871	21.60	15.58	158.00	0.00	
NO	Spring	555	20.96	15.25	87.63	1.25	0.001
	Summer	531	15.87	11.34	69.38	0.17	
	Autumn	432	32.44	23.89	141.75	1.13	
	Winter	353	26.93	20.92	106.33	1.13	
	Totally	1871	23.37	18.93	141.75	0.17	
NO_2	Spring	555	25.81	16.81	94.92	2.00	0.001
	Summer	531	21.08	16.79	94.04	0.38	
	Autumn	432	24.27	19.67	107.20	0.04	
	Winter	353	24.30	12.34	74.04	3.98	
	Totally	1871	23.83	16.78	107.20	0.38	
PM_{10}	Spring	555	148.70	131.03	1294.65	0.00	0.001
	Summer	531	165.88	179.65	2758.60	4.22	
	Autumn	432	103.26	48.78	402.05	21.51	
	Winter	353	98.33	88.18	916.9	12.12	
	Totally	1871	133.88	137.74	2757.50	0.00	
SO_2	Spring	555	19.32	13.45	88.21	0.08	0.001

	Summer	531	28.25	19.14	136.04	0.21	
	Autumn	432	25.43	15.69	156.46	5.75	
	Winter	353	20.40	5.69	44.00	3.33	
	Totally	1871	23.47	15.31	156.46	0.08	
CO	Spring	555	1.59	1.22	8.08	0.21	0.001
	Summer	531	1.45	0.78	4.39	0.23	
	Autumn	432	2.24	1.032	5.65	0.32	
	Winter	353	1.88	0.95	4.42	0.20	
	Totally	1871	1.75	1.06	8.08	0.20	

Table-4: The variation trends of pollutants in Kermanshah during 2006 to 2011 years based on months of study.

Parameters	Months	Sample no	Mean	SD	Max	Min	P_{value}
O_3	March	186	12.13	12.04	52.29	2.00	0.001
	April	186	16.16	12.49	47.50	1.75	
	May	183	31.72	14.77	119.08	2.00	
	June	159	38.02	11.76	69.13	5.00	
	July	186	37.14	9.71	58.14	13.54	
	August	186	30.24	9.84	52.32	8.67	
	September	180	22.16	15.56	158.00	6.00	
	October	136	10.24	7.14	38.00	1.96	
	November	116	8.23	6.99	19.17	1.46	
	December	118	9.23	7.51	33.29	0.00	
	January	120	12.34	9.97	43.58	2.00	
	February	115	14.47	11.98	47.46	2.00	
	Totally	1871	21.61	15.59	158.00	0.00	
NO	March	186	21.73	15.57	81.42	1.25	0.001
	April	186	22.93	16.29	87.63	1.63	
	May	183	18.18	13.41	73.50	1.71	
	June	159	15.59	9.20	48.83	1.04	
	July	186	14.93	10.98	62.56	1.46	
	August	186	16.71	13.19	69.38	0.17	
	September	180	25.39	19.22	96.40	2.04	
	October	136	32.74	22.64	141.75	1.13	
	November	116	43.03	27.76	129.63	2.75	

