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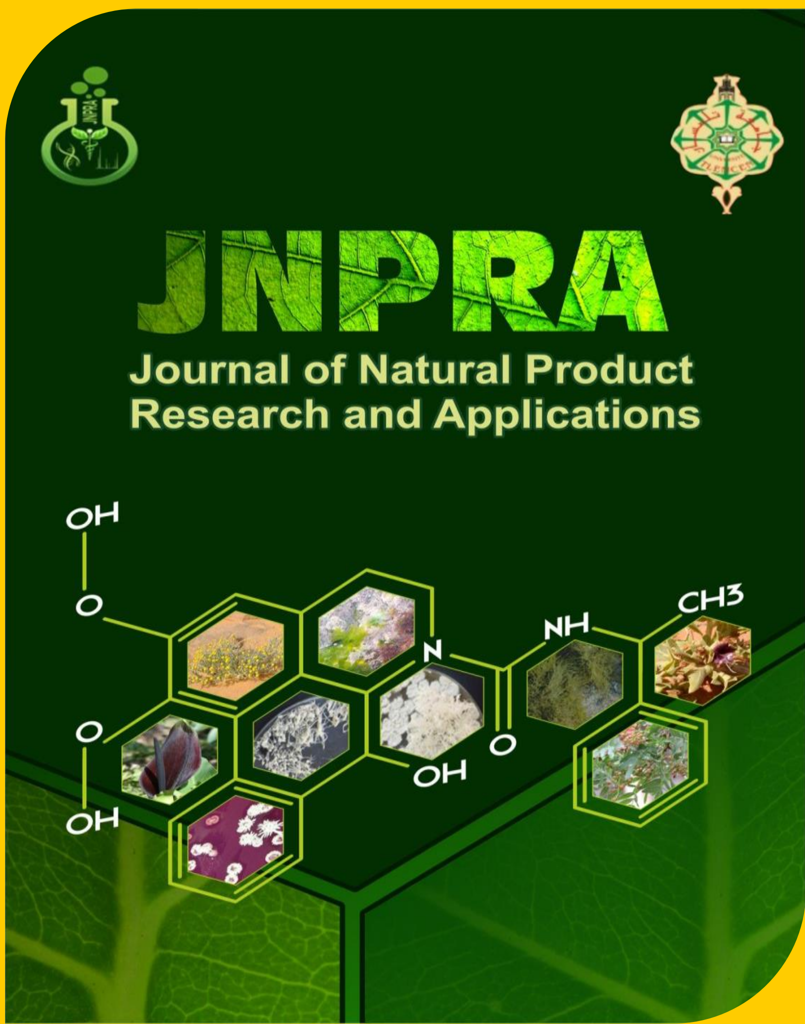

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Research Article

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Spatial Interpolation of Toxic air Pollutants in Jeddah City, Saudi Arabia

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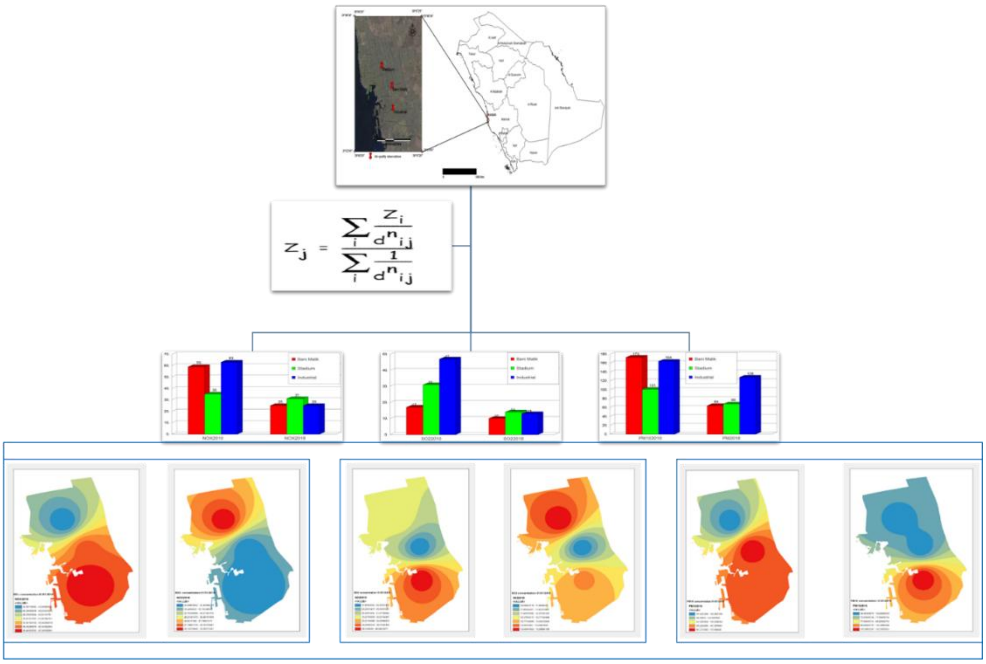
Graphical Abstract



