EMJ MS
EUROPEAN MULTIDISCIPLINARY JOURNAL OF MODERN SCIENCE
ISSN 2750-6274 https://emjms.academicjournal.io Volume: 13 | Dec-2022

# Evaluation of Particulate Matter Air Pollution over Iraq using Copernicus Dataset and GIS

***Sabah Hussein Ali***
*University of Mosul, Remote Sensing Center, Mosul, Iraq*

**Abstract**: Air pollution is one of the most serious environmental issues confronting the world today. Particulate matter (PM2.5) pollution is a type of air pollution that is hazardous to both the environment and people. It is a suspension of solid or liquid particles in the atmosphere and is also known as aerosols. The majority of PM2.5 emissions come from cars, trucks, and operations that burn fuel or coal, as well as natural sources like forest fires and herbs. The present study focus on the PM2.5 concentration in Iraq for the period) January 1, 2020 to December 31, 2020) depending on the PM2.5 dataset downloaded from the Copernicus Atmosphere Monitoring Service (CAMs). It is found that the higher PM2.5 concentration was occurred in Spring with maximum value of (112.49 µg /m3) at the west area of Iraq (especially in Governorate of Anbar), while the lower PM2.5 concentration was occurs in Winter with a values of (95.39 µg /m3) at Governorates of Ninawa, Kirkuk, Salahaddin and Anbar. Also, it's found that, the annual average PM2.5 concentration of Iraq was ranging (11.17- 83.40µg/m3). The study's findings revealed the impact of climatic factors, particularly winds, on the amount and direction of particle concentration spread in Iraq as well as a different sources of pollutants. Also, indicates that, the annual average level of PM2.5 concentrations exceeded the WHO and Iraqi standards annual mean values.

