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SPATIAL DISTRIBUTION OF ATMOSPHERIC POLLUTION IN DUHOK URBAN AREA BY USING GIS TOOLS

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ABSTRACT:

Air pollution is becoming a serious challenge in thickly populated areas in the world. The air pollution in Kurdistan region is clearly noticed, especially in areas where pollution sources and human population are concentrated. Urbanization and economic growth are proceeding at a rapid pace, accompanied by increasing emissions of a mixture of greenhouse gases especially from transporting sector, that positively contribute to accelerate climate change around the globe, and also have impacts on public health and vegetation. In order to decrease the effects that caused by atmospheric pollution, suitable monitoring systems are urgently needed that can rapidly and reliably detect and quantify polluting sources and concentration for monitoring by local authorities in order to restrain more damage of the current pollution levels. In this study, GIS with portable gas detector (K-60 IV) KELISAIKE safety equipment, China, have been used to assess the status of NOx, VOCs and noise pollution at 54 randomly selected urban locations of Duhok city. The measurements were taken during the week and weekend days started from 9 am until 4 pm. The results showed that there is a variation in the values of the three variables NOx, VOCs and noise, where the highest values recorded during working days in the locations distributed along the highway and the city center with heavy traffic load and dense human population in comparison to lowest values obtained during weekend days in locations distributed outskirt of the city with lower population and traffic loads. Therefore, likely such connections exist between the urban traffic density and low air pollution quality within urban locations around Duhok city.

KEYWORDS: Air Quality, Noise Pollution, Artificial Intelligence, Urban Area.

INTRODUCTION

Urban atmospheric pollution is becoming increasingly a serious issue for human health all around the globe. Different sources considered the principal causes of urban pollution are polluted domestic technology, urban transportation, fuel combustion, industrialization and urbanization (Appannagari, 2017; Bernhardt et al., 2019). The past decades have seen rapid urban development combined to city-dwellers lifestyles changes that adversely affect the human health and other living organisms are affected as well (Cowls et al., 2019; Deng et al., 2019). In this circumstance, the urban transportation system is documented as the premier source of air pollution in various cities and towns worldwide (Rajé et al., 2018).

In megacities, the urban transport sector is considered as a main contributor to climate change caused by greenhouse (GHG) emission that comprise about 20% of the total GHG emission (Beer et al., 2002). The foremost traffic toxins released into the environment are carbon monoxide (CO), particulate matter, volatile organic compounds (VOCs), and nitrogen oxides (NOx). Their oxidizations lead to the formation of tropospheric ozone in urban areas, due to a complex series of transformations, which in turn has sever influence regarding people's health (Geng et al., 2008). Alongside these atmospheric pollutants, noise pollution is considered one of the significant types of environmental pollution in urban areas on account of the incessantly population demography combined with high number of vehicles introduced to the streets each year. Road traffic is related to undesirable human health effects caused by air pollution, noise and accidents (Liu, J. et al., 2020). Furthermore, this perilous traffic noise threats the residents of the metropolis more than the small cities or even the rural people (Tahir and Khaled, 2015; Morel et al., 2016; Flores and Gagliardi, 2017; Fredianelli et al., 2017).

Recently, geographic information system (GIS) has becoming one of the highly effective tools in respect to modeling spatial and temporal variation of air quality in urban areas. Various artificial intelligence networks related to GIS technology have increasingly installed in metropolis for monitoring the air quality (Pummakarnchana et al., 2005; Briggs et al., 2007; Kumar et al., 2016). This current vital urban air quality networks demonstrate significant spatio-temporal variations which permit the implementation of efficient strategies and policies regarding the urban infrastructure development (Shad et al., 2008; Banja et al., 2010; Gerdol et al., 2014). Moreover, GIS technology is frequently the modern-day tool that simplifies connecting spatial data to non-spatial information (Matejicek, 2005; JIA, 2019). Along with its embedded relational database component, this artificial intelligence system participates in storing, mapping and analyzing geo-referenced data in an organized form (Yerramilli et al., 2011). In current urban environment perspective, the GIS tools effectively participate in the monitoring of the spatio-temporal multi-scales which in turn play a vital role in eliminating the cost and time of field surveys (Nara, 2017; Mouhri et al., 2013). Furthermore, several studies investigating the spatio-temporal dynamic of the noise pollution have showed that the crowded street (city center, commercial areas, highways, etc.) are more suffering, particularly during rush hours (Alesheikh and Omidvari, 2010; Yang et al., 2020).

