INVESTIGATION OF THE LEVELS OF AIR CRITERIA POLLUTANTS EFFECTING ON HEALTH IN DOGONBADAN CITY AND DESCRIPTION OF AIR QUALITY USING AQI INDEX

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ABSTRACT

Introduction: *Urbanization and rapid industrial development along with enumeration of population result in development of a variety of pollutants in the environment. The aim of this study is determination of the air's health status relying on AQI index in Dogonbadan City.*

Materials and methods*: In this research, using the information provided by air quality monitoring stations of environmental protection organization of Dogonbadan City, the average concentration of air criteria pollutants (PM_{10}, SO_2, O_3, and NO_2) during different months and seasons of 2012-2013 has been investigated. The obtained concentrations were then converted to AQI index using AQI calculator software. Further, the averageconcentration of the mentioned pollutants was compared with the country's environmental organization standards.*

Results*: In general, during the years of 2012-2013, the air quality index was in a good and medium level (AQI<100) in 96% of cases, while in 4% of cases, it was beyond the standard limit. The PM_{10}, SO_2, O_3, and NO_2 pollutants had the greatest and slightest rules in the air pollution of Dogonbadan City. August was the worst month in terms of PM_{10} pollution, since in this month 30% of pollution status had lied within the range of hazardous and above, whereas for other pollutants in this month, new unhealthy status was observed.*

Conclusions*: Suspended particles were recognized as the major factor of air pollution in Dogonbadan City. Considering high levels of this pollutant, through timely notification, it is possible to prevent further complications for people with heart or lung diseases.*

Key words*: Air pollution, Air quality index, Dogonbadan City, Suspended particles.*

Received *June 30, 2015;* ***Accepted*** *January 02, 2016*

Introduction

With the ever-increasing rate of population growth, urbanization, rapid industrial and economic development and consumption of energy and transportation have also risen. This development has brought about numerous environmental problems including air pollution, where there problems naturally adversely affect human health(1,2). Clean air is an essential need for the health and welfare of human beings. However, air pollution is still a big threat to human health throughout the world. Air pollution includes the pollution of indoor and outdoor environment by any type of chemical with physical or biological agent, resulting in changes in the natural characteristics of the atmosphere. The household combustion appliances, motor vehicles, the industrial and fire equipment of forests are the typical sources of air pollution(3). The pollutants that cause health issues to humans include particles, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide. According to the report by World Health Organization, in 2012 around 7 million persons (one per every 8 mortalities) have lost their lives due to contact with polluted air. Low- and mid-income regions such as the Southeast Asian countries and the western regions of Pacific Ocean have claimed the highest rate mortality related to air pollution in 2012 with a total of 3.3 million deaths in indoors and 2.6 million deaths in the outdoors[4].

Air quality index is a key tool to become informed about the air quality, the way air pollution affects human health, and protective measures against air pollution[5,6]. Knowing the air quality status and the real level of pollutants, and describing it to general people that is easily understandable are some effective measures in the arena of air pollution of a region. Air quality index is an index for daily reporting of air quality. It demonstrates whether the air is in a healthy state or is hazardous with respect to health effects[7]. The American Environmental Protection Agency has selected six pollutants as the criteria. These pollutants include carbon monoxide, nitrogen dioxide, sulfur dioxide, and suspended particles with a diameter lower than 10 micron, lead, and ozone. Presence of each of these pollutants in the air respirator by humans can be dangerous to their health[8].

Ozone is a gas present in our respiratory air. Ozone pollution most probably occurs during warm months of the year, i.e. when climate conditions are typically well-suited for formation of ozone at the ground level. EPA considers the short-term effects of being in contact with ozone as coughs, sore throat, burning and discomfort of the chest during deep respiration, and short breath[9]. The sources that could produce ozone are automobiles, plants, industrial boilers, refineries, and chemical factories. People suffering from lung diseases including asthma, chronic bronchitis, and emphysema together with children and the elderly are more at risk of being in contact with ozone[10].