**Keywords:** PM2.5, NetCDF, ArcGIS, Iraq, CAMs.

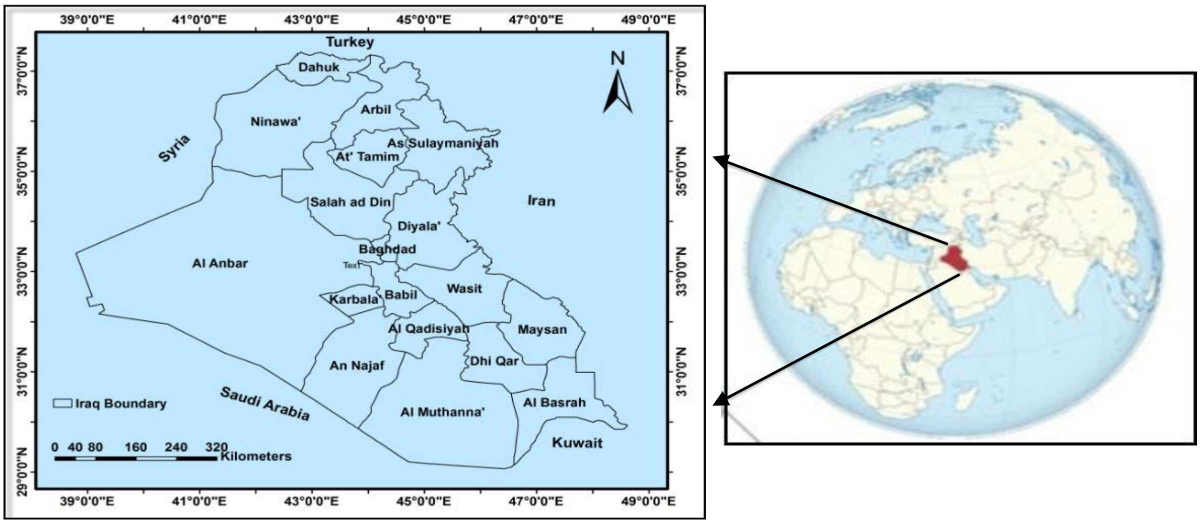
## Introduction

Air pollution is a global key issue in the fields of health and the environment, affecting both the economic and social life at the same time. Air pollutants having a diameter of 10µm and 2.5µm or smaller are included in air pollutants that have negative health impacts, especially in urban regions (Francis, 2016). Particulate matter (PM) represents an excellent index for other air pollutants as well as its impact on public health is more effective than other pollutants. PM of 2.5 µm (PM2.5) or less can be emitted directly from sources like forest fires, or they can formed in the air when gases generated from power plants, factories, and automobiles react. Since PM2.5 is very small, so it remains in the air and can travel for long time (Hassony and Zaid, 2010). PM10 or less are classify as coarse dust particles can be found in the sources of crushing and grinding activities, as well as dust stirred up by vehicles traveling on highways. The presence of PM in the atmosphere decreases visibility range and influences cloud formation, which impacts the process of heat transmission in the air, and so they can be considered to contribute to climate change (Kossay and Hussain M. O., 2015). In Iraq, both the transportation and electric power generation sectors (particularly local generators) contribute significantly to air pollution, causing severe environmental problems (Zainab et al., 2019). The continuous burning of oil fields creates natural gas, resulting in significant amounts of emissions linked to Iraq's deteriorating air quality. The use of low-quality fuel in transportation, power production, and the industrial companies, as well as emissions from industrial facilities, dust storms, open waste burning, and an increase in illegal logging, are all contributing to the urban air pollution (Abbas and Abbas, 2021). Furthermore, the use of low-quality fuel in transportation, power production, and the industrial companies, as well as emissions from industrial facilities, desert dust and storm, open waste burning, and an increase in illegal logging, also all contributing to the urban air pollution. Regardless of the sources of pollution by the PM, there is a lack of instrumentation and pollution monitoring networks that can determine the concentration levels of air pollution with these particles, as well as their negative impact. Therefore, most countries in the world are currently dependent on satellite dataset as well as ground stations for air quality monitoring and forecasting services like, Copernicus Atmosphere Monitoring Service (CAMs) for providing timely, accurate, and quality-controlled information which helps preventing the negative effects of the air pollution (Areti. and Ioannis, 2021). The aim of the present study is to analyze the spatial variation of air pollutions by PM2.5 concentrations in Iraqi for a period of one year, from January 1, 2020 to December 31, 2020, by using remote sensing dataset and GIS. All the data adopted in the present study were downloaded from CAMs website (https://atmosphere.copernicus.eu/data, 2022).

## Study area and climate

The study area covered the entire country of Iraq, which located in Asia's south-west, northeast of the Arab homeland. It's extended from latitudes of (29°04'N-37°23'N), and longitude of (38°50'E-48°32'E), Fig. 1. The total area is 438,317 km2 and the population is about 39,309,783. The terrain elevation of the study area is range from 0 m (Mean Sea Level) at Arabian Gulf to about 3607m at Halgurd Mountain (https://worldpopulationreview.com/countries/iraq/location, 2022).

**Figure (1): Location of the study area**




In general, the climate in Iraq is cold in winter, with few rains, and hot–dry in summer, with a few dusty storms. This climate increases the temperature and enlarges Iraq's desert land (Kadim, 2012). The monthly average temperatures range from above 48 °C in July and August to below zero in January. The most of the precipitation falls between Winter and Spring, this is because the study area is located in the air depressions coming from the Mediterranean, which affect the climate of Iraq. The average annual precipitation of (100-180 mm) (Sabah et al, 2015). Precipitation is heavier in the northern mountainous region than in the central and southern regions. Fig.2 illustrates the mean annual temperature of Iraq for the period (1901-2020) as retrieved from the era 5 reanalysis of ECMWF (https://www.ecmwf.int/en/forecasts/datasets, 2022), while the Fig.3 illustrates the annual mean of the precipitation for the same period. The red line of the figures refers to the year 2020. The conditions of air pressure and winds in Iraq are affected by two main actions for pressure in the summer, where the low pressure zone is concentrated in the Indian subcontinent and Arab Gulf with a high pressure area above the Anatolia Plateau, so the prevailing wind in Iraq is northwesterly and a portion of the southeast (Abdulaziz, 2006). Fig.4 shows that the average wind speed is about 5 knot (9 m/s) for the year of (2020) as reported by (https://www.weatheronline.co.uk, 2022).