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In the context of Kurdistan Region, the urban environmental issues have grown in importance in light of recent increasing awareness of their absolute risk for human health. A number of researchers in Duhok city have attempted to address urban air quality, atmospheric pollution (Khaled and Raoof, 2019), characterization of airborne particles (Mahdi et al., 2018) and noise issues (Jaff et al., 2009, Aziz et al., 2012; Tahir and Khaled, 2015). With regard to GIS application on environmental issues of Kurdistan cities, the previous studies have focused more on the spatial distribution of heavy metals (Haji et al., 2020; Umer et al., 2021) and the assessment of the urban environment quality related to CO_2 (Hassan, 2012) or to the human population density (Muhammed et al., 2020). In spite of its productive success globally relating urban modeling and management, yet relatively a little attention has been paid to the importance and implementations of GIS within Duhok urban atmospheric issues. Therefore, the aim of this paper is to (i) determine the limits of current spatial distribution for each of Nox, Vocs and noise pollution; (ii) provide a solid baseline dataset for further projects related to urban atmospheric pollution; and (iii) assist in establishing priorities, measurements of air pollution in Duhok and increasing public awareness and enhanced public participation.

2. MATERIALS AND METHODS

2.1 Study Area

This current study was performed within urban areas throughout Duhok city in northern part of Kurdistan Region of Iraq (36˚52′03″ N; 42˚59′34″ E). The city is situated on 430 to 540 m above sea level and it covers about 52 km² (according to directorate of planning). At this time, Duhok population is roughly 421858 inhabitants (KRG, 2021) which consist of both multi-ethnic and multicultural communities. The city holds a remarkable landscape structure as it is within a valley bordered by two chains of foothills, Zawa from south while from north side Bekher chain Mountains located. From a climate attitude, Duhok possess a Mediterranean microclimate: warm and dry in summer whereas cold and rainy in winter (Youssef et al., 2019).

2.2. Samples Surveying

In order to achieve the spatial distribution of atmospheric pollution 54 locations were selected (Fig. 1). The chosen points were located within four main city categories. They are: city centre (CBD = central business district, highway (HW = Barzan street), urban (UR = involves the secondary roads, residential areas and other areas within the city) and Urban fringe (UF = includes only the areas around the city and partially far from the crowdedness). Out of 54 locations, 25, 10, 10 and 9 points were located within each of UR, CBD, UF, and HW, respectively, where human settlement, traffic density and vegetation cover are taken into consideration. Furthermore, for each single location the measurements of both NOx, VOCs were indicated by using portable monitor multi-gas detector (K-60 IV) KELISAIKE safety equipment. The former mentioned device is an Electrochemical Gas Analyser specialized in determining CO, H_2S, NOx, VOCs and Other Combustible Gases. Whereas, the minimum and maximum noise levels were taken by Digital Noise Meter (Decibel Meter) the measurements ranged between 30-130 dB.

