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Application of satellite data and GIS services for studying air pollutants in Basra province, south of Iraq

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Abstract

Satellite remote sensing, with its relatively short history, will play a major role in fields that encompass topics related to place and space. Through this innovation in technology, real-time monitoring and mapping of changing phenomena on Earth's surface is possible. The purpose of this study was to investigate and evaluate the spread of air pollutants in Basra city from 3/12/2018 to 3/1/2019 using stationary environmental station data and satellite data. Satellite data and pollutant data gathered from an air quality monitoring station located in different parts of Basra Province were used. The data were downloaded for the days mentioned above for the geographical boundary of Basra City. The results showed a strong correlation between the SO_2 concentration values of the satellites and the ground station, whereas there was some slight convergence of the NO_2 concentration values between the satellite data and the ground station. Regarding the BC concentration, a difference was observed between the satellite values and the values measured by the ground station.

Keywords: Satellite; GIS; Air pollutants; Basra

1. Introduction

Air pollution is a pressing issue that poses significant risks to both human health and the environment (Assaf & Abdulla, 2023). Ambient air pollution consists of a mixture of solid, liquid, and gaseous components, including over 40 toxic substances from various man-made and natural sources (Sicard et al., 2023). Of the most common atmospheric pollutants are particulate matter (PM), black carbon (BC) nitrogen dioxide (NO_2), tropospheric ozone (O3), carbon monoxide (CO) and Sulphur (SO_2) (Burns et al., 2020). sulfur dioxide has adverse health effects on the human respiratory, cardiovascular, and nervous systems. Although some evidence suggests that sulfur dioxide at given concentrations has no adverse health effects, its synergistic effects in combination with other air pollutants may be significant (Khalaf et al., 2022). NO_2 is highly important because of its negative effects on the environment and human health (Muthulakshmi et al., 2019). Long-term exposure to this gas is known to cause various diseases such as hypertension, deficits in pulmonary function, and chronic obstructive pulmonary disease (COPD) (Lyons et al., 2020), in addition to increasing the risk of contracting viral infections (Jurado et al., 2020). BC is a major constituent of PM2.5 BC is an essential component of carbonaceous aerosols, which are the most significant segment of airborne particles (Prasad et al., 2018). According to modern scientific studies and current research, exposure to BC may cause serious health issues in humans, such as non-cancer (respiratory-related problems, cardiovascular diseases) and cancer (lung cancer) (Ambade et al., 2021). To address this problem, satellite data and GIS services can be utilized to study air pollutants in the Basra Province. These technologies can provide valuable insights into the distribution and concentration of pollutants in a region. By analyzing satellite imagery, researchers can identify pollution sources, monitor changes in pollutant levels over time, and assess the impact of air pollutants on local communities and ecosystems(Sorek-Hamer et al., 2020). Satellite data can also help track the movement and dispersion of pollutants, as well as identify areas most affected by air pollution(Jumaah et al., 2023). Furthermore, GIS services can integrate

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satellite data with other geographical information, such as population density and land use patterns, to analyze the relationship between air pollution and various socioeconomic factors(Mohammed et al., 2018). This integrated approach can inform decision-making processes and support the development of effective strategies to mitigate air pollution in the Basra Province. Overall, the application of satellite data and GIS services to study air pollutants in Basra province can provide valuable information for understanding and addressing air pollution issues in the region, leading to improved air quality and better health outcomes for the residents of Basra Province. One of the key benefits of using satellite data and GIS services to study air pollutants in Basra Province is the ability to create detailed spatial maps that illustrate the distribution of pollutants. These maps can help identify hotspots of air pollution, which in turn can inform the development of targeted intervention strategies to mitigate the impact on public health and the environment. In addition, the integration of satellite data with GIS services allows the monitoring of air quality over time, enabling researchers and policymakers to assess the effectiveness of mitigation measures and environmental policies(Jin et al. 2018). Moreover, a combination of satellite imagery and GIS can facilitate the identification of vulnerable populations and ecosystems that are disproportionately affected by air pollution. This information can guide the implementation of protective measures and resource allocation to minimize the adverse effects on these at-risk groups.(Jumaah et al., 2023) Using satellite data and GIS services can reveal intricate patterns and correlations between pollution sources, meteorological conditions, and local topography, offering a deeper insight into the factors influencing air quality in the region(Sorek-Hamer et al., 2020). Furthermore, remote sensing technologies enable the identification of specific types of air pollutants such as particulate matter, nitrogen dioxide, and sulfur dioxide with a high degree of accuracy(Streets et al., 2013). The integration of socioeconomic data with satellite-derived pollution information through GIS services enables researchers to assess the social and economic disparities associated with the impact of air pollution (Cooper et al., 2020). By overlaying demographic data, income levels, and health indicators with pollution hotspots, it becomes possible to identify areas where air quality concerns intersect with vulnerable communities, informing policy decisions and resource allocation to address these disparities. Overall, the application of satellite data and GIS services to study air pollutants in Basra Province can provide crucial insights into the sources, distribution, and impact of air pollution(Mohammed et al., 2018). This information can support evidence-based decision-making to implement effective measures for air pollution control, improve public health outcomes, and protect the environment in Basra Province.

