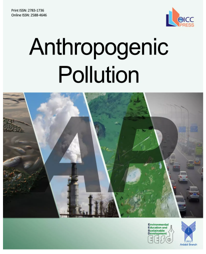

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The role of meteorology factors on urban pollutants (Case study: data analysis of Tabriz city 2012 – 2022)

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Abstract:
In this research, using research-descriptive methods and using data from the years 2012 – 2022 of meteorology and air pollution in Tabriz city, the correlation of meteorological factors and their effect on the level of air pollution in Tabriz city was investigated and zoning maps were presented. Based on the results of the research, high amounts of CO, NO_2, SO_2 and O_3 pollutants are mostly accumulated in areas 6, 7 and 8 of Tabriz municipality, and these pollutants have different amounts in different seasons and changing the impact of meteorological factors. Investigating the role of climatic elements in the increase of air pollutants in Tabriz city shows the existence of an inverse relationship between pollutants and the increase in altitude and rainfall. The role of wind in the spring and summer seasons leads to an increase in pollutants compared to the wind direction and is almost ineffective in the winter season. As the temperature increases, the amount of carbon monoxide pollutant increases and the amount of sulfur dioxide gas decreases. In general, the examination of the temperature factor shows that the amount of air pollution increases at lower temperatures.

Keywords: Air quality index; Air pollution; Correlation; GIS; Tabriz

1. Introduction

Most air pollution research has focused on assessing the urban landscape effects of pollutants in megacities, little is known about their associations in small- to mid- sized cities (Lim et al., 2018). Air pollution represents a prominent threat to global society by causing cascading effects on individuals, medical systems (Yang and Zhang, 2018), ecosystem health (Bell et al., 2011), and economies (Matus et al., 2012), in both developing and developed countries (Bereitschaft and Debbage, 2013). About 90% of global citizens lived in areas that exceed the safe level in the World Health Organization (WHO[1]) air quality guidelines (Moore, 2023). Among all types of ecosystems, urban produce roughly 78% of carbon emissions and sustainable airborne pollutant that adversely affect over 50% of the world's population living in them (O'Meara and Peterson, 1999). While air pollution affects all regions, there exhibits substantial regional variation in air pollution levels. Air pollution is one of the problems faced by most big cities, including Tabriz. The most important factors affecting the pollution of Tabriz until the eighties were the large industries located in the west and southwest of this city (Raabi et al., 1999). Various factors are effective in the air pollution of Tabriz city, the main ones are large industries located in the west and southwest of Tabriz. The increased traffic volume has been reported as one of the most significant causes of ambient air pollution in 20 European cities (Gulia et al., 2015). Also, the most important and biggest source of pollution in this city is motor vehicles (Abbasi, 2012). Due to the lack of natural ventilation and atmospheric stability in the cold period of the year, the air of Tabriz city is always faced with temperature inversion, which often causes air pollution (Asghar et al., 2016). Bourne (2008), in his research, modeled the surface temperature inversion in Alaska and determined that the temperature inversion causes the intensification of air

1. The World Health Organization (WHO) is a specialized agency of the United Nations responsible for international public health.

stability and the trapping of pollutants. Chen et al. (2008) in the study of air quality in North China found air pressure to have a significant correlation with the concentration of pollutants and identified high-pressure deployment as the main factor in increasing the concentration of pollutants in autumn and winter. According to the research results of Iacobellis et al. (2009) in California, the frequency of occurrence of pollutants such as ozone and sulfate and has a correlation of more than 99%. Wang et al. (2016) and Fiddes et al. (2016) found the increase in atmospheric stability in the winter season to have the greatest effect on increasing the concentration of pollutants. Meteorology change is undeniable in reducing or increasing air pollution and other urban phenomena in big cities, especially in Tabriz (Alijani and Ramezani, 2018). The smallest changes in the climate affect the ecosystem (IPCC, 2007; Ghasemibactash et al., 2015). In the research (Yang et al., 2024), they considered ozone gas as the most worrying air pollutant in China and measured its changes between 1980 and 2019. Their studies showed that the increase in O_3 gas is directly related to the decrease in air temperature and relative humidity. In 2023, Miri and his colleagues investigated the concentration of certain bacteria during one year in Sistan and Baluchistan Province, Iran. The results show that the concentration of bacteria decreases from summer to winter, which coincided with the decreasing trend of air pollutant indices and meteorological factors such as wind speed and temperature, as well as the increasing trend of relative humidity, this research was only used on the type of correlation and relationship between air pollutants and meteorological factors. In research (Danek et al., 2022; Sadigh et al., 2021) that studied the impact of meteorological factors on the concentration of air pollution in migration, the results show the relationship between topography, meteorological variables and PM concentration. In this research, the important finding was related to the main relationship between wind and altitude on the number of suspended particles (PM). In another study (Ebrahimi-khusfi et al., 2024; Mostofie et al., 2014) which has been conducted in order to determine the factors affecting meteorology and some types of air pollutants in the change of PM10 concentration, the results show that the contribution of dust concentration and relative humidity in the changes PM10 in spring is more than other variables. Also, in summer, wind direction and ozone gas and in autumn and winter, air pollutants and dust concentration had the greatest impact on PM 10.