Abstract
This work aimed to study hazardous air pollutants in Jeddah city, between 2010 - 2018. The study of the spatial distribution of (NO_X, SO_2, PM_{10}) was done by the application of the geostatistical method IDW. Daily observation Data were collected from three field observation stations (Bani Malik, Stadium, Industrial activity), and treated in ArcGIS environment. According to the obtained results, in the year 2010, NO_X varies between (25 – 62.99 ppb), with very important concentrations in the south of the study area, surrounding the industrial activities. While in the year 2018, the highest concentrations were between (25 – 30.99 ppb) in the north of the study area. the spatial distribution of SO_2 was very important in the south of the study area, compared to the highest concentrations in the north in 2018. The spatial distribution of PM_{10} was between (153 – 173 µg/m^3**)** in the south of the study area, in 2018 we noticed a decrease of the PM_{10} concentration, in the industrial area with values between (67 – 77 µg/m^3). Even though a lot of work must be done to improve air quality in the city of Jeddah to meet international air quality standards in modern cities.

Keywords: Spatial interpolation; toxic air pollutants ; Jeddah ; Saudia Arabia.

1. Introduction

Air quality is one of the most important concerns in modern cities and environmental planning. Air quality is primarily affected by particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3) concentrations in the atmosphere (Filonchyk et al., 2016). The spatial variations in pollution have considerable implications, both for air pollution monitoring and management and for environmental epidemiology (Briggs et al., 1997). The growing concern about the effects of traffic emissions on respiratory health, and growing pressures for policy and management action to reduce air pollution levels, have highlighted the need for improved methods of mapping traffic-related pollution in urban areas both for exposure assessment and policy support (Briggs et al., 2000). Transportation as such plays a crucial role in urban development through the accessibility it provides to land and activities (Meyer and Miller, 2001). As a result of the urban expansion, many areas have become polluted by traffic and industrial emissions. Transportation constitutes one of the major sources of environmental pollution in urban areas (WHO, 2018). Studies, mainly in the USA, have reported associations, between traffic and air pollution (Dockery et al., 1989; Schwartz, 1993; Pope et al., 1995). Saudi Arabia has experienced high urban growth rates over the last four decades (Al-Hathloul and Mughal, 2004). The urban population has increased, from 21% in 1950 to 58% in 1975 and 81% in 2005 (Al-Ahmadi et al., 2009). This huge increase has created excessive spatial expansion and demand for transportation infrastructure in the major Saudi cities, including Jeddah (Al-Hathloul and Mughal, 2004), and this demand imposes constant urban planning challenges, also the environment is facing very difficult challenges, with harmful consequences on air affecting negatively on humanity and environment (Salman et al., 2016). Jeddah has experienced rapid urban growth, spatial expansion, and transportation infrastructure expansion over the last 40 years, with rates of change ranging from 0% to over 100%, indicating a wide variability across space and a complex urban dynamic (Aljoufie et al., 2011). After 1980, Jeddah has experienced gradual urban growth pattern and transport infrastructure expansion (Aljoufie et al., 2012; Almazroui et al., 2017). Jeddah's population has grown rapidly, from 960,000 in 1980 to 3,247,134 in 2007. Jeddah's urban mass has also expanded dramatically, from 32,500 ha in 1980 to 54,175 ha in 2007 (Aljoufie et al., 2011). GIS and spatial interpolation have been increasingly used for predicting air quality in cities (Salman et al., 2016). This paper aims to use geostatistical methods to explore the reciprocal spatial-temporal effects of transport and urban expansion, on air quality in Jeddah.

2. Material and methods

The scope of this study is to apply the spatial interpolation Inverse Distance Weighted (IDW) method to explore the effect of traffic, urban expansion and industry, on air quality in Jeddah city.

