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Monitoring and assessment the covariance of suspended particulates concentration levels over Kirkuk Governorate, Iraq

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ABSTRACT

Due to the health effects of suspended particulates matter in the air as well as consider a major concern for many of the major cities in Iraq and all over the world, so this study was designed to monitor, mapping and assess the extent of variability in the levels of suspended particulate matter in the air of Kirkuk governorate using statistic and Geographic Information System (GIS) techniques. Inverse distance weighting (IDW) interpolation method has applied for spatial spreading mapping of total suspended particulates at the study area. Also, the findings were aligned with Iraqi standards locally and the World Health Organization (WHO) International requirements. In addition, determine the most important factors contributing the increase of this pollution. The study was carried out by measuring the concentrations of suspended particulate matter in the air of Kirkuk governorate by relying on three fixed and main stations distributed over the Kirkuk governorate for a period of five years from January 2014 to January 2019. The annual concentration rate for 2014 at Layaln Station is 74.16 $\mu g/m^3$, 144.08 $\mu g/m^3$ at the Taza station, while 229.15 $\mu g/m^3$ at the Amal shaby station. The annual rate of concentration for particulate matter in the Layaln zone was within the specifications and determinants of Iraqi standards which identified by 150 $\mu g/m^3$ throughout the study period. However, when the results were compared with WHO standards, the annual concentration rate for 2015 exceeds the allowable limits which identified by 60 $\mu g/m^3$ to 90 $\mu g/m^3$. In Taza zone, we find that all annual concentrations were identical and within the limits allowed in the Iraqi specifications, however in 2014 and 2017 it exceeded the limits in the international WHO standards. While the zone of Amal shaby the measured annual rate exceeded both the Iraqi standards and WHO throughout the duration of the study except in 2018, the annual concentration rate of both Iraqi and international standards, all areas were within the limits permitted.

Key words : *Air Pollution, GIS, IDW, Interpolation, Suspended particulates*

Introduction

There is growing global interest in the negative effect of the increase in the concentration of air pollutant on humans. In addition, air pollution is considered a major component of health problems in developing countries (Brunekreef and Hogate, 2002). Air pollutants are substances suspended in the air that can be natural or man-made and maybe in the form of solids or liquid or gas droplets (Pope *et al*., 2013). The United State Environmental Protection Agency (EPA) has divided contaminants into microorganisms, volatile organic compounds, toxic gases and halogens. Suspended air minutes may be a mixture of solids, water droplets and liquid compounds in solids (U.S. EPA, 2012). Total suspended particulate (TSP) refers to all particles in the atmosphere. TSP ranges in size between 0.001 micrometers to 500 micrometers and, depending on their size and other characteristics may remain suspended in the air for a few seconds or indefinitely. Suspended particles can result from a variety of natural and human sources (Akimoto, 2003). These sources include road dust, industrial emission sources, vehicle exhaust emissions, soil, dust resulting from other human activities (i.e. agriculture), smoke from forest fires, smoke from recreational sources (i.e. campfires and fireplaces) (Medjber *et al*., 2016).

The studies conducted on the suspended Particulates in the air around the world, (Dionisio *et al*., 2010) Studied air pollution in the Accra city in Ghana, where they found that the highest concentration of dust particulates was in December and January as a result of the dust from the deserts. Moreover, the concentration of particulates with the size of (2.5 μm) between (39 μg/m^3) to (53 μg/m^3) in locations near the sides Roads, while the concentration was between (30 μg/m^3) and (70 μg/m^3) in residential areas. The concentrations of particulates of size (10 μm) ranged from (80 μg/m^3) to (108 μg/m^3) in locations near the sides Roads and from (57 μg/m^3) to (106 μg/m^3) in residential areas. (Gumrukcuoglu, 2011) studied the particulate matter (PM10) emissions in Kirkuk city for the period of (2013-2017). The data were obtained from forty-four measuring stations distributed in the study area.The results show that the PM10 emissions are clearly increased in the city's main entrances spatially near the checkpoints due to the exhaust emission from the large trucks and small vehicles. In addition, it was found that the higher pollution in the sampling location occurred near the North Oil Company (NOC), which was (460 μg/m^3). The annual average PM10 pollution obtained from all stations was about (120.8 μg/m^3).