In order to reduce and moderate the air pollution in Tabriz city and then the effects and problems caused by it, it is necessary to investigate the spatial relationships between meteorological factors and air pollution in Tabriz city. Based on the review of the previous sources, it was observed that until now, a complete study and research has not been done in terms of the time period of the study and also in terms of considering the appropriate number of urban pollutants in order to determine the relationship between these pollutants and the changes in meteorological factors. In this research, the relationship between four meteorological and climatic factors: precipitation, wind direction, temperature, solar radiation and human climate changes with the air quality of Tabriz city during the years 2012 to 2022 has been investigated. Therefore, by modeling the spatial effects of various meteorological and climatic parameters on each of the air quality parameters in the city of Tabriz, it is possible to present the spatial changes of their positive or negative effects in the form of a map, and as a result, urban air polluting areas identified in different areas.

The results of this research will be a fundamental step for the country's experts and researchers in managing air quality and identifying critical and air polluting areas, which can be used for decision-making and air pollution management and in preparing future Detailed Master plan.

2. Material and methods

2.1 Geographical location of the region

The city of Tabriz with a population of about one million and five hundred thousand people is located in the geographical coordinates of 46° 17′ east longitude and 38° 4′ latitude (Dinpazhooh et al., 2016) (Fig. 1). This city has industrial centers such as Powerhouse, refineries, Petrochemical, brick kiln and machine manufacturing. The climate of Tabriz is dry with hot and dry summers and cold winters (**Shafaati2022**).

Considering that the city of Tabriz is one of the large industrial cities of Iran, therefore, the establishment of large and small industries, as well as the improper location of the petrochemical and refinery and thermal power plants of Tabriz in the direction of the main winds of the region, lead to an increase in pollutants in the air of Tabriz city. Therefore, the scale of studying the meteorological data of Tabriz city is considered to be comparable with the scale of studying pollutants effective in reducing the air quality of the city (Fig. 2).

2.2 Climatic and meteorological factors of the studied area

Tabriz was studied through two parts, the mountainous part and the flat and low-altitude plain part. The highest point in the mountainous part is more than 1724 meters. Due to the high slope and impenetrable soil in this area, we see the flow of large amounts of water with a factor of 30-40%. The flat and low-altitude part covers about 87.31% of the total area of the city (CHoubin et al., 2022).

The smallest area of Tabriz is located at an altitude of more than 1600 meters (Fig. 3). According to the slope map, about 79% of the area has a slope of less than 5% and 17.33% is between 5 and 10%. In general, 96% of the studied area has a slope of less than 10%. But lands with a slope of 15% or more have covered about 4% of the total area of the city (Fig. 4).

The largest area in the direction of the slope corresponds to class 9 and in the northwest direction, and the smallest area in the direction of the slope corresponds to class 5 (southeast), (Fig. 5). According to the statistics of floods that occurred in the catchment area (Fig. 6), the most floods occurred in July and August.

According to Fig. 7, the average air temperature of Tabriz city is 13.5 degrees Celsius. In Tabriz, August is generally the hottest month and Bahman is the coldest month of the

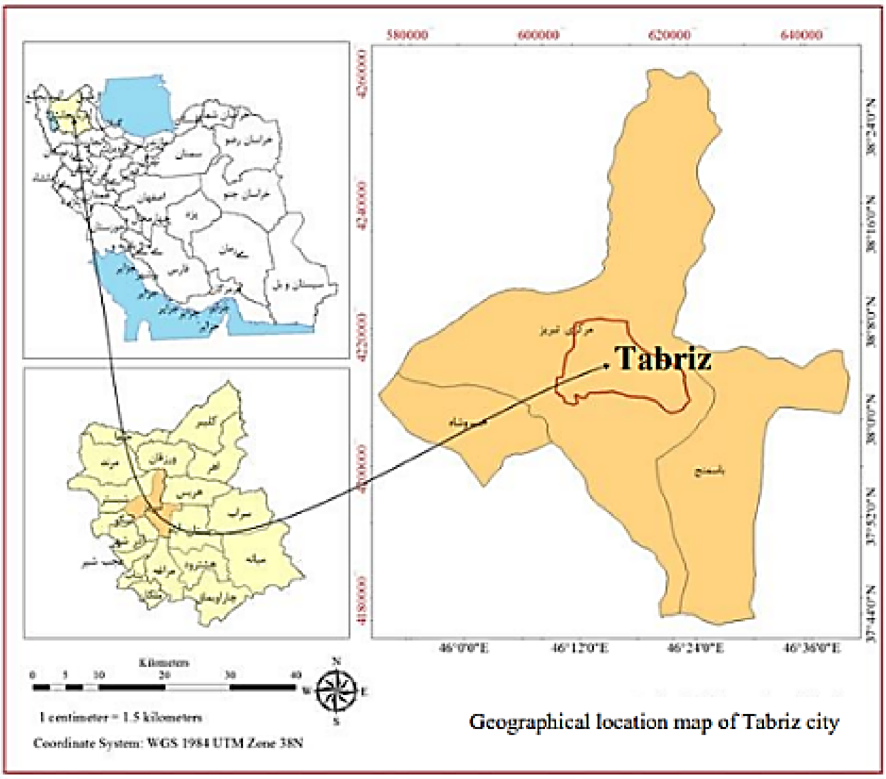


Figure 1. Geographical location map of Tabriz city.