2.1 Study area

Jeddah is the second largest city in the Kingdom of Saudi Arabia, with a population exceeding three million. Jeddah is located on the west coast of the Kingdom, at the confluence of latitude 29.21 north and longitude 39.7 east, in the middle of the eastern shore of the Red Sea, and it is surrounded by the plains of the Tahoma in the east. The city is surrounded by mountains in the north-east, east and south-east. According to the land use map, the southern part is the old city, is densely populated, whereas the northern part of the city is new, well organized, and less populated (Figure 1), the study area is located in the west of Jeddah covering 230,5 Km^2, and englobing BaniMalik and the industrial area (Figure 2).

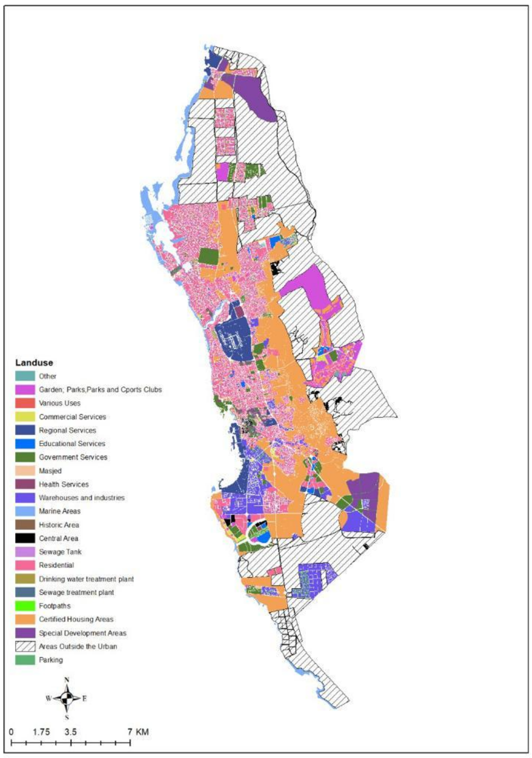


Figure 1. Land use of the study area.

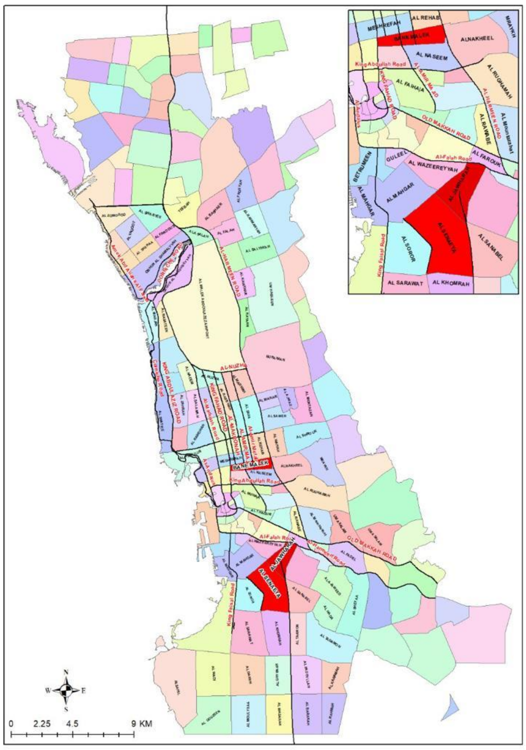


Figure 2. Study area location

2.2 Air quality data

Data from three air quality monitoring stations were used to measure air quality parameters such as NO_x, SO_2, PM_{10}. Data of air quality was obtained from the averaging hourly observation between (2010 -2018), released by the General Authority for Meteorology and Environmental Protection (Table 1, Figure 3).

Table 1. Localisation of observation points.

Air quality observation station	Latitude	Longitude
Bani Malik	21,524667	39,203088
Stadium	21,566103	39,173342
Industrial Area	21,47776	39,206275