(Mohammed *et al*., 2018) Studied the air pollution over AL-Kut city and the results show that the average monthly concentrations of (TSP) measured during the study period was (504.4 μg/m^3, 359.5 μg/m^3, 32.2 μg/m^3, 324.8 μg/m^3, and 392.45 μg/m^3) from November 2015 to March 2016. These results were significantly higher than the permissible allowable limits of the Iraqi national standard (350 μg/m^3) and international allowable limits (150 μg/m^3), except for January is founded (32.2 μg/m^3) within the acceptable limits due to heavy rainfall. (Ilyas *et al*., 2010) They studied air pollution in urban areas and its impact on public health in the Quetta city / Pakistan, and they found that the concentration of solid suspended particles exceeded the permissible limits, ranging from (170 μg/m^3) to (500 μg/m^3). This was attributed to the impact of the vehicles as well as the impact of factories, including brick factories located around the city.

GIS techniques offer the ability to integrate various data sets and also provide investigators with deeper understanding (Noori *et al*., 2019). A GIS allows for spatial analysis of different pollutant applications, and the findings are very valuable to decision-makers for taking remedial action (Liu*et al*., 2017; Noori, 2018). A new area of air pollution modelling has been developed by the creation of GIS spatial management (Jumaah *et al*., 2019). The objective of the present study is to monitor, mapping and evaluate the concentrations of suspended particulate matter in the air over Kirkuk city as well as illustrate the seasonal and annual variations of these concentrations.

Study area

Kirkuk city is located in the north of Iraq with geographic coordinate between (429082.1) to (455910.9) to the east, and (3908331.3) to (3935107.2) to the north. It lies on about (236 km) from Baghdad (capital of Iraq), and about (83 km) from Erbil (capital of Kurdistan, Iraq). The surface area of Kirkuk city is about (7247 km^2) and a population rate about (784444 capita). Kirkuk city includes the areas among the Zagros Mountains and the rivers of lower Zab and Tigris also it is bounded from the south with Himreen mountains chains, with represents the southern boundaries of submountain district besides the chain of hills (Kamal *et al*., 2018). Fig. 1. shows the location of Kirkuk governorate and the samples locations.

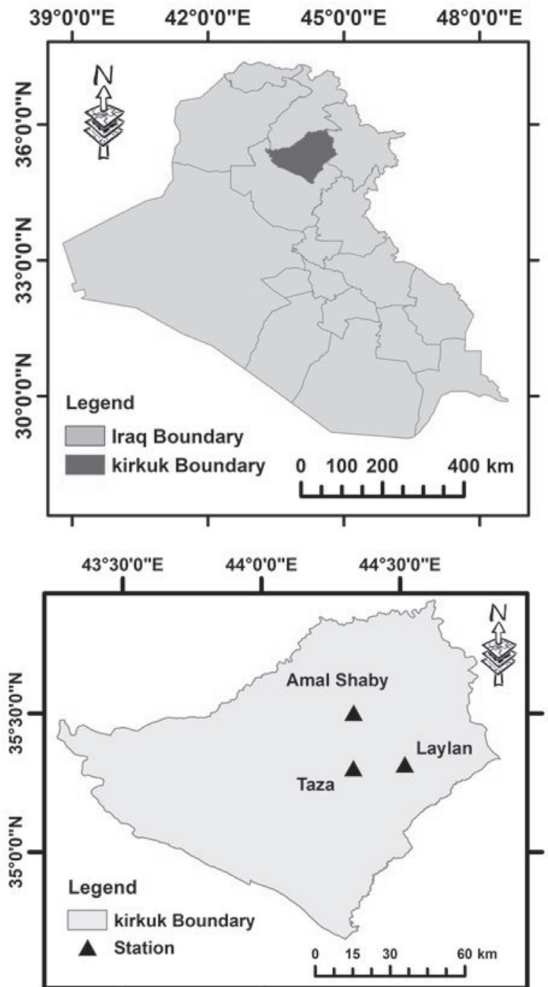

Fig. 1. The location of Kirkuk governorate and the samples locations in Kirkuk

Methodology

Data

The current work involved the collection of air pollution data of suspended particulates from three main stations in Kirkuk. Where, the measurement device of total suspended particulates was located in three sites in the Kirkuk province. These sites included the health center in Taza zone with geographical coordinates (35.30362 N, 44.33056 E), the health center in Amal shaby zone with geographical coordinates (35.50341 N, 44.33186 E), as well as the health center in laylan zone with geographical coordinates (35.31718 N, 44.51575 E).