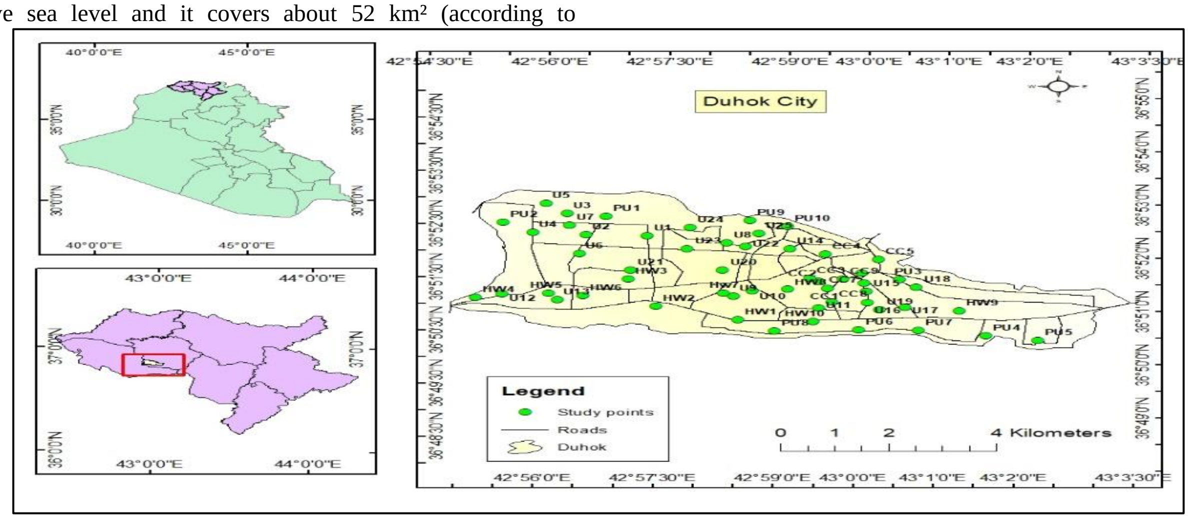

Fig. 1: Duhok city map, Google earth, 2021
with the 54 selected locations according to four main urban categories: CBD = central business district, HW = highway, UR = urban areas, and UF = -urban fringe. They include all sources of air pollution in the surrounding area (vehicles, electric generators and other human activities).

2.3. Spatial Distribution Of Atmospheric Pollution By Using Gis Tools

The concentration of pollution present in spatio-temporal maps allows the readers and deciders to better understand the area's real level of pollution. This pollutant spatial distribution level can be predicted via a GIS-based image of the coordination and concentration of atmospheric pollution parameters (Ibrahim et al., 2012). However, different interpolating methods are used to predict the global air pollution variations. Each has its advantages and drawbacks. The technique of IDW interpolation is frequently employed in variable mapping. It is a precise and convex method of interpolation that only accommodates the continuous model of spatial variation. The value gained from the known location is used to estimate the value of a variable at some new sites. This technique is based on locations weighted simply by distance and was developed in mining and geological engineering (Jones et al., 2003). The fundamental idea behind IDW interpolation is the use of a weighted linear combination set of sample points. It relies on both statistical and mathematical techniques to build surfaces and determine forecasts for unmeasured locations. in command Equation (1) used to calculate the IDW reads as follows:

$$\check{Z}(X_o) = \sum_{i=1}^{n} Z(X_i)\,.\,{d_{ij}}^{-p} / \sum_{i=1}^{n} {d_{ij}}^{-p}$$

Where: where Z is a grid node's interpolated value, Zi are the node's nearby data points, and dij are the distances between the gride node and the data points

Inverse Distance Weighted (IDW) is an example of calculating the unknown value by means of a known value with a decrease in value by increasing the distance sample as a simple method of interpolating air pollutants (Kumar et al., 2016).

3. RESULTS & DISCUSSION:

3.1. Volatile Organic Compounds (Vocs) Concentration In Duhok

From an overview to the Fig. 2, the results show that the dominated ranges in the area for VOCs concentrations are located within class three (11.488-12.414). While, only one location has been recorded within the first class, three locations within second class and also a single location for the last and highest class of VOCs has been noticed. Here, our results substantiate that Duhok city is moderately polluted within weekdays taking in consideration the abnormal situation of working days crowdedness due to Covid-19 pandemic. Whereas, during the weekend days (Fig. 3) the rate of VOCs for most of the locations appear between class 2 and 3. Moreover, here no locations were highly polluted by VOCs as only one location results have been recorded within class 4 at (Moda Mall shop) and there is no result founded in class 5.