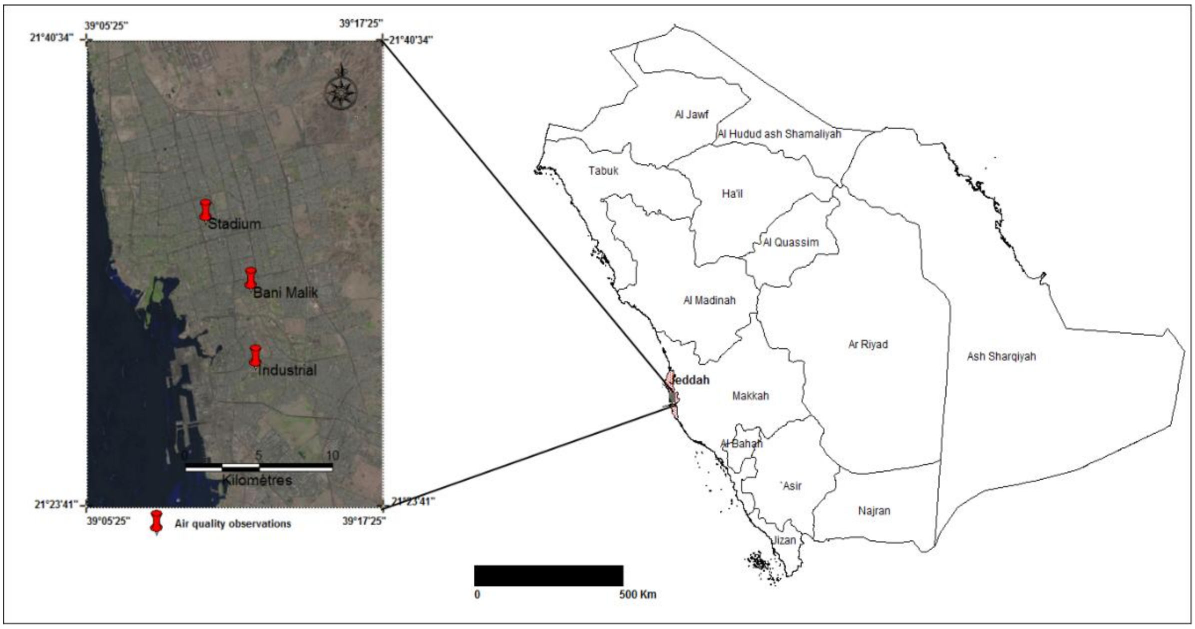


Figure 3. Study area and observation stations.

2.3 Data analysis

2.3.1 Air quality data analysis

Monitoring data, from three observation stations, were used to obtain the necessary values of (NO_X, SO_2, PM_{10}), in the study area between (2010 -2018) (Figure 4).

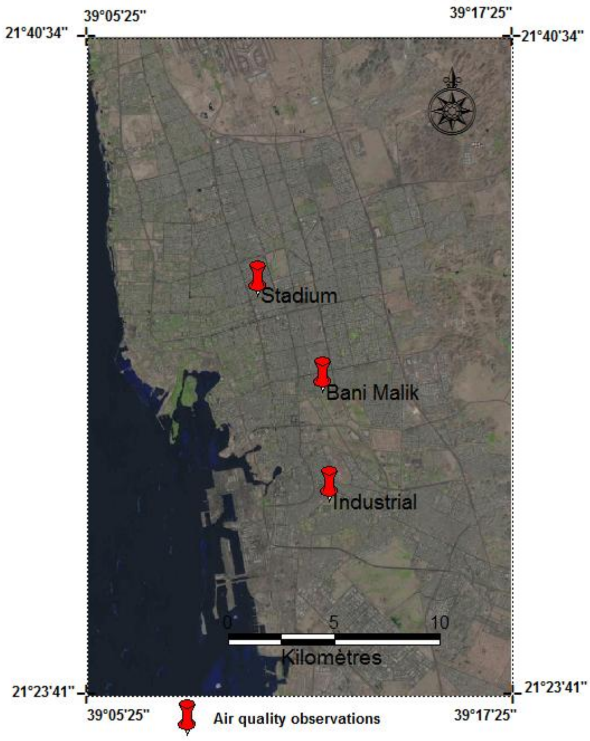


Figure 4. Air quality observation stations.

The second step is the interpolation of the collected data, from the three observation stations using ArcGIS 10.8 software, by applying the geostatistical method Inverse distance weighted (IDW), This method assumes that the variable being mapped decreases in influence with distance from its sampled location (Philip and Watson, 1982; Watson and Philip, 1985), this method was commonly used in the meteorological forecast. Where it takes the relation of interpolation and sampling points as the prediction weight (Varatharajan et al., 2018).

$$Z_j = \frac{\sum_i \frac{Z_i}{d^n_{ij}}}{\sum_i \frac{1}{d^n_{ij}}}$$

Zi is the value of a known point; **Dij** is the distance to a known point; **Zj** is the unknown point **n** is a user selected exponent

The weight contribution was inversely proportional to the distance. The use of this method enables to map the distribution of NO_X, SO_2, PM_{10}, and compare the spatial and temporal variability of pollutants during the period (2010 – 2018).

4. Results and discussion

4.1 Variability of NO_X concentration between (2010 - 2018)

The concentration of NO_X in the three monitoring stations decreased, between 2010 and 2018, where NO_X concentration in 2010 fluctuates, between (35 – 63 ppb), compared to (25- 31 ppb) in 2018. The highest concentration in 2010, is registered in the industrial area, while the highest value, in 2018 is registered in the station (Stadium) (Figure 5).