year. More than 45% of the area of Tabriz benefit from 2300 to 2400 hours of sunlight per year (Fig. 8).
Although the relative humidity in the air can provide a part of the humidity required by the plant through its leaves, the high relative humidity may interfere with some plants or at least part of their phytological activities, so knowing the relative humidity of the air and its monthly and annual distribution is of special importance for planting planning and choosing the type of materials and tools for structures (Fig. 9).Correct information about land use is necessary for any type of activity and planning at the level of any country. Spatial and geographical distribution of different land uses in Tabriz city includes 5 types of land use, where urban land use is the largest with 72.05%, and garden-agricultural land use is in the second order of land use (Fig. 10).

2.3 Data analysis

The study methods of the present research are divided into two categories: statistical methods and remote sensing methods. Sampling using the results of air measuring stations and the data of the General Directorate of Meteorology (Tables. 1& 2) and the General Directorate of Environmental Protection of East Azerbaijan was used in the area of Tabriz city to investigate the effect of climatic factors on air pollution and integrated maps were prepared using ARC GIS software.

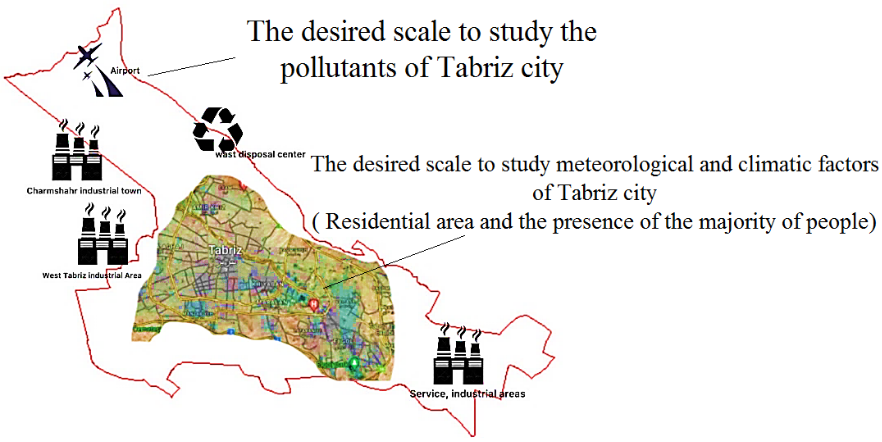


Figure 2. The spatial scale of the studied areas.

Table 1. The average data of meteorological and climate factors separately from 2012 to 2022.

Year	Average temperature	Average relative humidity	Average rainfall	Average frost days	Average evaporation	Average hours of sunshine	Average wind speed	Average wind direction
2012	14.5	52	245.1	77	2113	2881.4	20	210
2013	12.7	51.5	225.6	66	2038	245.6	20	350
2014	14.2	52.5	300.8	87	166.7	245.6	19	210
2015	13.8	52.5	286.2	81	2021.3	2781.1	21	220
2016	11.7	51	264.3	104	1908	2818.3	17	230
2017	14.6	50	313.8	73	2122.4	2978.2	23	220
2018	14.4	53.5	361	74	2040	2820	19	150
2019	13.4	52.5	286.2	82	1951	2851.1	23	280
2020	13.5	51	335	82	1878	2883	19	170
2021	14.45	52	23.30	97	2180	2914	19	290
2022	13.6	46.2	181.6	83	2168.5	2848.7	19	250

2.4 Temporal and spatial distribution of various types of polluting gases

The temporal and spatial distribution of air pollutant gases is different according to climatic and environmental conditions in different areas and different months and seasons. In this part, the temporal and spatial distribution of air pollutant gases in the city of Tabriz has been analyzed, and each gas was analyzed separately. The temporal distribution of studied urban pollutants in the period of ten years (2012 to 2022) in different districts of Tabriz city is as follows (Tables 3-6).

3. Results and discussion

The amount of seasonal pollution in Tabriz city during the study period (2012-2022) was obtained based on the statistics of 9 pollution measurement stations. Air pollution zoning maps were obtained through Arc GIS software and were compared and analyzed. Zoning of pollution in the spring season of Tabriz city shows that districts 4 and 8 of the municipality have the highest amount of pollution in the study area and also district 2 of the municipality has the lowest amount of pollution (Fig. 11). In summer, Tabriz city shows that districts 6, 8, 4 and 10 of the municipality have the highest amount of pollution in the study area and also districts 2 and 5 of the municipality have the least amount of pollution (Fig. 12).

The zoning of pollution in the autumn season of Tabriz city shows that district 8 and 3 of the municipality have the highest amount of pollution in the study area and also district 2, 5, 9 and 1 of the municipality have the lowest amount of pollution (Fig. 13). Also, and the results of zoning in the winter season showed that districts 10, 4, 3, and 8 of the municipality have the highest amounts of pollution in the study area, and also districts 2, 9, 5, and 1 of the municipality have the lowest amount of pollution (Fig. 14).