Methods

The concentration measurements of total suspended particulates were collected for the period from January 2014 to January 2019. Concentrations levels of total suspended particulates were measured daily and 24 hours per day to cover the variation in the concentration of pollutants throughout the day, seven days a week for 61 months. After finding the monthly average for each month during the study period (61 months), the results that measured in situ for the study area were compared with the local Iraqi determinants and (WHO) (Mohammed *et al*., 2018). Table 1 illustrates the local specifications and determinants of Iraq and (WHO). Fig. 2 shows the type of device used in the current work to measure concentrations of air pollutants (total suspended particulates in the air) throughout the measurement period.

Fig. 2. Hi-Volume Air Sampler

Inverse Distance Weighted (IDW)

As one of the most common interpolation methods, IDW has been preserved. This is used to forecast values for any unmeasured place by calculating the expected location of the surrounding values (Ajaj *et al*., 2018; Mohammed *et al*., 2019). It is based mainly on two principles: Firstly, the effect of unknown point value is directly increased by far to a near-control point. Secondly, the degree of impact is directly proportional to the opposite of the distance. In this study IDW interpolation method has used to produce maps of suspended particulates concentration in the study area.

Results and Discussion

The results of the tests carried out to examine the Fig. 3. and Fig. 4. shows the variation in the concentration of suspended particulate matter in the air at 2014 over a period of 12 months in three stations distributed in Kirkuk governorate. The monthly concentration rate ranged from 15 μg/m^3 (lowest value) in July at the Layaln station to 587 μg/m^3 (highest value) in October in the Amal shaby station. The annual concentration rate for 2014 at Layaln Station is 74.16 μg/m^3, 144.08 μg/m^3 at the Taza station, while 229.15 μg/m^3 at the Amal shaby station.

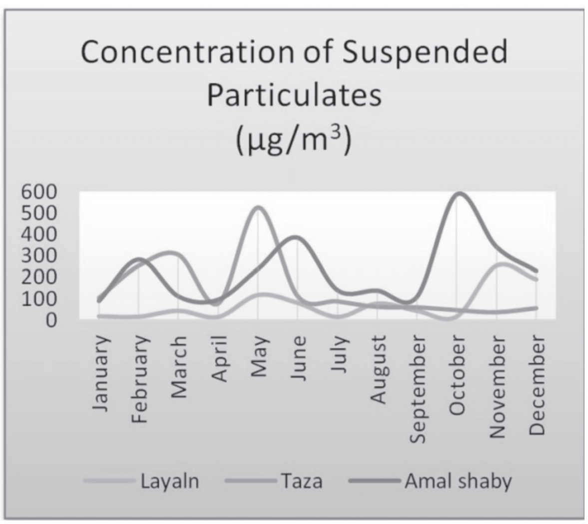

Fig. 3. Concentration of suspended particulates for the year 2014

The annual concentration rate for 2014 at Layaln Station is 74.16 μg/m^3, 144.08 μg/m^3 at the Taza station, while 229.15 μg/m^3 at the Amal shaby station. Comparing the results with the specifications shown in Table 1 above, the annual concentration rate at Layaln station was within the Iraqi determinants as well as the global determinants of the WHO. While in Taza station, the annual concentration of suspended particulate matter was within the Iraqi specifications while surpassed the restrictions allowed the WHO. At the Amal shaby Station, the annual concentration rate exceeded the limits and specifications allowed in the local Iraqi determinants as well as the international determinants of WHO.