According to the spatial distribution, the most important concentrations of NO_X, is in the south of the study area, surrounding the industrial activities between (25 – 62.99 ppb). In 2018, the highest concentrations are between (25 – 30.99 ppb) in the north of the study area, with such values in the urban part of the city, the concentration of NO_X are lower, than the situation in 2010, but more important, than the other parts of the study area (Figures 6, 7).

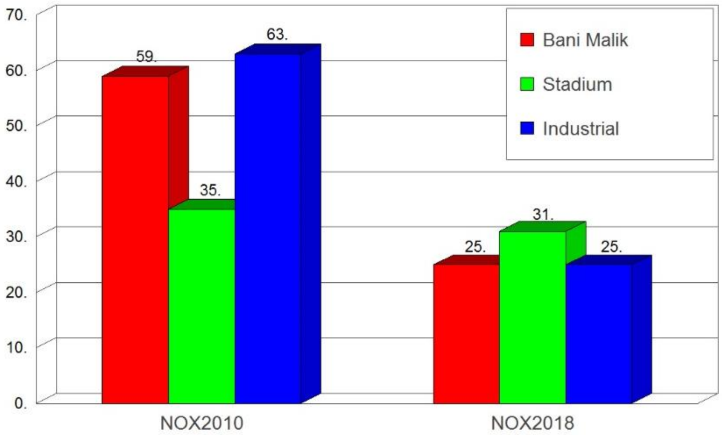


Figure 5. Variability of NO_X concentration between (2010 -2018).

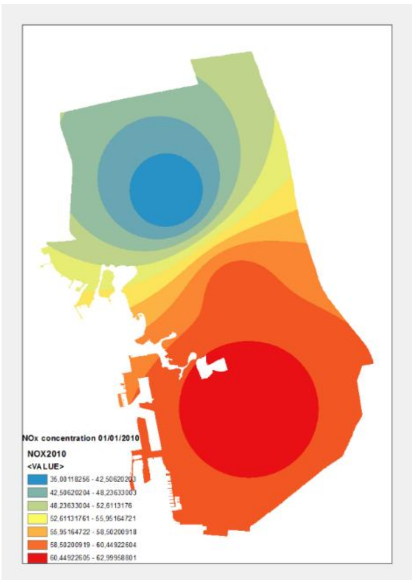


Figure 6. Spatial distribution of NO_X in 2010.

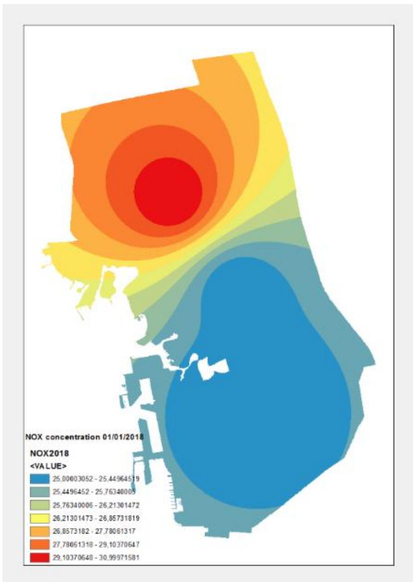


Figure 7. Spatial distribution of NO_X in 2018.

4.2 Variability of SO_2 concentration between (2010 - 2018)

The concentration of SO_2 fluctuates, was between (17 – 47 ppb) in 2010, to (10 - 14 ppb) in 2018. In 2010, the highest concentration is registered in the industrial area, while the highest value, in 2018, is registered in the station (Stadium). The obtained results refer to the improvement of air quality between 2010-2018 (Figure 8).

According to the spatial interpolation of $S0_2$, the most important concentrations of SO_2 are in the south of the study area, surrounding the industrial activities. In 2018, the highest concentrations are in the north of the study area, with such values in the urban part of the city. The concentration of $S0_2$ is lower, than the situation in 2010, but more important, than the other parts of the study area (Figures 9, 10).