The temporal and spatial distribution of pollutants were compared with the air quality index (Table. 7). The amount of rainfall in the ten-year period of the city of Tabriz in relation to the numerical index of air quality has changed sporadically, and in the northern part of the city of Tabriz, the amount of rainfall is less, and in this area, the number of the air quality index is also higher, and as a result, the air pollution is higher. It is known that in the southeastern part of the city, the quality index is low and the amount of rainfall is higher.

Due to the high wind speed in spring and summer, pollution from the east side moves towards the city and causes an increase in the concentration of pollutants in the central part of the city, while the air quality in the east side is more favorable than the air quality in the west side of the city. In the graphs below, the correlation of the air quality index and the selected climatic factors in this research, in the increase

Table 2. The average data of the studied pollutants separately between the years 2012 to 2022.

year	CO	O_3	NO_2	SO_2
2012	-	-	-	-
2013	88	21.28	13.28	14.42
2014	24.5	20	34.71	50
2015	42.25	37	25.62	12.16
2016	30.9	34.9	62.5	20.9
2017	43.28	27.14	40.55	14
2018	37.25	31.27	29.41	12.75
2019	31.83	25.16	32.41	10.36
2020	-	26.75	34.08	12
2021	27.08	29.08	31.33	27.25
2022	46	29.33	27.5	31.08

Table 3. Seasonal distribution of CO gas during 2012 – 2022.

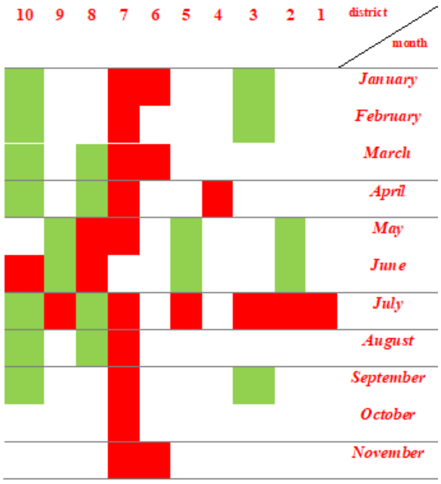
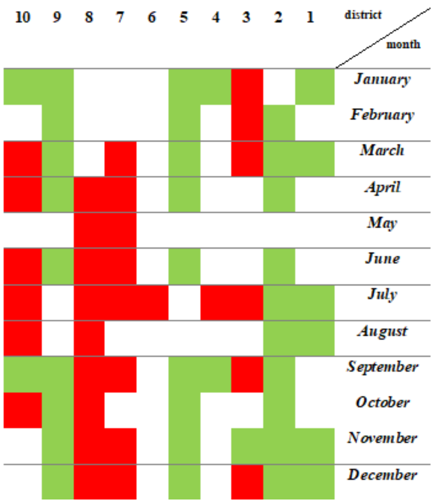


Table 4. seasonal distribution of NO_2 gas during 2012 – 2022.



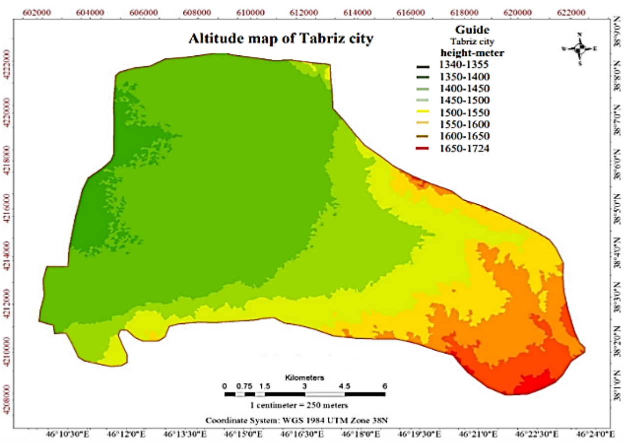


Figure 3. Altitude map of Tabriz city.

or decrease of the desired pollutants in this research (CO, NO_2, SO_2 and O_3) were analyzed. The green dots in the graphs represent each of these pollutants.

The amount of ten-year rainfall in Tabriz city in relation to

Table 5. seasonal distribution of O_3 gas during 2012 – 2022.

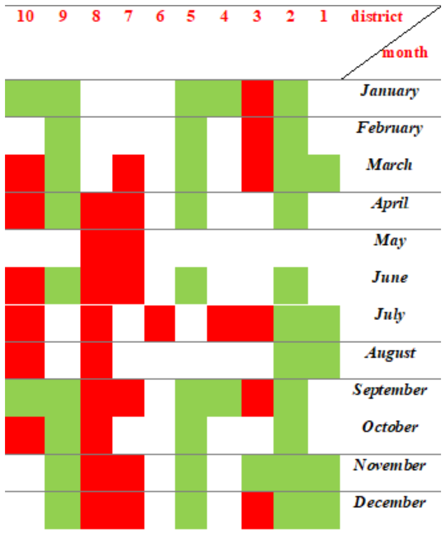
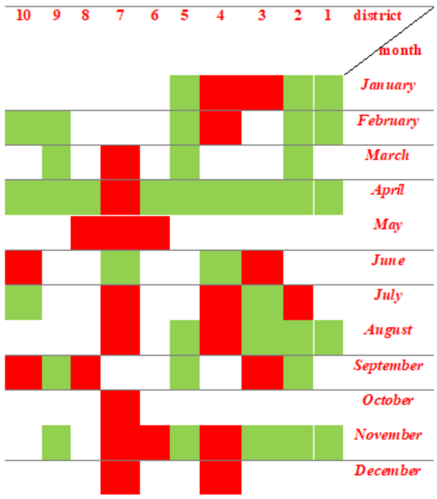