What standout in the two maps of VOCs is that there is a significant different between VOCs concentrations during the week and weekend days. In the weekend, the results showed a considerable reduction in the rate of VOCs. Furthermore, most of the area results located within the primary classes including more than five locations within the first class especially in the west of city center unlike weekdays which shows many results within higher classes. It is worth mentioning that no results were stand for the 5th class during the weekend. The results show the clear effects of traffic congestion on the elevation of VOCs concentration within Duhok. These results are consistent with those of other studies and suggest that the VOCs contaminate the city due to the increasing number of vehicles introducing to the urban streets (see Bray et al., 2019). These VOCs are atmospheric pollutants representing a hazard to human wellness (Montero-Montoya, 2018). They released into the environment mainly from mobile sources in urban surroundings; whereas, recently contaminated locations are becoming increasingly important in countries where hastened industrialization is taking place in peri-urban and rural areas (Bray et al., 2019).

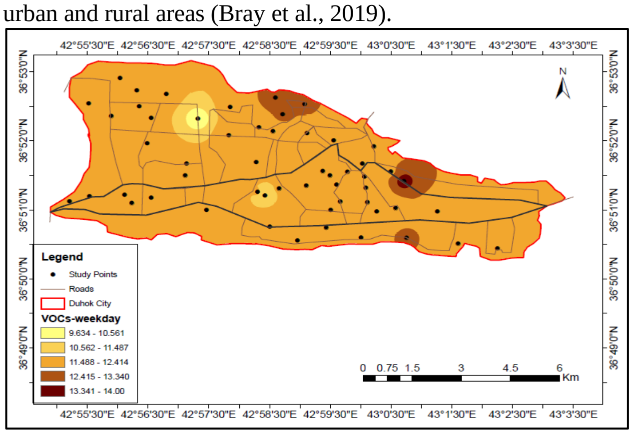

Fig. 2. Spatial distribution of the VOCs at weekday in Duhok city.

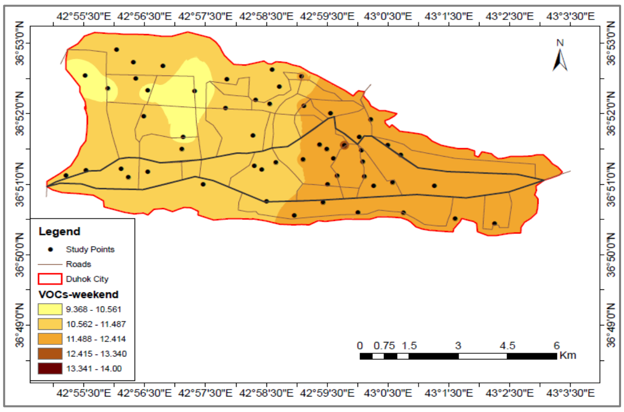

Fig. 3. Spatial distribution of the VOCs at weekend in Duhok city.

3.2 Nitrogen Oxides (Nox) Concentration In Duhok City

NOx are one of the primary atmospheric pollutants which are the mixture of Nitrogen and Oxygen gasses. The Nitrogen dioxide and Nitric oxide are two of highly toxicological NOx forms. They are introduced into the air from various sources including motor vehicles (ATSDR, 2002). NOx are responsible for a serious of environmental issues take into consideration acid rain, ozone layer depletion, photochemical smog besides global warming. Further to the abovementioned causes they lead to many different health problems in case of exposing to high level of these gasses (Brüggemann and Keil, 2008).

The results of figures 4 and 5 show the spatial distribution of NOx within the week and the weekend days. As shown in figure 4, the most of detected rates of NOx has found to be within the first two classes (low and intermediate level of pollution); while, 9, 1 and 1 locations have fallen within the third class (high level of pollution), the fourth and the fifth class, respectively. It is apparent from this figure that, the location was within a secondary route and the main source of pollution was constructions. In Fig. 5 (thee spatial distribution of NOx during weekend), the locations are mainly scattered over the first three classes, while only one location recorded within the fourth class at the main road. The single most striking observation to emerge from the data comparison was that during the weekend, more than 13 locations pinpointed within the 3rd class while during the working days only 9 locations were found to be within the same mentioned class. In general, during the weekdays the low values NOx are founded in the east and some northern parts of Duhok while, in the weekend the low values are found in the north-west of Duhok. It is difficult to explain this difference between week and weekend days, but usually it's related in part to the main wind direction and heavy traffic between east and west parts of Duhok.