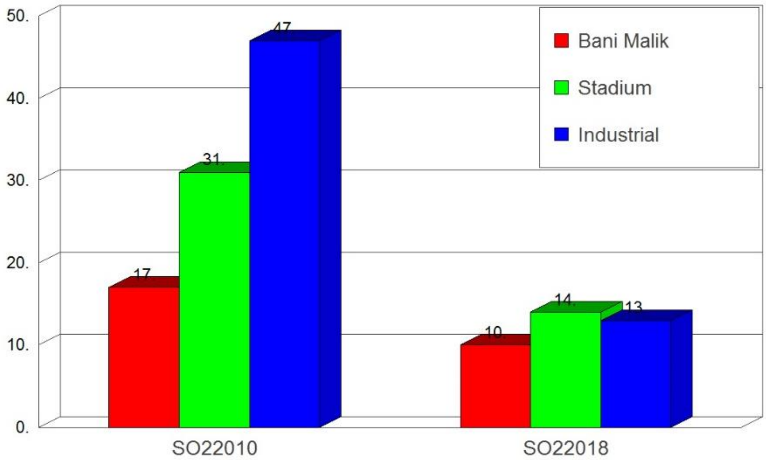


Figure 8. Variability of SO_2 concentration between (2010 - 2018)

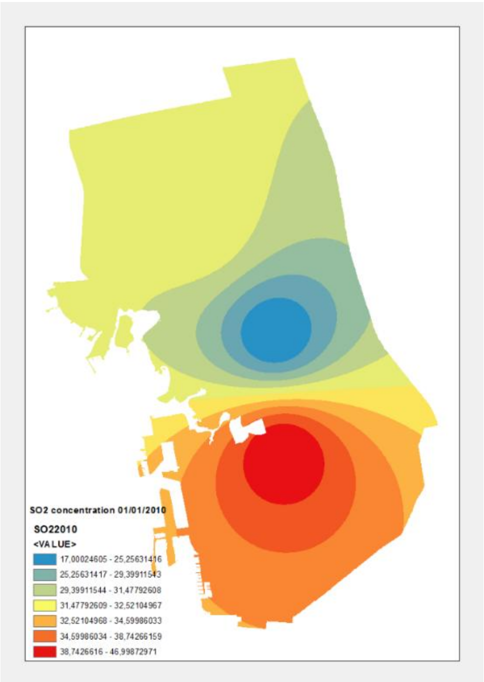


Figure 9. Spatial distribution of SO_2 in 2010.

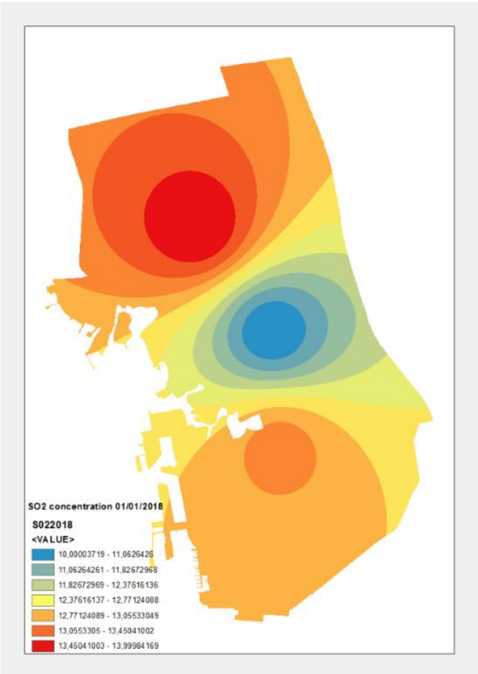


Figure 10. Spatial distribution of SO_2 in 2018.

4.3 Variability of PM_{10} concentration between (2010 - 2018)

The concentration of $\mathbf{PM_{10}}$ in the different stations decreased, between 2010 and 2018, where the concentration is between (101 – 173 µg/m^3), in 2010, and (64 - 128 µg/m^3) in 2018. The highest concentration in 2010, is registered in the urbanised area, while the highest value, in 2018 is registered in the industrial part of the city (Figure 11).

According to the spatial interpolation, the most important values of **PM_{10}**, are in the south of the study area, in the industrial part of the city, with values between (153 – 173 µg/m^3**)**. In 2018, we notice the decrease of the PM_{10} values in the industrial area and the extension of the first and the second class in the map with values between (67 – 77 µg/m^3), (Figures 12, 13).