	December	118	30.96	24.60	106.33	1.67	
	January	120	24.18	19.14	92.04	1.13	
	February	115	25.65	92.97	79.04	1.83	
	Totally	1871	23.27	18.94	141.75	0.17	
NO_2	March	186	28.00	16.91	79.92	5.46	0.001
	April	186	27.91	18.33	94.92	3.21	
	May	183	21.44	14.10	62.71	2.00	
	June	159	20.35	13.26	52.96	2.92	
	July	186	22.00	17.71	94.04	0.13	
	August	186	20.79	17.45	88.58	0.38	
	September	180	23.49	21.86	107.10	0.21	
	October	136	22.65	18.31	53.13	0.04	
	November	116	27.74	17.66	53.13	4.58	
	December	118	27.46	12.93	60.50	3.92	
	January	120	24.84	12.74	74.04	6.25	
	February	115	20.18	10.07	75.93	7.42	
	Totally	1871	23.83	16.79	107.20	0.37	
PM_{10}	March	186	135.21	137.67	1294.66	24.41	0.001
	April	186	139.40	105.04	765.23	0.00	
	May	183	171.86	144.76	1002.02	9.73	
	June	159	235.34	328.04	2758.02	19.35	
	July	186	140.98	69.16	527.42	8.76	
	August	186	131.42	96.53	1060.89	4.11	
	September	180	127.58	49.65	402.05	50.06	
	October	136	92.74	36.25	207.93	21.51	
	November	116	81.56	44.86	384.13	24.08	
	December	118	68.45	24.74	152.68	19.04	
	January	120	90.10	66.43	455.81	15.69	
	February	115	137.58	127.43	916.80	12.12	
	Totally	1871	133.81	137.75	2758.62	0.00	
SO_2	March	186	19.61	14.57	70.92	0.08	0.001
	April	186	15.86	9.09	37.96	0.21	
	May	183	22.56	15.09	88.13	0.83	
	June	159	27.26	12.38	136.04	0.21	
	July	186	28.16	18.31	101.76	4.04	
	August	186	29.18	17.95	97.08	7.58	

	September	180	30.55	22.16	156.46	6.13	
	October	136	20.50	6.24	39.33	5.75	
	November	116	23.28	6.17	37.67	8.83	
	December	118	20.96	5.42	58.37	6.16	
	January	120	21.16	6.24	44.00	3.33	
	February	115	19.04	5.13	39.21	4.25	
	Totally	1871	23.47	15.31	156.46	0.08	
CO	March	186	1.61	1.16	4.97	0.21	0.001
	April	186	1.83	1.46	8.08	0.21	
	May	183	1.31	0.93	5.66	0.21	
	June	159	1.36	0.77	3.91	0.23	
	July	186	1.45	0.71	4.39	0.40	
	August	186	1.52	0.83	4.31	0.39	
	September	180	1.85	0.91	4.31	0.32	
	October	136	2.47	0.98	5.48	0.35	
	November	116	2.59	1.05	5.65	0.65	
	December	118	2.02	0.91	4.41	0.21	
	January	120	1.91	0.94	4.43	0.21	
	February	115	1.71	0.98	4.43	0.25	
	Totally	1871	1.75	1.06	8.08	0.20	

Discussion

The results showed that the pollutant variations in years, seasons and month has significant changes ($P_{value}<0.0001$) and this shows that concentrations of these pollutants in the atmosphere depends on a lot of factors and variables. These factors can be related to the source of production, weather conditions, the state of transportation (vehicle inspection), heating in homes and offices and so on. A study conducted by Mansuri et al. also shows that the variations of O_3, SO_2, CO and PM_{10} concentrations in atmosphere of Shiraz had significant differences (10). The results also show the O_3 concentration variations decreased since 85 to 86 and then increased to 90 years, according to the years and dropped from heat to cold season. The results also show the O_3 concentration variations decreased since April to June, increased from July to November and again decreased from December to February. The highest average concentrations of O_3 were 39.34, 34.99 and 38.03 for 2011, summer and June respectively and the lowest average concentrations of O_3 were 13.05, 12.03 and 8.23 for 2006, winter and November, respectively. The reason for high levels of O3 in the hot season can be sun radiation and increasing of ozone producing photochemical reactions.

A study conducted by DA SILVA JÚNIOR RS showed that there is positive correlation between solar radiation and temperature with O_3 concentrations, So that whenever radiation intensity of solar is more than 500 Wm^{-2}, the concentration of ozone is more than standard (11).

The results also show the NO_2concentration variations based on years, decreased since 2006 to 2009 and then increased, and based on season decreased from summer to winter (decreased from warm to cold season). Based on month, this pattern increased from March to July, then decreased from August to November and again decreased. The highest average concentrations of NO_2 were 41.15, 32.44 and 43.03 for 2061, autumn and November, respectively and the lowest average concentrations of NO were 11.53, 15.78 and 14.93 for 2009, summer and July, respectively. Contrary to ozone, NO concentration in the warm season is lower than cold season and this is related to photolysis of NO by sunlight and conversion to ozone. Thus, the concentration of NO is lower in summer (11)The other reason for this phenomenon is the heating appliances of homes and offices and NOx caused by vehicles and entrapment it due to inversion in the air(12).Considering that urban NO_2 concentration is controlled by NOx emissions by burning process in factories, houses and traffic as well as by the proportion of O_3 / NOx, so the lower concentration of NO_2 in summer can be justified with these causes. A study conducted by Rozbicka K et al. shows that there is a significant correlation between O_3 and NOx concentrations with air temperature, relative humidity and sunlight (13). Bralić M et al. report that NOx concentrations in winter are higher than the other seasons (14).