The health effects of PM_{10} particles depend on their physiochemical compounds. PM_{10} is of great importance in terms of health, since these particles have a high area and contain many numbers, and are able to carry other pollutants with themselves. The effects caused by these particles on human health are damage to the lung, lung tissue plus negative effect on respiration and respiratory system, cancer, and premature death[11,12]. In addition to these particles, they also adversely affect plants by damaging their fruits and flowers. They also significantly decrease the volume of crops, thus the majority of health and environmental problems are attributed to the particles. Furthermore, the particles severely limit the vision field. The sources that produce particles are motor vehicles, power generation plants, wood burning, forest fires, industrial activities, and other combustion processes[13].

When the fuels that contain coal and oil are burnt, SO_2 is produced. SO_2 is also produced by volcanoes, mine stones, and oceans, where humans produce it through combusting fossil fuels that contain sulfur[14]. In general, the highest level of sulfur dioxide is found in the vicinity of large industrial complexes. The major sources are power plants, refineries, and industrial boilers[15]. People with respiratory diseases such as asthma along with those working outdoors, are more exposed to these pollutants.

Around 90% of the entire nitrogen oxides produced by humans originate from combustion of various fuels. Approximately half of the nitrogen oxides are produced from fixed sources, while the rest is generated by mobile sources. In terms of health effects, nitrogen oxides are not regarded as health hazard, but their major problems in large metropolitan areas stem from their role in photochemical reactions that lead to smug, eventually resulting in formation of ozone and negatively affecting the humans and plants life. Burning sensation in the nose and throat, followed by short breath particularly in individuals suffering from asthma after being exposed to increased levels of SO_2 and NO_2 and some heavy metals are developed[16,17]. Therefore, the main objective of this research is determination of the air quality of Dogonbadan City during 2012-2013 using AQI index. By knowing the air quality states of this region and the main sources of air pollution, it is possible to take measures to plan what is required for controlling the air pollution and informing people about the daily status of their surrounding air.

Materials and methods

Study area and sampling

Dogonbadan City with a population of 91739 in 2011, is located within the Gachsaran region at the end of Iran's oil-rich region. This city is the capital of Gachsaran city and is situated 720 m above sea level with an area of 18 km^2, 157 km away from the capital of Kohgiluyeh and Boyer-

Ahmad province[18]. This city has a warm and dry climate. Due to the geographical position of Dogonbadan City and existence of large oil and gas resources around this city and in turn large traffic of vehicles and high consumption of fossil fuels, along with being positioned in the vicinity of Khuzestan Province have resulted in development of micro dusts and various pollutants in the respiratory air of people.

This research was cross-sectional study. First, the information about the hourly concentration of pollutants was obtained from the air pollutants measurement station of Dogonbadan City, owned by The Environmental Protection Organization. Then, wrong data (negative and zero numbers) and the data that might have been caused by local phenomena at the station site (the numbers that are not compatible with their previous or subsequent hours, based on the difference of over 5 times the concentration numbers with each other) were eliminated.

Thereafter, the hourly average of the concentration of air pollutants related to the ozone and nitrogen dioxide; PM_{10} and SO_2; and 8-hour ozone were calculated by Excel based on 1-h, 24-h, and moving average, respectively across various seasons of 2011 and 2012. The qualitative state of air by AQI is shown in Table 1.

The obtained concentration was then calculated by AQI calculator, where the AQI level was calculated for individual pollutants on a daily basis. Finally, the results were analyzed by Excel and descriptive statistics.

Values of Air Quality Index(AQI)	Levels of Health Concern	Meaning	Colors
0-50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	
51-100	Moderate	Air quality is acceptable however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	
151-200	Unhealthy	Everyone may begin to experience health effects members of sensitive groups may experience more serious health effects.	
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	
301-500	Hazardous	Health alert: everyone may experience more serious health effects.	

Table 1: Air Quality Index (AQI) for air pollutants.