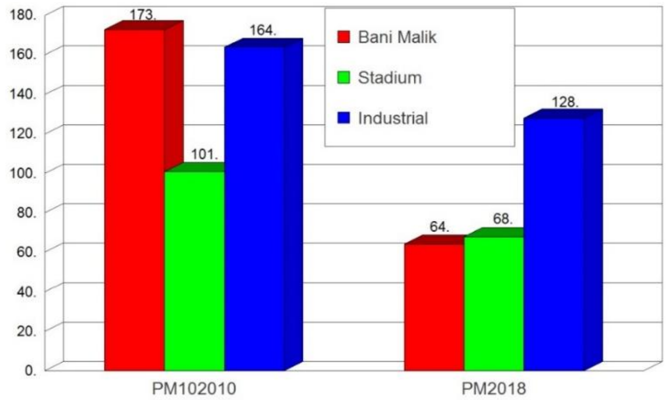


Figure 11. Variability of PM_{10} concentration between (2010 - 2018)

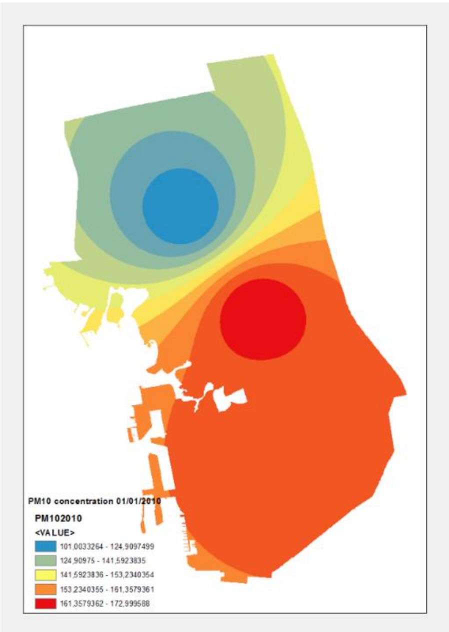


Figure 12. Spatial distribution of PM_{10} in 2010.

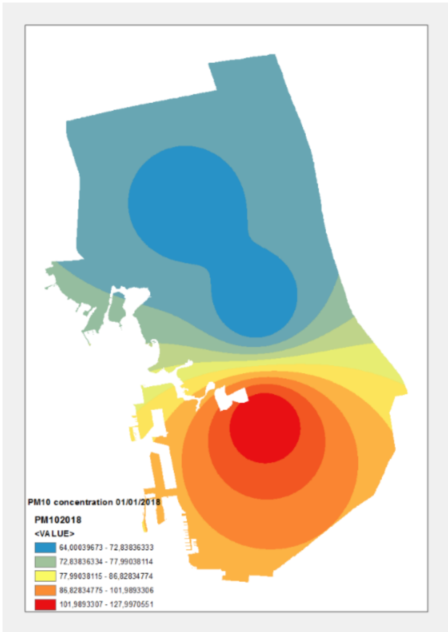


Figure 13. Spatial distribution of PM_{10} in 2018.

The obtained results refer to the improvement of air quality in the city of Jeddah between 2010-2018. Where the values of NO_X and SO_2 concentrations between (2010 -2018), are always under the level adopted by the American Environmental Protection Agency (EPA), for air quality, where the maximal value is 75 ppb (EPA, 2016), But the values are so far, from air quality standards, mentioned by world health organisation (WHO, 2018), the lowest value of PM_{10} in Jeddah is higher than the standard 50 µg/m^3 mentioned in WHO (2018) report, as maximal value, for particulate matter concentration in cities. This situation can be explained, by the impact of traffic on air quality (Hussein et al., 2014), where more than 1.4 million vehicles running in the streets of Jeddah city, mainly use gasoline and diesel (Khodeir et al., 2012).

5. Conclusion

This paper studied the relationship between urban expansion and air quality in the city of Jeddah, between 2010-2018. The use of geostatistical method IDW, enabled us to predict the spatial distribution of the three air quality indicators (NO_X, SO_2, PM_{10}), where the results refer to the improvement of air quality, in the study area. The improvement of air quality is related to the urban policy, based on the relocation of the industrial activities, out of the city. Even though a lot of work must be done to attend the air quality standards of the World Health Organisation for modern cities.

Author Contribution Statement

MEM and WEZ performed the study, wrote and approuved the paper.

Conflict of interest

There are no competing interests related to this work.

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References

Al-Ahmadi, K., See, L., Heppenstall, A., & Hogg, J. (2009). Calibration of a fuzzy cellular automata model of urban dynamics in Sfig Saudi Arabia. *Ecological Complexity*, 6 (2), 80–101.

Al-Hathloul, S., & Mughal, M. (2004). Urban growth management—the Saudi experience. *Habitat International*, 28 (4), 609–623.

Aljoufie, M., Zuidgeest, M.H.P., Brussel, M.J.G., & van Maarseveen, M.F.A.M. (2011). Urban growth and transport understanding the spatial-temporal relationship. In: Pratelli, A., Brebbia, CA. (Eds.), Urban transport XVII: urban transport and the environment in the 21st Century. WIT Press, Southampton, pp. 315–328.