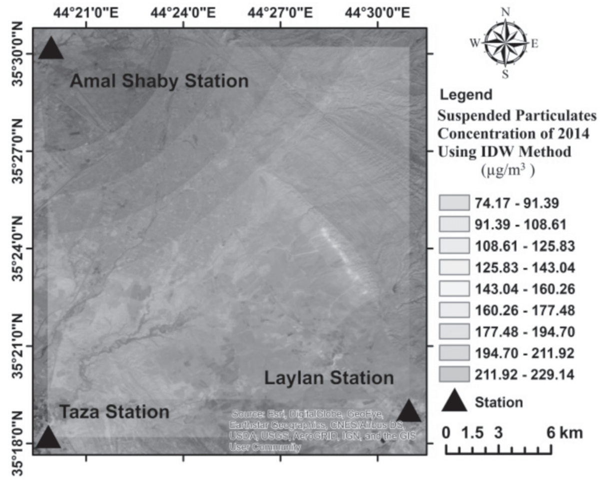

Fig. 4. Concentration of suspended particulates map for the year 2014 using IDW technique

The amount of variance in the monthly average concentration of suspended particulate matter in air at 2015 shown in (Fig. 5). However, (Fig. 6) shows the concentration of suspended particulates map for the year 2014 using IDW technique. The result illustrates that the lowest value was measured in March at Layaln station with average concentration 15 μg/m3, while the highest recorded value was in June in the Amal shaby station with average concentration 573 μg/m^3. The annual concentration rate at Layaln station was 139.91 μg/m^3 and considered to be within the limits allowed in Iraqi specifications but is not in accordance with international standards. At Taza station, the annual concentration rate was 67.5 μg/m^3 which is identical to both Iraqi and international specifications. While in the Amal shaby station, the annual concentration rate was 215.66 μg/m^3 which is exceeded the permissible limits in Iraqi

Table 1. local specifications and determinants of Iraq and (WHO).

Pollutant type	Period of Exposure	Iraqi Standards	WHO Standards	Standards Method of Analysis
TSP	24 hr.	250 μg/m^3	150 μg/m^3	Hi-Volume Air Sampler
TSP	1 year	150 μg/m^3	(60 - 90) μg/m^3	Hi-Volume Air Sampler

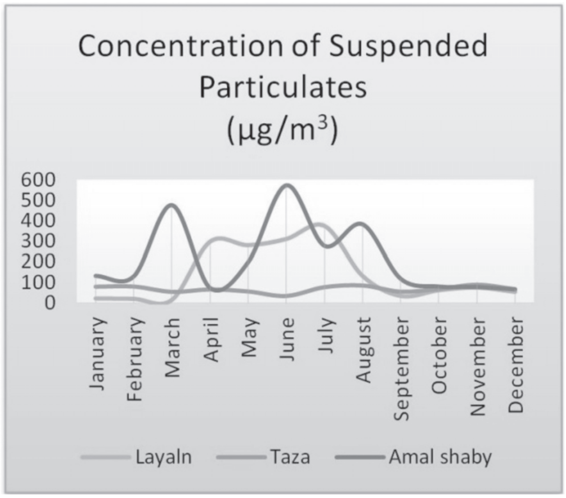

Fig. 5. Concentration of suspended particulates for the year 2015

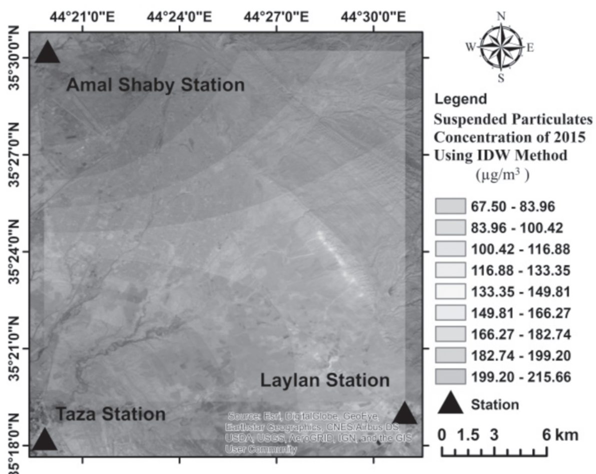

Fig. 6. Concentration of suspended particulates map for the year 2015 using IDW technique