Table 6. seasonal distribution of SO_2 gas during 2012 – 2022.



Guide to tables	Very low pollutant distribution in ten districts of Tabriz city
	Very high pollutant distribution in ten districts of Tabriz city

the numerical index of air quality has changed sporadically, and in the northern part of Tabriz city, the amount of rainfall is less, and in this area, the number of air quality index is also higher, and as a result, air pollution is higher. In the southeastern part of the city, the quality index is low and the amount of rainfall is higher. The ten-year rainfall (2012 to 2022) of Tabriz city has changed sporadically compared to the numerical index of air quality, and in the north of Tabriz city, the amount of rainfall is less, and in this area, the air quality is low, and the pollution index is also higher, and as a result, the air is more polluted. So, in the southeastern part of the city, the quality index is low and the amount of rainfall is higher, so according to R = 0.24, it shows that there is a direct relationship between the air quality and the amount of rainfall. Due to the high wind speed in spring and summer, pollution from the eastern side is drawn to-

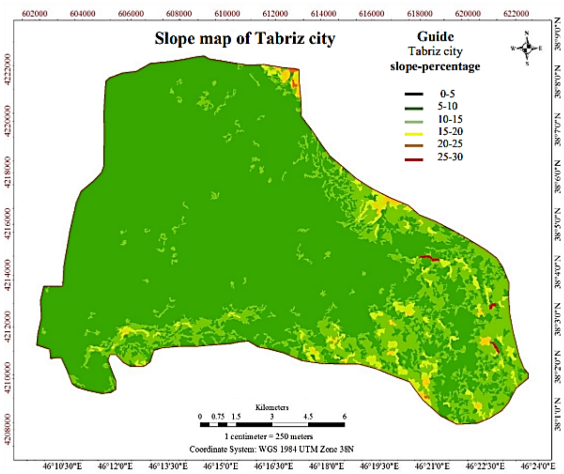


Figure 4. Slope map of Tabriz city.

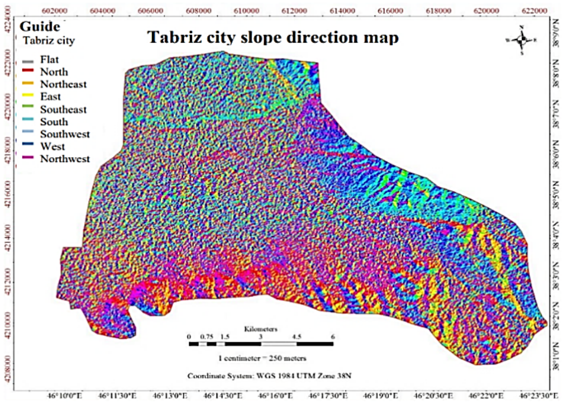


Figure 5. Direction map of Tabriz city.

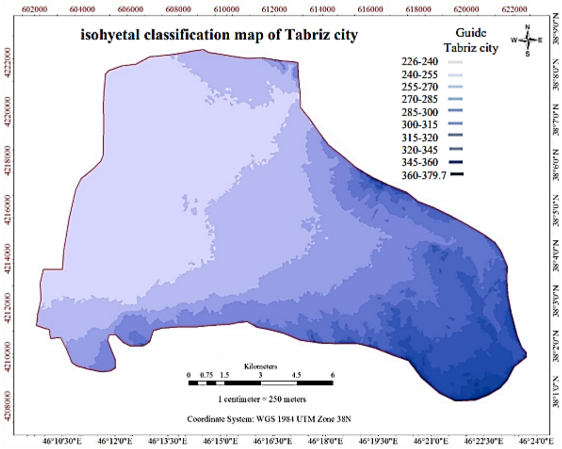


Figure 6. Hydrological map of Tabriz city.

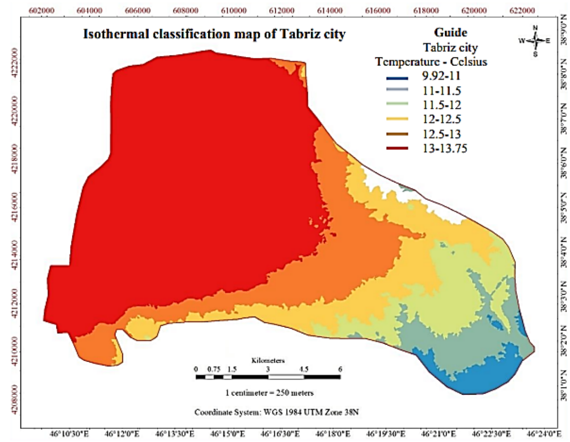


Figure 7. Isothermal map of Tabriz city.