2. Materials and Methods

2.1. Study area

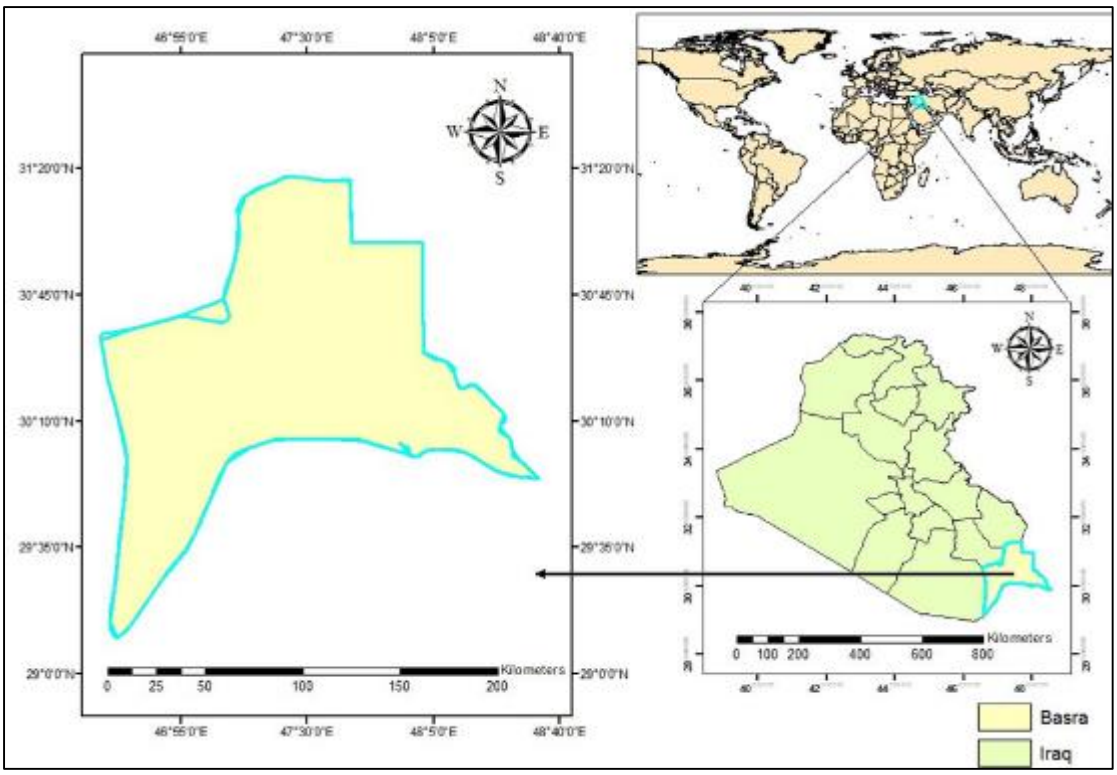

Figure 1 Map of the Study area

Basra is the southernmost major city in Iraq. With a population of more than 1.5 million it is densely populated, congested, and a hub of commercial and industrial activities (Al-Tameemi et al., 2023). Basra Province lies between latitudes (31° 30′–29° 00′) and longitudes (30° 48′–46° 30′) (Taher et al. 2023). Figure(1) below shows the province of Basra for Iraq and Iraq for the world, where the province of Basra is characterized by its distinctive geographical location for Iraq and the world.

The data used in this study were divided into ground and satellite data.

2.2. Air pollutants data from ground-based station

Air pollutants (sulfur dioxide, nitrogen dioxide, and black carbon) were collected by the fixed air monitoring station of the Directorate of Environment of the South in Basra Governorate, located at the University of Basra. The concentrations of the pollutants were then collected weekly from December 2018 to January 2019. Figure (2) records the fixed air quality monitoring station (Horiba) located at the University of Basra site, which is used to continuously measure and monitor pollutants over large areas.