The results also show the PM_{10} concentration variations based on years, increased since 2006 to 2009 and then decreased in 2010 and again increased to2011. Based on season from increased spring to summer and decreased from autumn to winter. Based on month, this pattern increased from February to June, then decreased from June to November and again increased. The highest average concentrations of PM_{10} were 169.05, 165.88, and 235.34for 2009, summer and June, respectively and the lowest average concentrations of PM_{10} were 89.63, 0.33 and 68.45 for 2006, winter and January, respectively. The reason of this issue can be the entry of dust in the months of February to July in the city of Kermanshah. It's also likely due to the increasing trend from January to March due to increased humidity and a temperature inversion in the city of Kermanshah in cold seasons. For those reasons, these changes cannot be considered irrelevant by atmospheric pressure differences.

Entrance of particulate matters from north-west, west and south-west leaded to high levels of PM10 concentrations in summer in Kermanshah. This result are consistent with Lelieveld and et al (2002) which north wind during summer transferred the pollutants from Europe to east of midtrial (15). Our findings are in disagreement with studies such as

Baraldo and et al (2006, Italy), Gu and et al(2010, China), Vassilakos and et al(2005, Greece) and Mohammadi et al(2007, Iran) (Because they reported the highest concentration of PN10 and attributed this to increase in humidity, biomass and charcoal consumption in buildings, heavy traffic and inversion (16-19). Although in Kermanshah it is assumed the input of particulate matters from neighbor country can increase the concentration of PM10 in winter, but PM10 concentration in summer is much higher than winter. This is in accordance with the study of Querol and Joksić that transfusion of particulate matters from Afirica, sea and south wind caused to increase the pm10 concentration in warm season comparing cold season (20, 21). The results also show the SO_2 concentration variations based on years, increased since 2006 to 2009 and then decreased in 1010 and again increased to1011. Based on season from increased spring to summer and then decreased. Based on month, this pattern increased from April to September and there is a variation in other months. The highest average concentrations of SO_2 were 43.69, 28.25, and 30.55 for 2009, summer and September, respectively and the lowest average concentrations of SO_2 were 12.10, 19.32 and 15.86 for 2010, autumn and April, respectively. Unlike the present study, Mulla EF et al (22) showed that the highest and lowest concentrations of SO_2 were found in winter and summer, respectively and it is related to proper management of traffic. But more concentration of SO_2 in summer in Kermanshah can be related to diesel cars and lower concentration of SO_2 in winter can also be due to precipitation. Our findings are in disagreement with Bralić M et al(14). So that they found the highest and lowest average concentrations of SO_2 in summer and winter, respectively. The results also show the CO concentration variations based on years, increased since 2006 to 2011and based on season from increased autumn to summer. Based on month, this pattern increased from August to November. The highest average concentrations of SO_2 were 2.59, 2.28, and 2.58 for 2006, winter and November, respectively and the lowest average concentrations of CO were 0.94, 1.45 and 1.31 for 2011, summer and August, respectively. High levels of CO_2 could be attributed to heating devices of buildings and also vehicle to heating. The study of Stephens (2008), showed the CO concentration due to decrease of factories activities and traffics in 1990 has been reduced. In the contrary of current study, the highest concentration of CO during 2001 to 2007 is reported in dry season (23).

Conclusion

According to the results and the increasing pattern of pollutants such as O3, NO and NO_2 from 2006 since then, these results represents an increase of cars and industries that it is necessary to develop appropriate arrangements to reduce travel within the city and take public transport system. Also according to the variations of pollutants in seasons and months, it is necessary to understand the causes of increasing and reducing the emissions is needed to Public education to deal, harm reduction and management measures.

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