Aljoufiea, M., Brussel, M., Zuidgeest, M., & van Maarseveen, M. (2012). Urban growth and transport infrastructure interaction in Jeddah between 1980 and 2007. *International Journal of Applied Earth Observation and Geoinformation*, 21(1), 493–505. https://doi.org/10.1016/j.jag.2012.07.006

Almazroui, M., Mashat, A., Assiri, M. E., & Butt, M. J. (2017). Application of Landsat Data for Urban Growth Monitoring in Jeddah. *Earth Systems and Environment*, 1(2), 1–11. https://doi.org/10.1007/s41748-017-0028-4.

Briggs, D.J., Collins, S., Elliott, P., Fischer, P., Kingham, S., Lebret, E., Pryl, K., van Reeuwijk, H., Smallbone, K., & van der Veen, A. (1997). Mapping urban air pollution using GIS: a regression-based approach. *International Journal Geographical Information Science*, 11(7), 699–718.

Briggs, D.J., de Hoogh, C., Guiliver, J., Wills, J., Elliott, P., Kingham, S., & Smallbone, K. (2000). A regression-based method for mapping traffic-related air pollution: application and testing in four contrasting urban environments. *Science of the Total Environment*, 253(1-3), 151–167. https://doi.org/10.1016/S0048-9697(00)00429-0

Dockery, D.W., Spiezer, F.E., & Stram, D.O. (1989). Effects of inhaled particles on respiratory health of children. *American Review of Respiratory Disease*, 139(3), 587–594.

EPA (2016). Air Quality Guide for Nitrogen Dioxide.
Filonchyk, M., Yan, H., Yang, S., & Hurynovich, V. (2016). A study of PM 2.5 and PM 10 concentrations in the atmosphere of large cities in Gansu Province, China, in summer period. *Journal of Earth System Science,* 125(6), 1175–1187. https://doi.org/10.1007/s12040-016-0722-x.
Hussein, T., Alghamdi, M. A., Khoder, M., AbdelMaksoud, A. S., Al-Jeelani, H., Goknil, M. K., Shabbaj, I. I., Almehmadi, F. M., Hyvärinen, A., Lihavainen, H., & Hämeri, K. (2014). Particulate matter and number concentrations of particles larger than 0.25 μm in the urban atmosphere of Jeddah, Saudi Arabia. *Aerosol and Air Quality Research*, 14(5), 1383–1391. https://doi.org/10.4209/aaqr.2014.02.0027.
Khodeir, M., Shamy, M., Alghamdi, M., Zhong, M., Sun, H., Costa, M., Chen, L.C. & Maciejczyk, P. (2012). Source Apportionment and Elemental Composition of PM2.5 and PM10 in Jeddah City, Saudi Arabia. *Atmospheric Pollution Research*, 3(3), 331–340.
Meyer, M.D., & Miller, E.J. (2001). Urban Transportation Planning, 2nd ed. McGraw Hill, New York.
Philip, G. M., & D. F. Watson. (1982)."A Precise Method for Determining Contoured Surfaces." *Australian Petroleum Exploration Association Journal*, 22(1), 205–212.
Pope, C.A., Bates. D.A., & Raizenne, M.E. (1995). Health effects of particulate air pollution: time for reassessment? *Environ Health Perspect*, 103(5), 472–480.
Schwartz, J. (1993). Particulate air pollution and chronic respiratory disease. *Environmental Ressources*, 62(1),7–13.
Salman, A., Al-Tayib, M., Hag-Elsafi, S., & Al-Duwarij, N. (2016). Assessment of pollution sources in the southeastern of Riyadh and its impact on the population/Saudi Arabia. *Arabian Journal of Geosciences*, *9*(4), 1–16. https://doi.org/10.1007/s12517-016-2371-4
Varatharajan, R., Manogaran, G., Priyan, M.K., Balas¸, V.E., & Barna, C. (2018). Visual analysis of geospatial habitat suitability model based on inverse distance weighting with paired comparison analysis. *Multimeia Tools Application*, 77, 17573–17593.
Watson, D. F., & G. M. Philip. (1985)."A Refinement of Inverse Distance Weighted Interpolation." Geoprocessing, 4(2), 315–327.
WHO – World Health Organization. (2018). Air Pollution. Health and Sustainable Development. Available in: https://www.who.int/sustainable-development/ transport/health-risks/air-pollution/en/ Acess in 19/12/2018