Figure 2 Horiba station (inside view)

2.3. Satellite data

The NASA Giovanni data analysis system is a well-known and useful tool for analyzing various types of remote-sensing data. Therefore, air quality is a public health concern. Aerosol optical depth data products, acquired by MODIS and the ozone measuring instrument (OMI), are probably the most accessed air quality-related data in Giovanni. Some data on the chemistry of the atmosphere have been obtained through OMI (Soleimany et al., 2021). Air pollutant data were downloaded from the National Aeronautics and NASA Giovanni data analysis system. In this study, BC was measured by the satellite [MERRA-2 Reanalysis M2T1 NXAER v5.12.4] in $kg.m^{-3}$, NO_2 was measured by the satellite [OMI OM NO_2 d v003] in $molecules.cm^{-2}$ and SO_2 was measured by the satellite [MERRA-2 Reanalysis M2T1 NXAER v5.12.4] in $kg.m^{-3}$.

Using a geographic information system (GIS), weekly concentrations of BC, SO_2, and NO_2 were spatially distributed. A computer information system is a geographic information system. GIS provides capabilities for the accurate graphical depiction of objects in space as well as data collection, integration, management, analysis, modeling purposes, and data display (Hassan, 2018). IDW is a local interpolation method that estimates values at unknown locations based on the values of nearby known locations weighted by their distances. It assumes that closer points have a greater influence on

the estimated value, and allows the user to control the significance of known points based on their proximity to the output point (Huang, 2011).

3. Results and discussion

figure 3 shows the spatial distribution of black carbon concentration in the Basra Governorate during the measurement period, where the average concentrations ranged from 0.736 to 1.848 μg.m^{-3}, which was higher than the concentrations measured by Wahab et al. (2023), where the average concentrations measured in that study ranged from 0.78 0.96 μg.m^{-3}. It was noted that the highest concentrations were in the center and north of Basra Governorate, where oil production fields such as the Rumaila fields, West Al-Gharna fields, Nahran Ben Omar, and Majnoon oil field are located.

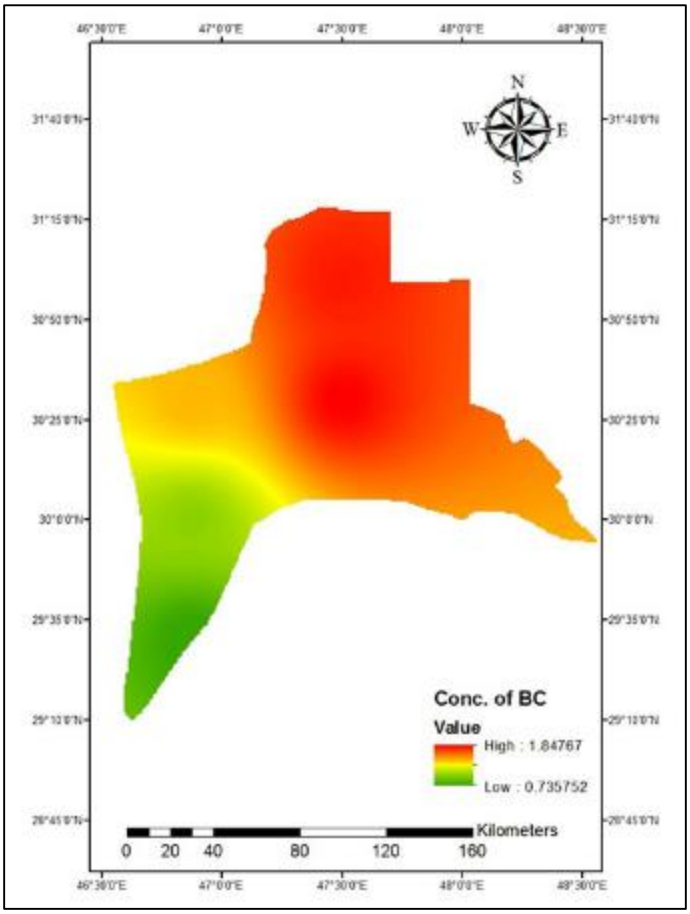

Figure 3 The spatial distribution of black carbon concentration in Basra Governorate during the measurement period

Figure 5 shows the spatial conversion of the average NO_2 concentrations in Basra Governorate during the measurement period, which was between 8.02 to 50.32 μg.m^{-3}, which was higher than the average concentrations measured by Soleimany et al. (2021), which ranged from 2.5 to 10.97 μg.m^{-3} for the same satellite (OMI). The gas concentration was high in the southern and southeastern regions, where the Burjisiya oil field and oil sites adjacent to the Iraqi-Kuwaiti and Iraqi-Iranian borders were located.