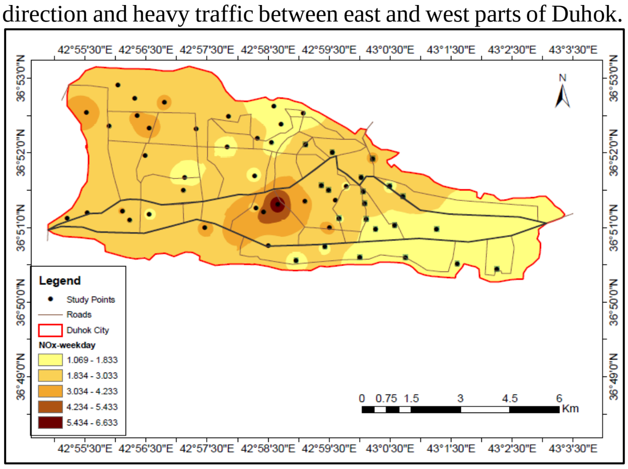

Fig. 4. Spatial distribution of the NOx at weekday in Duhok.

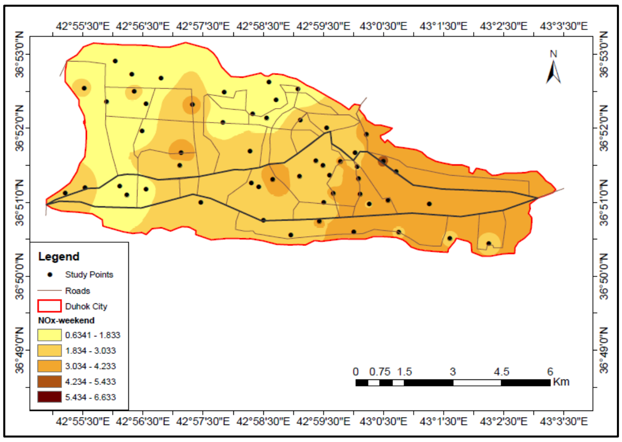

Fig. 5. Spatial distribution of the NOx at weekend in Duhok.

3.3 Urban Noise Pollutant In Duhok

Noise pollution is a consistent exposure to high sound levels. Nowadays, it has been well documented as a major trepidation that affects the standards of life in urban areas worldwide (Hunashal and Patil, 2012). Such noise exposure is in general formed by the public source roads (Morel et al., 2016), railway, traffic, airports (Flores and Gagliardi, 2017), industrial plants (Fredianelli et al., 2017, and electric generators (Menkiti et al., 2015). Among the mentioned sources perhaps road traffics are the most damaging sources of noise pollution (Jaleel, 2014). Worth mentioning, according to WHO, not all sounds considered as pollution, when they define noise only exceeding 65 dB is considered pollution and only over 75 dB is harmful. Persistent load noise exposure can deteriorate human health in various ways, physically and psychologically. Moreover, it may cause sleep and behavioral disorder, reduce the memory and concentration performance (Berglund et al, 1999).

From figures 6 and 7, it can be seen that by far the greatest rate of noises has been recorded on main roads where a high traffic congestion and an over speed driving can be found. During the weekdays, only some few locations were within the first class and tend to have relatively calm atmosphere that those location far from the traffic ways. Moreover, some selected locations being characterized by a very high noise rate. Whereas, most of the city locations were found to be within the high classes, where there are 33 locations founded class 4 and 5 classes. In parallel, during the weekend days, the most urban locations are less affected by the urban noise and situated within the 3rd class. While, the device set down high records only at two locations and one record with lowest concentration which was located within the first class. These findings further support the evidence that the urban traffic constitutes the main noise pollution resource where the urban areas are much more affected by it than in the rural areas (Morel et al., 2016). The results are in consistent with other research which found that noise pollution in urban areas of Duhok exceeded the permissible noise levels (Al-Dosky et al., 2014). It is therefore likely that such connections exist between the urban traffic and the noise pollution which certainly impact the health of the city-dwellers (Liu, J. et al., 2020). One of the issues emerging from this finding relates specifically to develop an urban planning to reduce air and noise pollution via innovative urban green initiative which will lead to measurable health improvements and more attractive urban green spaces.