**Figure (2): Annual mean Temperature of the Study area**

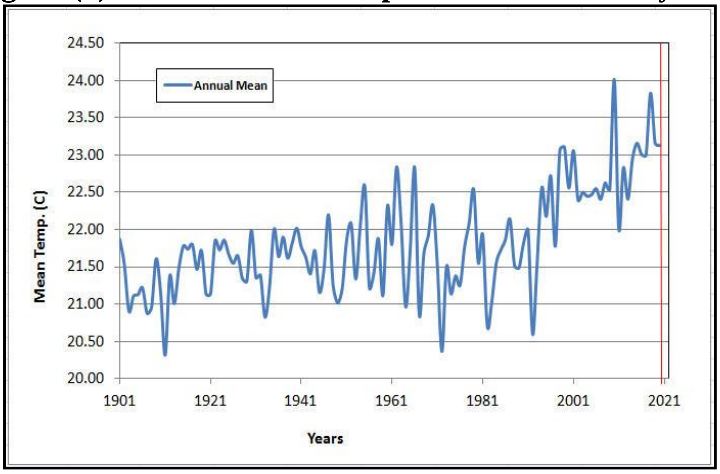



**Figure (3): Annual mean Precipitation of the Study area**

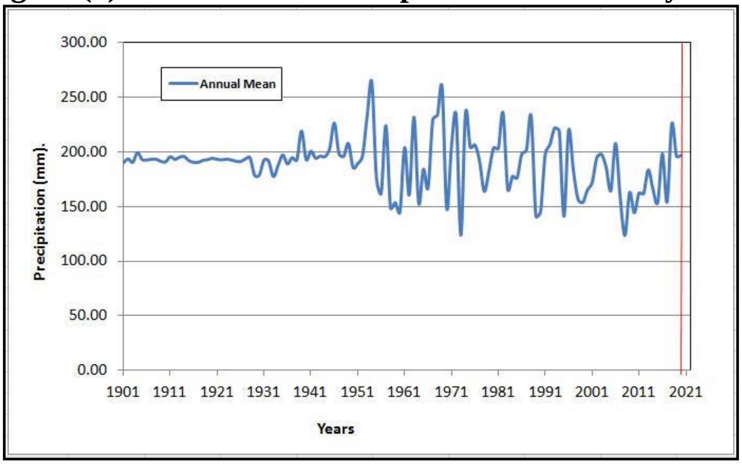
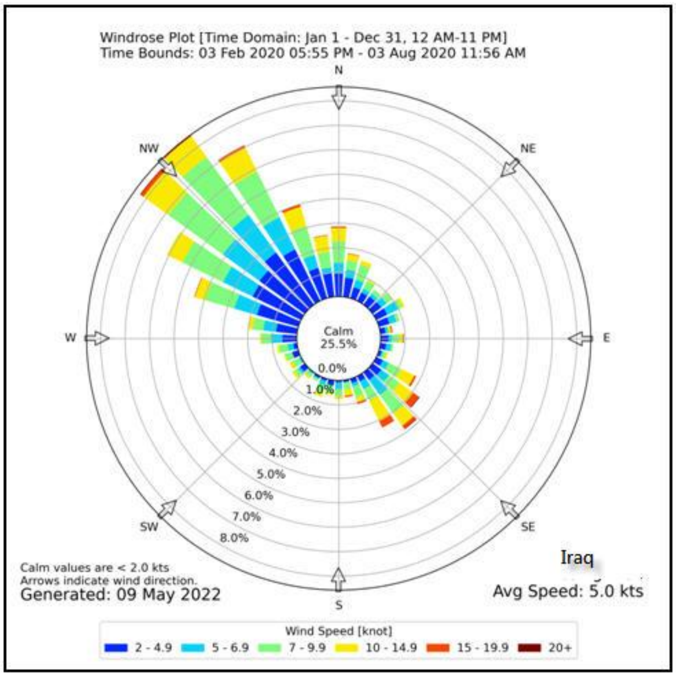