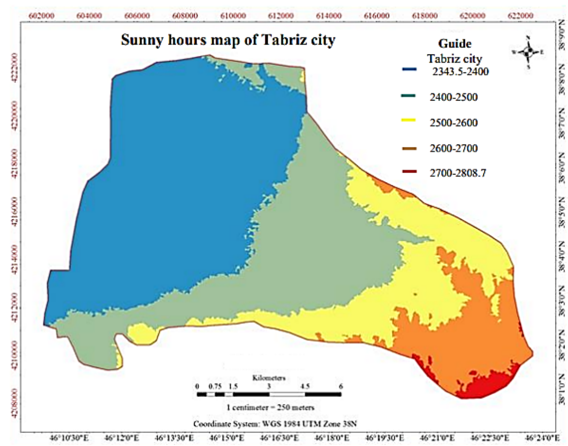


Figure 8. Sunny hours map of Tabriz city.

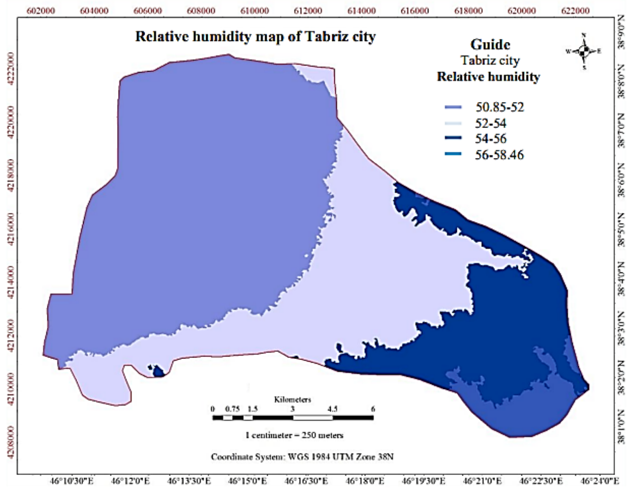


Figure 9. relative humidity map of Tabriz city.

wards the city and causes an increase in the concentration of pollutants in the central part of the city, while the eastern side has better air quality than the air quality of the western side of the city. There is a significant correlation between these two parameters (Fig. 16).
As we move towards the west of the city of Tabriz, the air pollution increases, in other words, in areas 1, 3, 4, 8 and 10, the numerical index of air quality is high and the air temperature is higher in these areas, so there is a significant correlation between these two parameters were observed (Fig. 17). In district 9, the city with the highest relative humidity has the lowest air quality index and the amount of air pollution in this district is less. According to the statistical results, there is a significant and inverse correlation between the climatic parameter of relative humidity and air quality index (Fig. 18).

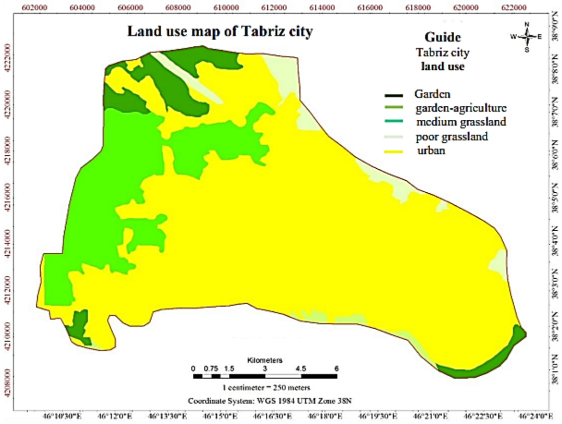


Figure 10. Land use map of Tabriz city.

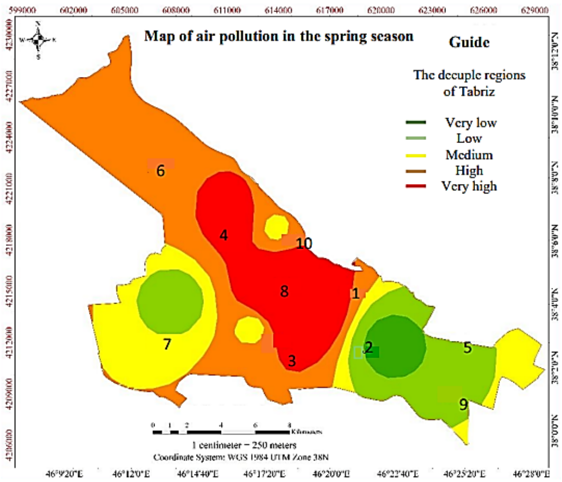


Figure 11. Air pollution in the spring season during 2012 – 2022.

The city of Tabriz, like a hole, is limited to the heights in three directions, north, east, and south, and from the west to the Tabriz plain, which leads to the transfer of pollutants to this city and its confinement there, therefore, with the increase in altitude, the amount of air pollution decreases; but this relationship is not linear and direct (Fig. 19).