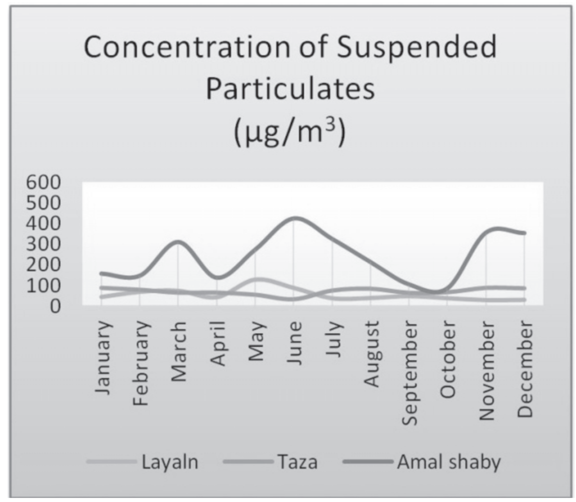

Fig. 7. Concentration of suspended particulates for the year 2016

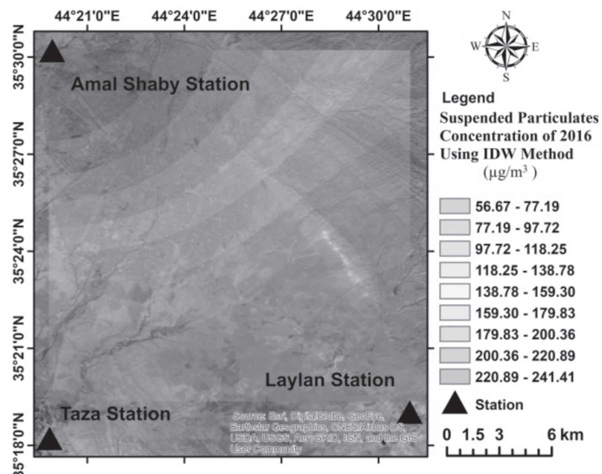

Fig. 8. Concentration of suspended particulates map for the year 2016 using IDW technique

and international standards.

The average monthly concentration of suspended particulate in the Layaln station ranged from 30 μg/m^3 in November 2016 to 129 μg/m^3 in May 2015 as shown in (Fig. 7 and Fig. 8.). At Taza Station, the monthly concentration ranged from 34 μg/m^3 in June 2016 to 89 μg/m^3 in November 2016, while the monthly concentration rates measured in the Amal shaby station ranged from 87 μg/m^3 during October 2016 to 425 μg/m^3 during June 2016 as shown in Fig. 7. The lowest monthly concentration of suspended particulate matter during 2016 was in the Layalnstation at a rate of 30 μg/m^3 during November, while the highest monthly concentration rate was 425 μg/m^3 in the Amal shaby station during June. The annual concentration rate was within the limits allowed in the locally Iraqi standards and the global standards WHO at Layaln and Taza stations. While in Amal shaby station the annual concentration rate was higher than the allowable bounds in the Iraqi and worldwide conditions.

During 2017, the average annual attentiveness of the suspended particulates at Layaln station was 43.08 μg/m^3 and this rate is within the limits allowed in the Iraqi specifications as well as the international specifications of the WHO. In Taza station, the annual concentration average rate was ing water results from laboratory tests. 127.83 μg/m^3 is considered to be within the permitted Iraqi specifications, but it exceeded the international limits. While in Amal shaby station, the annual concentration rate was 243.41 μg/m^3, which is not identical and is not allowed in the Iraqi specifications as well as the international specifications of the WHO. The monthly variation of the concentration of airborne particulate matter for 2017 is shown in Fig. 9. and 10.