**Figure (4): The Figure 4: wind rose plot of Iraq in 2020**



## Methodology

### Dataset

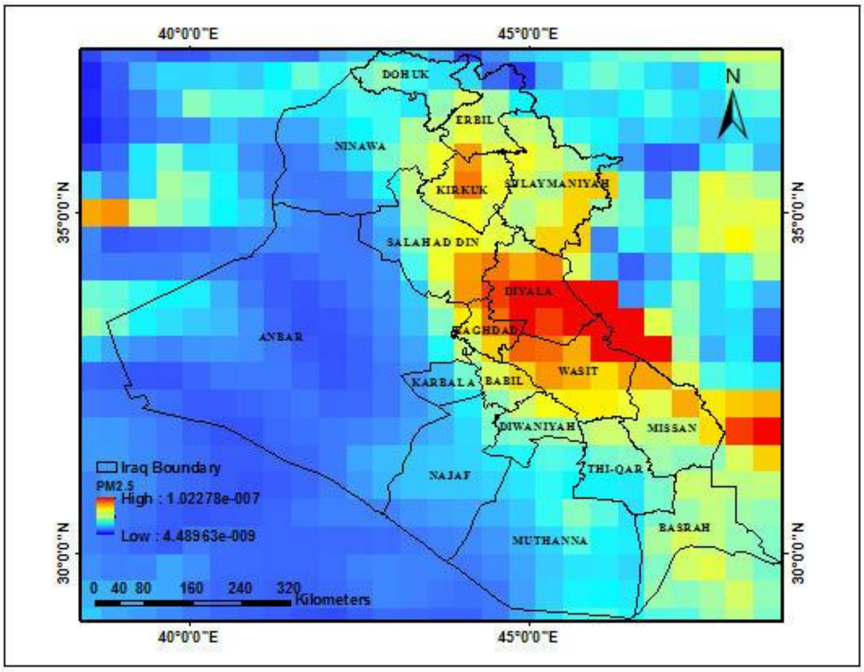
Due to the lack of automatic monitoring network for the air pollution in all of Iraq Governorates, the PM2.5 dataset applied in the present study were downloaded from Copernicus Atmosphere Monitoring Service (CAMS) of the European Center for Medium-Range Weather Forecasts (ECMWF) which is based on satellite data [https://atmosphere.copernicus.eu/data, 2022]. CAMS simulates the concentrations levels and dispersion of air pollutants that affect the atmosphere layer, which is essential for understanding its processes. This public platform offers global forecasts for common air pollutants. CAMS dataset of PM2.5 concentrations are obtained with 0.1degree (~10 km) horizontal resolution**.** The data were measured in (Kg/m$^3$)) and delivered in the form of Network Common Data Form (NetCDF). The NetCDF file format is very flexible and is an interface to a library of data access functions for storing and retrieving data in the form of multidimensional scientific array (variables). It's contains "PRODUCT" group that supplied the primary data parameter, such as latitude, longitude, and a variable to calculate the observation time and dimensions for the other required data [Layali and Sabah, 2021]. The NetCDF format of the air pollution (such as PM2.5) can be displayed in ArcGIS by making a spatially layer.

### Methods

In the present work, ArcGIS was used for mapping the spatial distribution of the PM2.5 in Iraq. The downloading data of the PM2.5 was in NetCDF format for the months from January to December, 2020. ArcGIS was deals with the NetCDF data through the Multidimension Tools in the ArcToolbox Window by the following procedure:

ArcToolbox------ Multidimension Tools-------- Make NetCDF Raster Layer, then the NetCDF files, the variable of the PM2.5, longitude (X Dimension) and latitude (Y Dimension) were selected for mapping the spatially distribution of the PM2.5 concentration level for each months of the 2020. Fig. 5 shows a sample of the output map before the resembling process.