Results

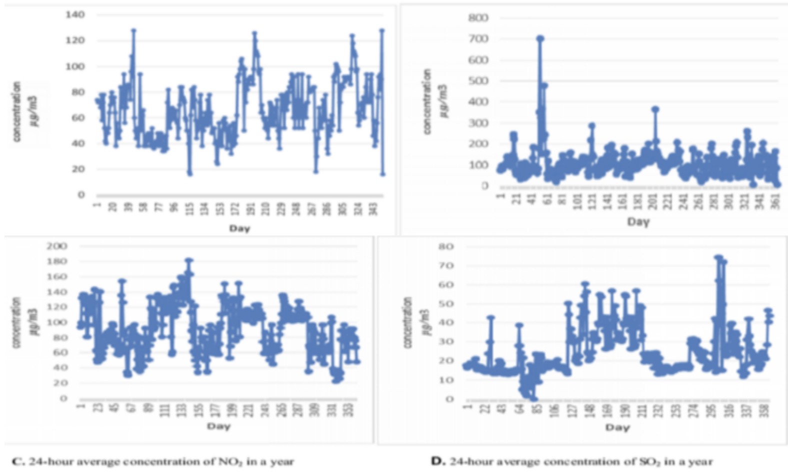

Fig. 1: Variations in the 24-h concentration of PM_{10}, SO_2, and NO_2 together with the 8-h concentration of O_3 during one year.

Variations in the 24-h concentration of PM10, SO_2, NO_2, and O_3 along with the 8-h concentration of ozone over one year of sampling are shown in Figure 1. In this Figure, the country's environmental protection standard related to the maximum allowable repetition for PM10 (50 μg/m3), SO_2 (50 μg/m3), 1-h concentration of NO_2 (200 μg/m3), and 8-h concentration of O_3 (100 μg/m3) can be observed.

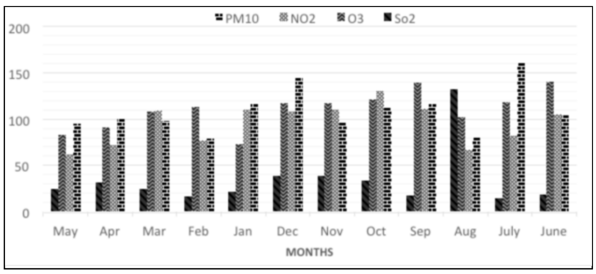

Fig. 2: Comparison of the mean values of PM_{10}, SO_2, NO_2, and O_3as μg/m3 during one year.

Figure 2 represents the average monthly concentration of PM_{10}, SO_2, NO_2, and O_3 over one year. Table 2 shows the obtained statistical results related to PM_{10}, SO_2, NO_2, and O_3.