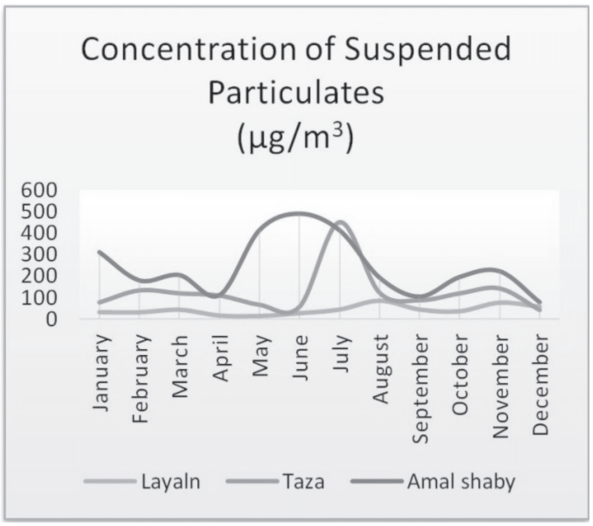

Fig. 9. Concentration of suspended particulates for the year 2017

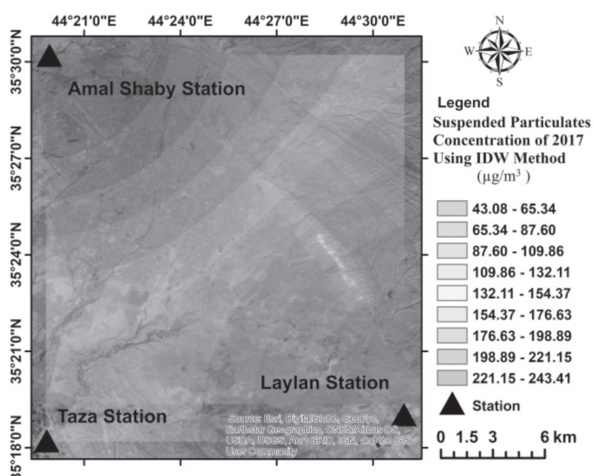

Fig. 10. Concentration of suspended particulates map for the year 2017 using IDW technique

The monthly average of concentrations are ranged between 15 μg/m^3 (lowest value) in the Layaln station during May to 490 μg/m^3 (highest value) in Amal shaby station during June.

(Fig. 11. and Fig. 12.) show the extent of variability in the monthly rates of concentration for suspended particulate matter in the air over Kirkuk province in 2018. The monthly concentration rates at Layaln station ranged from 5 μg/m^3 in August to 65 μg/m^3 in January.

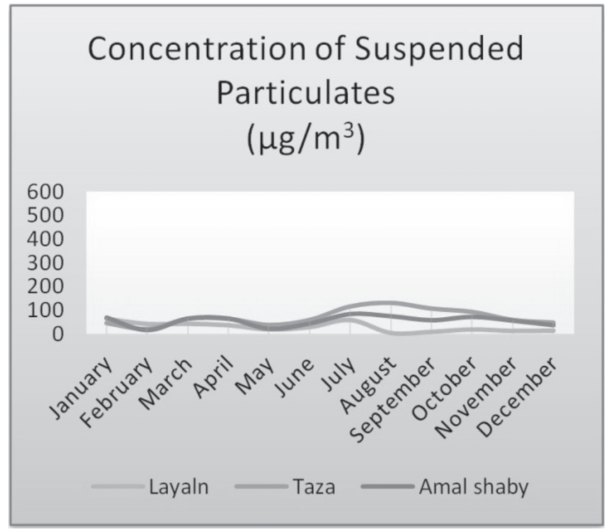

Fig. 11. Concentration of suspended particulates for the year 2018

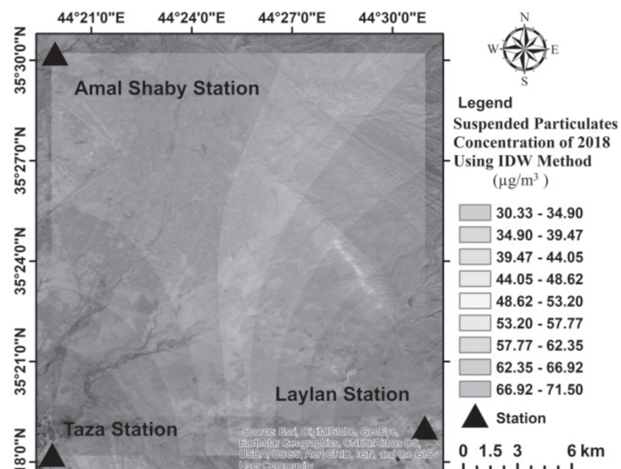

Fig. 12. Concentration of suspended particulates map for the year 2018 using IDW technique