4. Conclusion

The results obtained from the research show that the highest density in the city of Tabriz belongs to the center, west and southwest of the city, the place where the worn-out lay-out of the city is also present. By studying the previous research, we realized that most of the studies were conducted to determine the changes of one of the pollutants during a long period of time (finally 5 years). But in the current research, a number of important urban pollutants have been studied over a period of ten years (2012 – 2022), which shows the importance of the issue. Improper access along with heavy traffic is one of the main causes of carbon dioxide concentration in these areas of the city. On the other hand, the peripheral areas of the city with less congestion and lower building density have the least pollution. Although the existence of pollution should not be considered solely due to the existence of cars and traffic

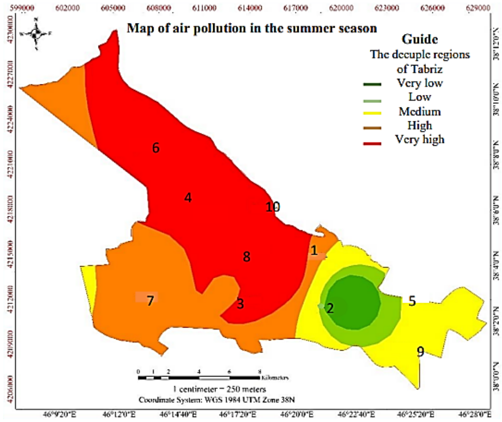


Figure 12. Air pollution in the summer season during 2012 – 2022.

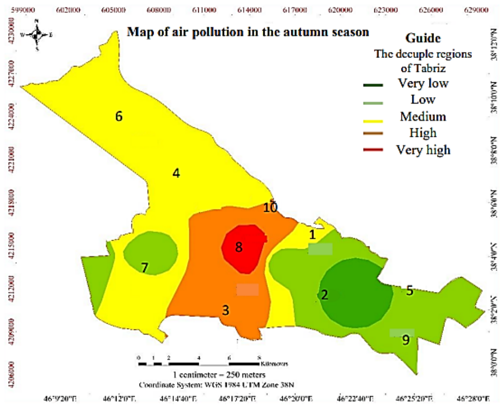


Figure 13. Air pollution in the autumn season during 2012 – 2022.

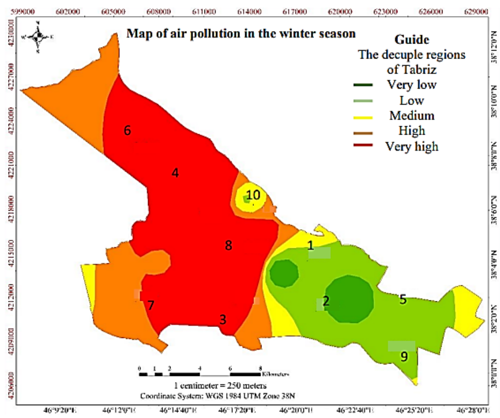


Figure 14. Air pollution in the winter season during 2012 – 2022.

and other fixed factors such as engine rooms of buildings play a large role in pollution, but in Tabriz the evidence shows that cars and the resulting traffic in polluting the air of the city and differentiating areas from It also plays an important role. According to the results of the research, the air quality of Tabriz city during the last ten years in spring and winter was such that in the west and center of the city, the Air Pollution Quality Index (AQI) shows a high number, in other words, the air in these areas is

Table 7. standard index of the composition of clean and polluted air.

Standard index of air pollutants					
dangerous	very unhealthy	Unhealthy	Healthy	good	Class
>300	201-300	101-200	51-100	0-50	Index value
Concentration range					Pollutant
>30	15-30	9-15	4.5-9	0-4.5	CO
>1.2	6-1.2	-	-	-	NO_2
>0.60	0.30-0.60	0.14-0.30	0.03-0.14	0-0.03	SO_2
>0.40	0.20-0.40	0.12-0.20	0.06-0.12	0-0.06	O_3

less favorable than other areas of the city have, but in the whole city, on average, the air quality is in a healthy range throughout the year. In the last ten years, the air pollution quality index has been high in almost the entire area of Tabriz city in the summer season, except for Tabriz region 3, which is in the medium and low range, and in the autumn season, this index has been in the low and medium range in the city of Tabriz, except Area 3 of the city that is located in a wide range. In general, the amount of rainfall is less in municipal areas 6, 4, 3, 8 and 10, and the air pollution in these areas is more than other areas, so according to the results, there is a significant correlation between the climatic parameter of rainfall and the air quality index. Due to the high wind speed in spring and summer, pollution from the east side is drawn towards the city and causes an increase in the concentration of pollutants in the central part of the city, while the air quality in the east side is more favorable than the air quality in the west side of the city. In urban area 9 with the highest relative humidity, the lowest air quality index can be seen and the amount of air pollution in this area is less. According to the statistical results, there is a significant and inverse correlation between the climatic parameter of relative humidity and air quality index. We also found that the distribution of air pollution parameters on the surface of Tabriz city shows that the most pollution caused by polluting gases O_3, NO_2, SO_2 and CO is in the west side and the center of the city, and the most pollution is related to suspended particles in the east side of Tabriz city. The air quality index in the seasons shows that summer and spring have the least air pollution and autumn and winter have the most air pollution. Also, the average intensity of air pollution during the studied statistical period shows that the air quality index is in the healthy category.