S.D	Average	MIN	MAX	Number	months	pollutant
30.93	116	66.7	208.88	30	Jan	PM_{10}
38.66	79.44	21.25	176.74	30	Feb	
40.02	98.15	38.54	201.79	30	Mar	
62.25	101.2	6.38	262.75	30	Apr	
48.01	95.1	6.38	206.5	30	May	
46.44	105	34.54	245.5	30	June	
147.39	162.06	38	600	30	July	
34.3	80.84	21.42	153.29	30	Aug	
19.92	72.66	30.64	96.82	30	Sep	
38.93	112.06	50.42	196.17	30	Oct	
31.69	97.09	41.75	178.83	30	Nov	
50.56	145.44	87.92	366.17	30	Dec	
4.92	110.02	98.9	122.97	30	Jan	NO_2
23.68	77.13	44.93	79.71	30	Feb	
6.59	108.79	101.12	127.27	30	Mar	
17.55	71.6	34.87	106.74	30	Apr	
23.65	61.53	22.18	96.44	30	May	
30.68	105.18	47.94	139.3	30	June	
21.9	81.83	57.52	154.35	30	July	
19.92	66.72	30.64	96.82	30	Aug	
22.46	111.87	58.28	136.86	30	Sep	
27.12	130	61.47	181.23	30	Oct	
16.56	66.32	34.4	96.25	30	Nov	
27.44	108.58	53.35	151.34	30	Dec	
8.92	73.06	53.84	88.66	30	Jan	O_3
18.88	133.5	85.2	182.8	30	Feb	
14.54	108.18	77.6	144.4	30	Mar	
15.34	90.68	58.8	120	30	Apr	
15.5	83.26	22.8	104.4	30	May	
24.74	140.64	82.8	178.8	30	June	
32	117.98	4.8	164	30	July	
29.06	102.7	25.6	146.8	30	Aug	
25.52	139.32	93.4	178.8	30	Sep	
23.98	121.6	69.4	164	30	Oct	
27.14	117.08	80.2	187.2	30	Nov	
27.14	117.08	80.2	187.2	30	Dec	
6.86	21.14	13.07	48.12	30	Jan	SO_2
1.12	16.34	14.2	18.15	30	Feb	
6.15	24.1	14.09	42.23	30	Mar	
15.19	32.14	14.22	74.48	30	Apr	
8.51	24.47	11.81	46.76	30	May	
5.5	18.23	14.01	42.78	30	June	
1.65	14.82	12.94	20.25	30	July	
9.01	13.57	0	38.64	30	Aug	
1.54	17.08	13.33	20.8	30	Sep	
12.6	33.82	189.68	60.47	30	Oct	
8.14	38.33	26.17	56.95	30	Nov	
8.14	38.35	26.17	56.95	30	Dec	

Table 2: The statistical results related to the concentrations of PM_{10}, SO_2, NO_2, and O_3as $\mu g/m^3$ during different months.

Table 3 shows the air quality index over one year. According to this table, 30% of the cases related to PM10 lied within the range of high and hazardous limit, but SO_2, NO_2, and O_3 had no unhealthy state.

Discussion

According to Figure 1, a total of 322 samples of the concentrations of PM_{10} particles have exceeded the standards of the country's environmental protection organization, whereas the maximum allowable limit for repetition in one year is 7 times. The WHO's and EPA's standard for PM_{10} is 50 and 150 $\mu g/m^3$, respectively, where the level of these particles has been 322 and 55 days beyond the standard specified by WHO and EPA, respectively[19, 20]. The maximum 24-h concentration of PM_{10} during the sampling period was reported to be 600, 478.63, and 366.17$\mu g/m^3$ for Sunday, 12 August 2012, Friday, 17 August 2012, Sunday, 14 January 2012, respectively. Their corresponding AQI was 496 (hazardous), 367 (hazardous), and 217 (very unhealthy). The minimum 24-h concentration of PM_{10} during the sampling period was 6.38 μg/m3 and 6.38 $\mu g/m^3$ in 20 May and 20 June, respectively.

According to Figure 2, the maximum monthly 24-h concentration of PM_{10} was related to August equal to 162.06, while the minimum counterpart was related to March equal to 79.44. The average 24-h concentration of PM_{10} exceeded the WHO standard of 50 over the entire months, where it was larger than the EPA standard of 150 in August. In this research, PM_{10} average during the sampling period was obtained to be 109.12 $\mu g/m^3$. This finding is consistent with the results a study by Draxler et al. (2001)[25] which the maximum PM_{10} concentrations in Iraq, Kuwait, and Saudi Arabia were observed on calendar days 120 through 180 $\mu g/m^3$, corresponding to May and June[21].

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 PM10 and attributed this to increase in humidity, biomass and charcoal consumption in buildings, heavy traffic and inversion[22-25]. Although in Dogonbadan it is assumed the input of particulate matters from neighbor country can increase the concentration of PM_{10} in winter, but PM_{10} concentration in summer is much higher than winter.

According to Table 3, in terms of air quality index, PM_{10} particles lied within the range of 'good' only in 10% of cases during August, 'moderate' in 60% of cases, and 17, 7, 3, and 3% within the unhealthy levels for sensitive groups, unhealthy, very unhealthy, and hazardous, respectively.