**Figure 5: PM2.5 concentration map form the NetCDF data**



## Results and Discussions

It is well known that particulate matter with diameters of (2.5) stay in the air for an extended period of time. PM2.5 deposit rate is relatively slow and is affected by the prevailing climatic (Seinfeld and Pandis, 2022), natural conditions such as moisture, wind, heat, and others, for example, temperature influences fuel consumption (emissions) and chemical reactions in the atmosphere while precipitation causes wet deposition, which removes air pollutants from the atmosphere. Also, It should be referred that the wind speed and its direction is an important factor that affecting (PM) concentrations and its source apportionment, high wind speeds contribute to the plume of PM, but in some cases, an area's topography can also impede the transport of PM2.5 to other regions. The wind speed varies throughout the year, with the maximum occurring in the summer and the lowest occurring in the winter due to low temperatures and an increase in rain, resulting in cold winds and relative calmness. By using ArcGIS package, all the output concentration maps in the form of NetCDF are resample to bilinear interpolation for continuous dataset and to show clearly the distribution of the PM2.5 over the study area. As shown in Fig. 6, the concentration of PM2.5 in the Summer season (June, July and August, 2020) are relatively much higher. A comparison between PM2.5 data concentration for the two seasons (Fig. 6a and Fig.6b) indicates that the PM2.5 have much higher concentrations in Summer than for the Winter season (December, January and February,2020). The concentration levels ranging from (15.47- 110.03µg/$m^3$) in Summer, while in Winter ranging from (7.63-95.63µg/$m^3$). This is because higher temperatures cause more excess moisture to evaporate, which helps to dry out the dust particles, reduces their weight, and thus increases the chance that they will volatilize. As a result, the concentration of PM2.5 rises as temperature rises (Saleh, and Al-Tai, 2015). In the case of low temperatures, high humidity and rain in the cold months, this will lead to washing the air from particulate matters Therefore, it's found that the concentration of PM2.5 in the winter is lower than in the summer as shown in Fig.6b. From Figures (6a and 6b), it's notice an increase in the concentration of PM2.5 in the governorates of Nineveh, Salahuddin and Anbar, which indicates the large number of sources of pollution with these particles due to the lack of rain and the increase in the percentage of uncultivated lands, which is an important source of pollution with suspended particles, especially when the winds transport the Soil, dispersal of dust and PM2.5. According to the figures(6a and 6b), Iraq's western and northwestern regions are look like to be affected by the pollution that is coming from Syria's eastern side.

The pollution level for the spring season (March, April, and May, 2020) is (4.47-112.69 µg/$m^3$), as shown in Fig. (6c). It also note the spread of PM2.5, particularly in Anbar Governorate, and the source may be the Western Desert, as well as the impact of climatic factors on the spread of these particles. The figure also depicts the presence of a small percentage of PM2.5 scattered along Iraq's eastern border with Iran.

Fig. (6d) shows the ranging concentration levels of the PM2.5 (17.10-108.10 µg/$m^3$) for the Autumn season (.September, October and November, 2020). At this season, temperatures begin to gradually decrease, and the weather begins to moderate gradually and tends to cool, which also affects the reduction in the spread of suspended particles. Fig. (6d) illustrates the focusing of PM2.5 particularly in the middle of Iraq, due to the relatively high temperatures, as well as the pollution resulting from the exhausts of various vehicles, which exceed the absorptive capacity of the roads, as well as the burning of agricultural and industrial waste, which leads to rise these pollutants to the top.