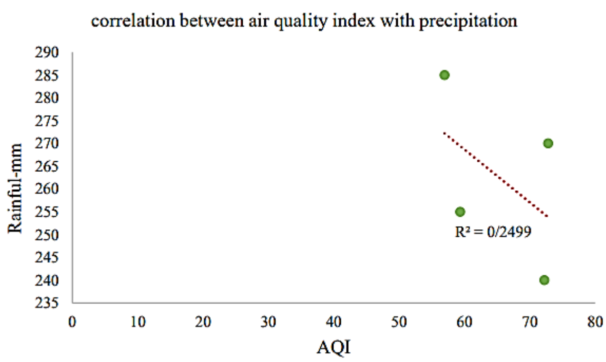


Figure 15. Correlation (R^2) between rainfall and AQI.

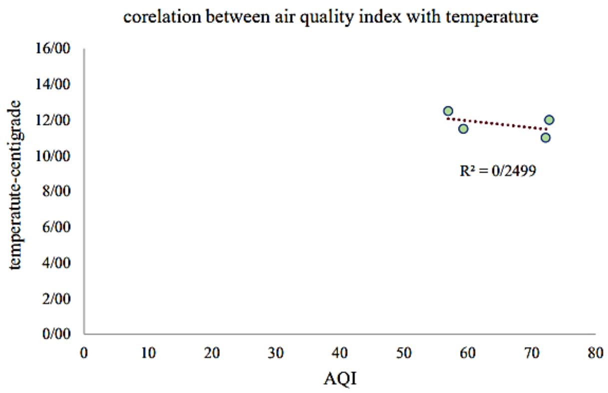


Figure 17. Correlation (R^2) between temperature and AQI.

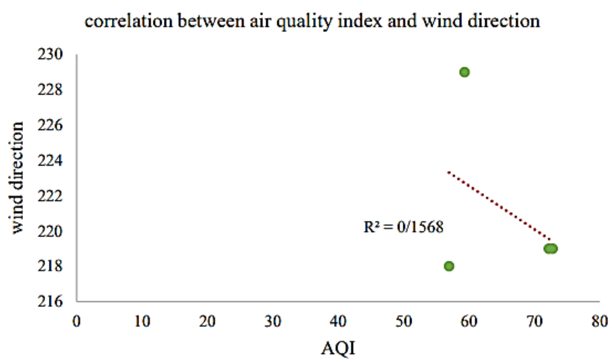


Figure 16. Correlation (R^2) between wind direction and AQI.

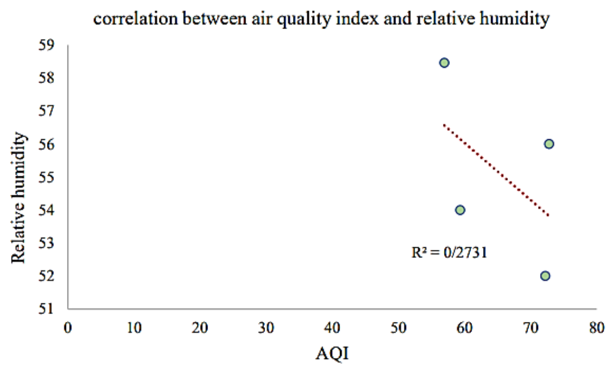


Figure 18. Correlation (R^2) between relative humidity and AQI.

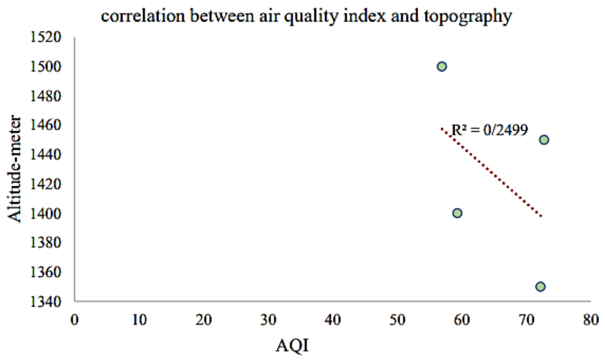


Figure 19. Correlation (R^2) between topography and AQ.

Therefore, the intensity of air pollution in Tabriz city does not increase in the summer season, but the intensity of air pollution increases in the winter season. Due to the importance of the work topic, a number of important points are suggested to control and reduce urban pollutants: It is suggested that in addition to climatic parameters, other parameters such as urban planning parameters and traffic volume should be examined simultaneously with climatic parameters; Correct positioning regarding the establishment of new pollution measurement stations in the city of Tabriz; Calibration of analyzers of air pollution measuring stations; Installation of all indicator pollution meters in all air pollution measurement stations; The amount of concentration or dispersion of polluting substances in cities is largely affected by the shape of the streets. If the streets are properly designed, the concentration of air pollution in high-traffic streets decreases and people are less exposed to polluted air.

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Availability of Data and Materials
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Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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