May 2013		Apr 2013		Mar 2013		Feb 2012		Jan 2012		Dec 2012		Nov 2012		Oct 2012		Sep 2012		Aug 2012		July 2012		June 2012		Months / Characterization	
%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num		
17 100 90	5 30 27	17 100 97	5 30 29	17 100 6	5 30 2	23 93.3 86	7 28 26	0 100 3	0 30 1	0 96.6 40	0 29 12	7 93.3 10	2 28 3	7 100 16	2 30 5	3 100 30	1 30 9	23 100 10	7 30 3	10 100 90	3 30 28	10 100 13	3 30 4	PM_{10} O3 NO_2	Good (0–50)
73 0 10	22 0 3	63 0 3	19 0 1	76 0 94	23 0 28	70 6.67 14	21 2 4	90 0 97	26 0 29	77 3.34 60	23 1 18	90 6.67 90	27 2 27	80 0 84	24 0 25	87 0 70	26 0 21	77 0 90	23 0 27	60 0 10	18 0 3	83 0 58	25 0 18	PM_{10} O3 NO_2	Moderate (51–100)
10	3	20	6	7	2	7	2	10	3	23	7	3	1	13	4	7	2	0	0	17	5	7	2	PM_{10} O3 NO2	Unhealthy for Sensitive Groups (101–150)
																3	1			7	2			PM_{10} O3 NO_2	Unhealthy (151–200)
																				3	1			PM_{10} O3 NO_2	Very Unhealthy (201-300)
																				3	1			PM_{10} O3 NO_2	Hazardous (301-500)

Table 3: Classification of pollutants based on Air Quality Index.

This value related to sensitive groups including those suffering from heart and lung diseases, adults, and children along with those who are active outdoors for long periods of time, is unhealthy and hazardous. According to Table 2, after August, October was the worst month in terms of PM10 pollution, when air quality was 3% in good, 87% in moderate, and 10% in unhealthy conditions. Out of this 10%, 7% was unhealthy for sensitive groups and 3% was in an unhealthy state. This situation is highly dangerous for those working outdoors for long periods of time, especially children who are student, the elderly, and the people suffering from heart and lung diseases, forcing them to reduce their activity.

According to Figure 1, the maximum 24-h concentration of SO_2 during the sampling period, was related to 22 April with a value of 74.48 μg/m3. Based on the guideline and standard presented for SO2, WHO=20 $\mu g/m^3$ and EPA=196 $\mu g/m^3$, the obtained number was 191 days more than the WHO's guideline, but none of the cases exceeded EPA standard. According to the country's environmental protection guidelines for the maximum allowable number of repetition of every pollutant in a year, the obtained number were larger than the guideline's in 13 cases, yet the allowable repetition for one year is 3 times. According to Figure 2, the maximum 24-h concentration of SO_2 was related to January with 14.64 $\mu g/m^3$ and its minimum was observed in September with 5.61 $\mu g/m^3$.

Like the present study, Mulla EF et al[26] showed that the highest and lowest concentrations of SO_2 were found in winter and summer, respectively and it is related to traffic and inversion. The average of NO_2during the year of sampling was 34.28$\mu g/m^3$. Regarding NO_2, according to Figure 1, the maximum average of the 24-h concentration of NO_2 during the year was related to 10 November 2012 with 181.232 $\mu g/m^3$. Based on the guideline and standard presented for NO_2, WHO=200 and EPA=200 $\mu g/m^3$, the obtained numbers were lower than WHO's and EPA's across all the cases. The obtained AQI was also equal to 96 in the most polluted day, lying within the range of moderate states for sensitive groups. The minimum 24-h concentration of NO_2 during the year proved to be related to 23 May 2013 with 22.18 μg/m3 and 10 AQI, representing a good status. According to Figure 2, the maximum and minimum monthly average 24-h concentration of NO_2 during the year were related to November=130 $\mu g/m^3$ and June=61.53 $\mu g/m^3$, respectively. The average 24-h concentration of NO_2 across all of the year's seasons was lower than WHO and EPA standard.