**Figure 6: The Seasonal concentrations of the PM2.5, 2020**

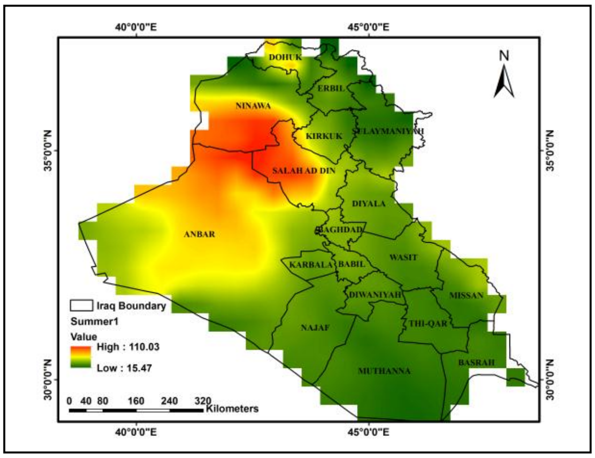



Figure 6a: PM2.5 concentration in Summer

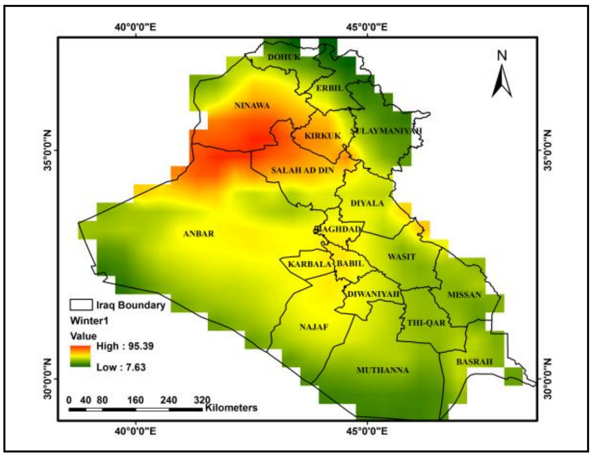



Figure 6b: PM2.5 concentration in Winter

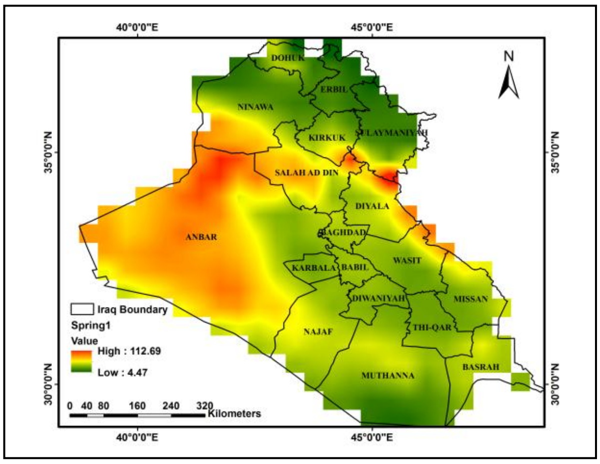



Figure 6c: PM2.5 concentration in Spring

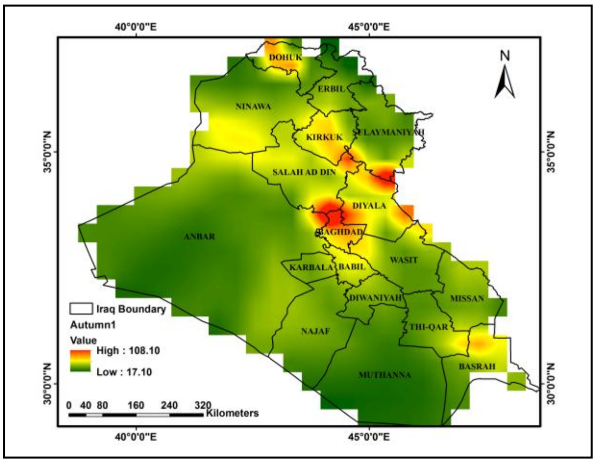



Figure 6d: PM2.5 concentration in Autumn

Finally, the annual average concentration of the PM2.5 for all Iraq area was shown in Fig. 7., the concentration level ranging from (11.17-83.40 µg/m$^3$). The figure illustrates that the study area is affected by dust storms from Syria and, to a lesser extent, the western desert. it's observed that the concentration is focused in the Ba'aj and Hatra districts in the south of Nineveh Governorate, northwest of Salahuddin, and north of Anbar.