In Taza station, the monthly average of the concentration for the suspended particulates ranged from 22 μg/m^3 in February to 132 μg/m^3 in August. While in Amal shaby Station, the monthly concentration rate was 17 μg/m^3 February to 85 μg/m^3 through July. When comparing the annual rates of atmospheric particulate concentrations for 2018 in Kirkuk governorate with the Iraqi standard and WHO standard, it was found that the annual rate of concentration measured in all stations was within the permitted

The results of the present study show the monthly concentration rate ranged from 15 µg/m^3 (lowest value) in July at the Layaln station to 587 µg/m^3 (highest value) in October in the Amal shaby station. The annual concentration rate for 2014 at Layaln Station is 74.16 µg/m^3, 144.08 µg/m^3 at the Taza station, while 229.15 µg/m^3 at the Amal shaby station. In 2015, the lowest value was measured in March at Layaln station with average concentration 15 µg/m^3, while the highest recorded value was in June in the Amal shaby station with average concentration 573 µg/m^3. The lowest monthly concentration of suspended particulate matter during 2016 was in the Layaln station at a rate of 30 µg/m^3 during November, while the highest monthly concentration rate was 425 µg/m^3 in the Amal shaby station during June. The monthly variation of the concentration of airborne particulate matter for 2017 are ranged between 15 µg/m^3 (lowest value) in the Layaln station during May to 490 µg/m^3 (highest value) in Amal shaby station during June. For the year 2018, the monthly concentration rates at Layaln station ranged from 5 µg/m^3 in August to 65 µg/m^3 in January. In Taza station, the monthly average of the concentration for the suspended particulates ranged from 22 µg/m^3 in February to 132 µg/m^3 in August. While in Amal shaby Station, the monthly concentration rate was 17 µg/m^3 February to 85 µg/m^3 through July. The annual rate of concentration for particulate matter in the Layaln zone was within the specifications and determinants of Iraqi standards which identified by 150 µg/m^3 throughout the study period. However, when comparing the results with WHO standards, the annual concentration rate for 2015 exceeds the allowable limits which identified by 60 µg/m^3 to 90 µg/m^3. In Taza zone, we find that all annual concentrations were identical and within the limits allowed in the Iraqi specifications, but it surpassed the bounds allowed in the WHO for the years 2014 and 2017. While the zone of Amal shaby the measured annual rate exceeded both the Iraqi standards and WHO throughout the duration of the study except in 2018, the annual concentration rate of all areas were in the bounds allowed in both the Iraqi and WHO.

Conclusion

This study shows that the annual rate of concentration for particulate matter in the Layaln zone was within the specifications and determinants of Iraqi standards which identified by 150 µg/m^3 throughout the study period. However, when comparing the outcomes with WHO standards, the annual concentration rate for 2015 exceeds the allowable limits which identified by 60 µg/m^3 to 90 µg/m^3. In Taza zone, we find that all annual concentrations were identical and within the limits allowed in the Iraqi specifications, but it surpassed the bounds allowed in the WHO for the years 2014 and 2017. While the zone of Amal shaby the measured annual rate exceeded both the Iraqi standards and the WHO specifications throughout the duration of the study except in 2018, the annual concentration rate of all areas have in the bounds allowed in both the Iraqi and global specifications. We conclude from the present study that the majority of high concentrations of suspended particulates in air of Kirkuk governorate is due to several reasons, the most important one is traffic congestion, and emissions from the chimneys, the uncleaned streets that full by dust which volatiles with the wind. As well as the lack of green areas and high trees around and inside the province of Kirkuk which, in turn reduce the impact of wind in increasing the concentration of pollutants in the air.

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