Air quality index was lower than the standard limit (AQI<100) across all the cases, where 30% was good and 70% was moderate. Based on the country's environmental protection organization standard, the maximum allowable limit for repetition of every pollutant in a year for NO_2 is 200 $\mu g/m^3$, where no case exceeded this standard limit. The average of NO2 during the year of sampling was 89.81 $\mu g/m^3$. Bralić M et al. reported that NO_2 concentrations in winter are higher than the other seasons[27].

The maximum 8-h average of ozone during the sampling years was related to 7 March with 128 μg/m3. Based on the guidelines and standards specified for 8-h ozone: WHO=100 and EPA=150 $\mu g/m^3$, the obtained value has been 17 days more than the WHO standard, while it has always been lower than the EPA standard. AQI obtained in the most polluted day was 64, considered to be moderate in terms of air quality index. The minimum 8-h concentration of ozone during the year of sampling was related to 19 September with 16 $\mu g/m^3$. The respective AQI was 7, considered to be good in terms of air quality index.

Based on the country's environmental protection standard, the maximum number for repetition of each pollutant in a year for 8-h ozone is 100 $\mu g/m^3$ with 20 repetitions, where based on the obtained data, the values have excceded the standard limit for 17 times.

According to Figure 2, the maximum and minimum monthly average 24-h concentration of ozone during the period were related to June and February with 70.32 and 36.53 μg/m3, respectively. The average 8-h concentration of ozone in summer, spring, fall, and winter was 32.26, 31.64, 33.58, and 34.68 $\mu g/m^3$, respectively. These numbers are less than the standard presented by EPA and WHO. In terms of air quality index, O3 was lower than the standard limit in 100% of cases. The average level of ozone during the sampling year was 112.06 $\mu g/m^3$. In general, during 2012-2013, air quality index was in the range of good and moderate (AQI<100) in 96% of cases, and was beyond the standard limit in 4% of the cases. On the other hand, in situations beyond the standard limit, the responsible pollutant was PM10. Since there are large oil and gas resources around Dogonbadan City and there are the effects of development and due to presence of industrial activities, entrance of suspended particles to the city's air is quite high.

Based on the position of Dogonbadan City and closeness to Khuzestan Province, diffusion of micro dust to this region is high, resulting in increased number of suspended particles. On the other hand, meteorological parameters such as temperature and wind direction also affect the magnification of concentration of air's suspended particles.

Conclusion

Based on the results of this research, the concentration of NO_2, SO_2, and ozone particles has been lower than the standard limit in the majority of cases and their respective AQI values have been within the range of good and moderate. However, regarding PM_{10}, we observed increased concentration of the particles and pollutants in the warm season of the year in the majority of cases, where it was mostly beyond the standard level. Based on the obtained results, we observed elevation of the level of particles early and late in the weeks. Those suffering from heart and lung diseases, the elderly and children should stay home during these days. They should also minimize their activities and avoid long or heavy outdoor activities.

Little attempt has been done regarding the control of air pollution of this region and the resulting health issues, where currently we are observing numerous peaks of these pollutants across different seasons. Therefore, considering the significance of this issue and its relationship with people's health, it requires more careful inspection, awareness, and information to people about the quality of the air surrounding them. Based on what was discussed and the significance of conducting further research on air pollution together with the limitations of this research, it is recommended that in similar studies, the effects of meteorological parameters are investigated on the distribution of criteria pollutants, samples are taken from various regions of Dogonbadan City, are not limited to the installment site of sampling device, and the relationship between the pollutant sources and their concentrations are investigated.

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Acknowledgment
We highly appreciate the assistance of the officials and employees in the department of environment of Kohguiluye and Boyerahmad Province who greatly assisted us in implementing this plan.

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