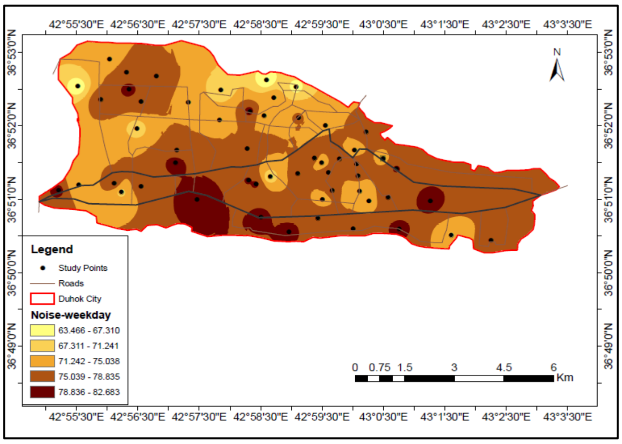

Fig. 6. Spatial distribution of the Noise at weekday in Duhok.

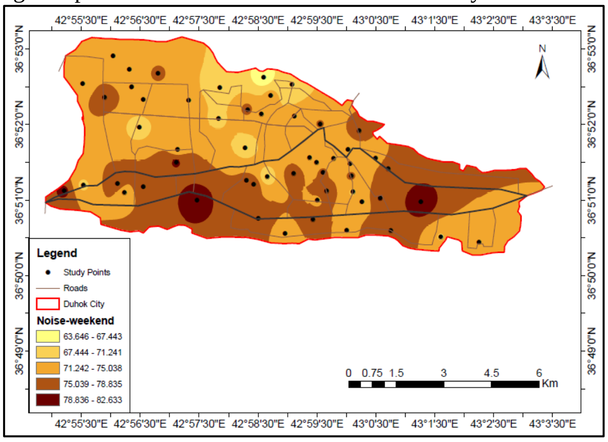

Fig. 7. Spatial distribution of the Noise at weekend in Duhok

3.4 Spatio-Temporal Distribution Of The Urban Atmospheric Pollution In Duhok

Recently, GIS tools are an increasingly important application in spatio-temporal distribution and in their prediction modeling. Unlike classical office automation tools, GIS applications help people transform data points into mapping features and explore with limitless visual analytics. An implication of this is the possibility that they considerably reduce with high efficiency the effort, budget and time used. To assess urban air quality in Duhok, we have provided a global overview for some atmospheric pollutant's spatial distribution due to anthropogenic activities. Nevertheless, this spatio-temporal data must be interpreted with caution due to an important concentration variation at different day times starting from morning to afternoon. The results have considerably changed during different day times and also an obvious change has been noticed in detecting air pollution concentrations among the initial measurements and the final ones within the same day.

4. CONCLUSION

Artificial intelligence tools like QGIS by collect monitored dataset was used to interpolate air pollution concentration by using IDW. The results of both weekday and weekend of VOCs, NO_x and noise are classified into five classes by use of the technique of IDW interpolation. The spatial distribution of VOCs showed that almost urban locations had a value between 11.448 – 12.414. Moreover, the NOx value showed a significant spatio-temporal difference. Indeed, during the weekday the low values are founded in the eastern part of Duhok while in the weekend the low values are founded in the NW of the city. Concerning the noise pollution, the values are ranged from 63.6- 67.3 in classes one to 78.836 - 82.683 in last class. The noise is high in the seven locations in the highway and urban areas, while low value indicated in three locations at pre-urban but in the weekend the low value only founded in one location at pre-urban area. Hence, it could conceivably be hypothesised that the urban areas of Duhok are globally affected by the noise and air pollution. Consequently, it constitutes a major urban environmental issue with a considerable risk for Duhok city-dwellers health. Future research studies on the current topic are therefore recommended to address urban air quality in Duhok.

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