**Figure 7: The Annual concentration of PM2.5**

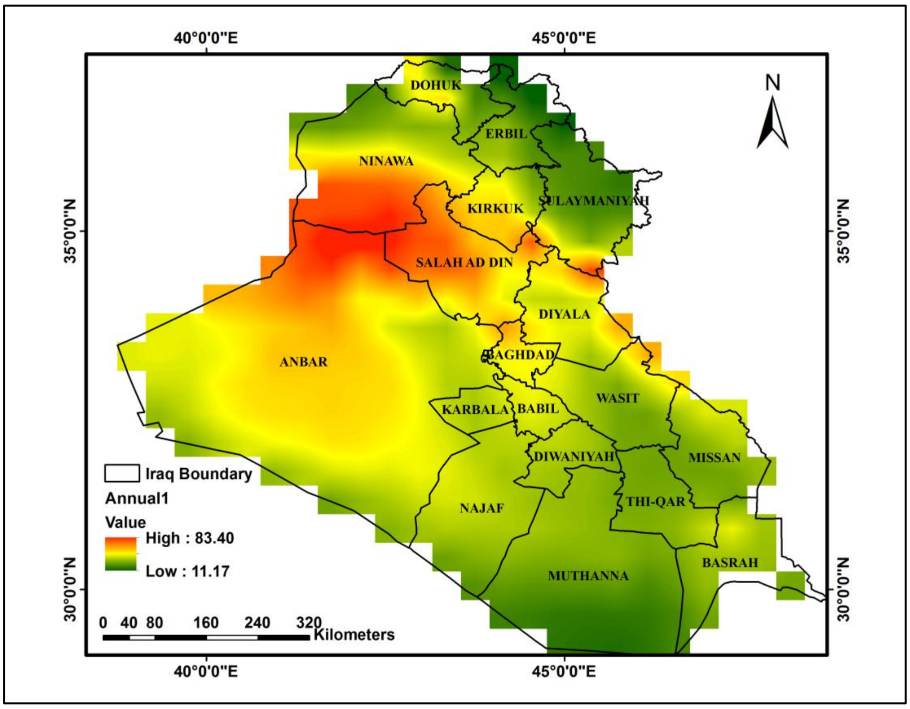
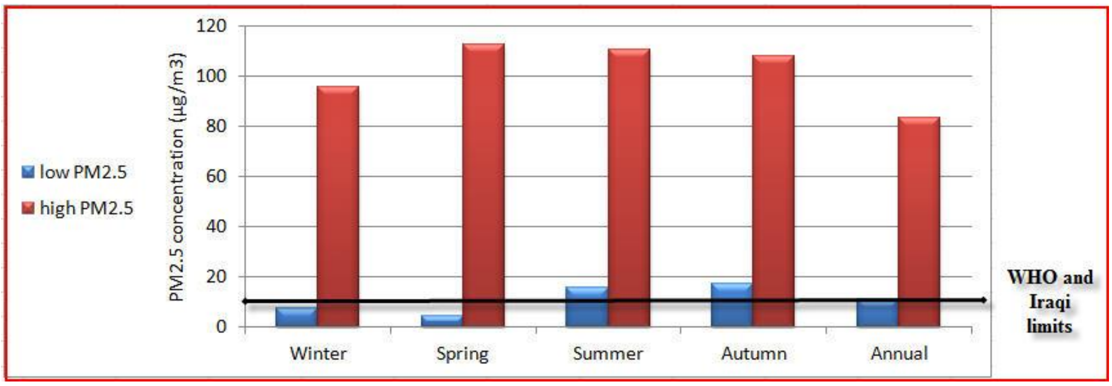



**Table (1) summarize the ranging values of the seasonal and annual PM2.5 concentrations for the Iraq at the period of (January 1, 2020 to December 31, 2020)**

| Seasons and Annual PM2.5 concentration | Min. (μg/m$^3$) | Max. (μg/m$^3$) |
|---|---|---|
| Winter | 7.63 | 95.39 |
| Spring | 4.47 | 112.49 |
| Summer | 15.47 | 110.3 |
| Autumn | 17.10 | 108.10 |
| Annual | 11.17 | 83.40 |

Figure (8) shows the exceeding of the seasonal and annual concentrations upper limits (PM2.5) in the study area with respect to the annual mean of (WHO) and Iraqi limits values (10 μg/m$^3$) (https://www.euro.who.int/sdgs, 2018].

**Figure 8: Comparison of Seasonal and annual PM2.5 concentrations with the WHO and Iraqi Limits**




One of the main reasons for the high concentrations of suspended particles in Iraq is the diversity of sources of pollution with these particles, including the drought caused by lack of rain, which in turn led to the spread of large areas of desertification, as well as the effect of atmospheric depressions that intensify the winds and the arrival of the effect of dust storms coming from the deserts of the Arabian Peninsula, as well as the Western Desert in the west of the study area. Also, don't forgetting the human activity sources represented by gases emitted by oil, factories, hospitals, and burning fields, waste, increased use of fossil fuels, and a lack used of clean energy**.**

## Conclusions

From the results of the present study, it can concluded that:

1. The study's findings revealed the impact of climatic factors, particularly winds, on the amount and direction of particle concentration spread in Iraq as well as a different sources of pollutants.
2. The concentration levels of PM2.5 in Summer was (15.47- 110.03µg/$m^3$) which higher form the PM2.5 ranging values in Winter (7.63-95.39µg/$m^3$ ), Winter was the lower pollution with PM2.5. The PM2.5 pollution of the two season were focusing in the governorates of Nineveh, Salahuddin and Anbar
3. Spring season suffers from increased PM2.5 pollution, where the ranging of PM2.5 about (4.47-112.49 µg/$m^3$) particularly in Anbar Governorate.
4. For the Autumn season, the ranging values of PM2.5 was (17.10-108.10µg/$m^3$) focusing in the middle of Iraq.
5. The annually PM2.5 concentration values was (11.17-83.40 µg/$m^3$ ), focused in the Ba'aj and Hatra districts in the south of Nineveh Governorate, northwest of Salahuddin, and north of Anbar.
6. The annual average concentration of PM2.5 exceed the WHO and Iraqi standards annual mean values which set to (10 $\mu$g/$m^{3)}$.

## References


1. Abdulaziz Y. T., 2006, *"Environmental pollution of the city of Mosul and ways to treat it"*, PhD thesis, University of Mosul, College of Science, Department of Biology. (In Arabic).
2. Abbas T. R. and Abbas R. R., 2021, "*Assessing Health Impact of Air Pollutants in Five Iraqi Cities Using AirQ+ Model", IOP Conference Series: Materials Science and Engineering*, doi:10.1088/1757-899X/1094/1/012006: 1-12.
3. Areti P. and Ioannis K., 2021, *"Forecasting Particulate Pollution in an Urban Area: From Copernicus to Sub-Km Scale*", Atmosphere, 12, 881. https://doi.org/10.3390/atmos12070881, Pp. 1-24.
4. CAMS. Available at: https://atmosphere.copernicus.eu/data, accessed at: 6 Feb. 2022.
5. ECMWF, available at: https://www.ecmwf.int/en/forecasts/datasets, accessed at: 29 Feb. 2022.
6. Francis O. A., 2016, *"Particulate Matter*: *An Approach To Air Pollution"*, Preprints (www.preprints.org), doi:10.20944/preprints201607.0057.v1, Pp. 1-14.
7. Hassony J. A. and Zaid Sh. N., 2010, "*Determining Air Quality Index of pollutant particles and its Health Impacts", AL- Mustansiriya J. Sci.*, 21(5): 328-336.
8. Kadim M. H., 2012, "*The detection of dust storms using meteosats Satellites, Iraqi Journal of Science", Proceedings of the First Conference of Dust Storms and Environmental Research - Causes and Processes*, 17-18 October. 2012: 116-124.
9. Kossay K. Al-Ahmady and Hussain M. O., 2015, *"Assessment of Air Particulate Pollution in New Badoosh Cement Factory/ Iraq", Al-Rafidain Engineering Journal,* 23(3):123-135.

10. Layali Y. S. and Sabah H. A., 2021, *"Evaluation of Tropospheric NO2 Column number Density and UVAI over Iraq Troposphere after the Outbreak of COVID-19 by Using Remote Sensing and GIS", Indian Journal of Ecology*, 48(2):607-614.
11. Saleh Z. M. and Al-Tai, O. T. 2015, *"Effect of temperature and relative humidity on the concentrations of particulate matters (TSP, PM10) recorded at Al-Waziriyah station", Journal Al-Mustansiriya for Sciences*, 27 (1). (In Arabic).
12. Sabah H. Ali & Namik A. Daood & Laith K. Ibrahim, 2015, *"Derivation of seasonal variation maps of the average precipitation in Iraq by using remote sensing data and Geographical Information System", Arab J Geosci*. l(8) :4741–4753, DOI 10.1007/s12517-014-1523-7.
13. Seinfeld J.H. and Pandis S.N., 2022, *"Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*", 3rd Edition, John Wiley & Sons, Hoboken, NJ, USA
14. Zainab B. M., Ali A. Kh., Ali S. R., Waleed M. Sh., 2019, "*Assessment of Air Pollution over Baghdad City Using Fixed Annual Stations and GIS Techniques", IOP Conference Series: Materials Science and Engineering*, 54(6):1-12. DOI : 10.35741/issn.0258-2724.54.6.36, Pp.1-12.
15. Weather Online, available at: https://www.weatheronline.co.uk/weather/maps/city?WMO=40608&CONT=asie&LAND=IQ&ART=WDR&LEVEL=150, accessed at: 12 March, 2022.
16. Where the Iraq in the world, available at: https://worldpopulationreview.com/countries/iraq/location, accessed at: 8 January, 2022.
17. WHO (2018). *"Air quality and health. Fact sheets on sustainable development goals: health targets*". Available from: https://www.euro.who.int/sdgs