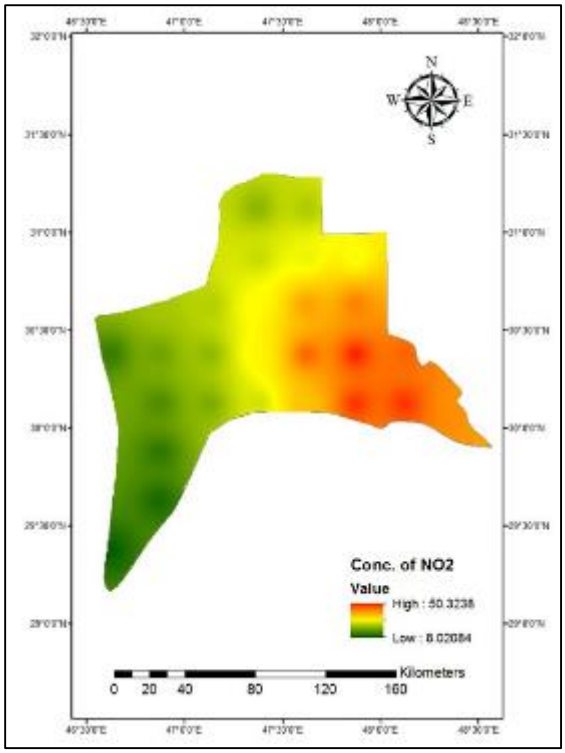

Figure 4 The spatial conversion of the average NO_2 concentrations in Basra Governorate during the measurement period

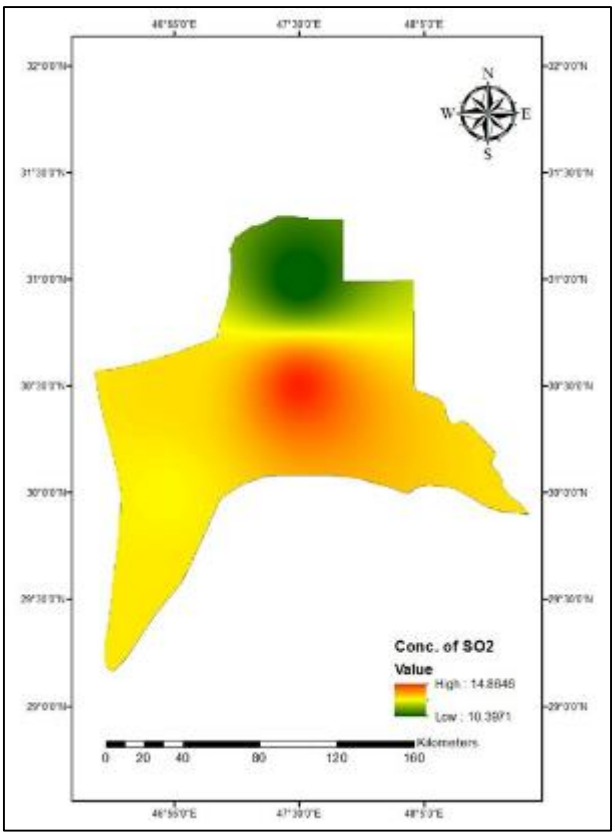

Figure 5 The spatial conversion of the average SO_2 concentrations in Basra Governorate during the measurement period

Figure 5 shows the spatial conversion of the average SO_2 concentrations in the Basra Governorate during the measurement period, which was between 10.39 to 14.86 $\mu g.m^{-3}$, which was lower than the average concentrations measured by Soleimany et al. (2021), which ranged from 4.91 25.27 $\mu g.m^{-3}$. The highest concentrations were observed in the center of the governorate, where the northern Rumaila oilfield is located to the west.

3.1. Comparison of Satellite data for BC, NO_2, SO_2 and in-situ measurements

Figure 6 shows the BC concentration measured by satellite data and stationary monitoring stations from 3/12/2018 to 3/1/2019, where the stability of BC concentration values measured by satellites was observed, while there was a rise in concentration and then a decrease for fixed station measurements during the measurement period.

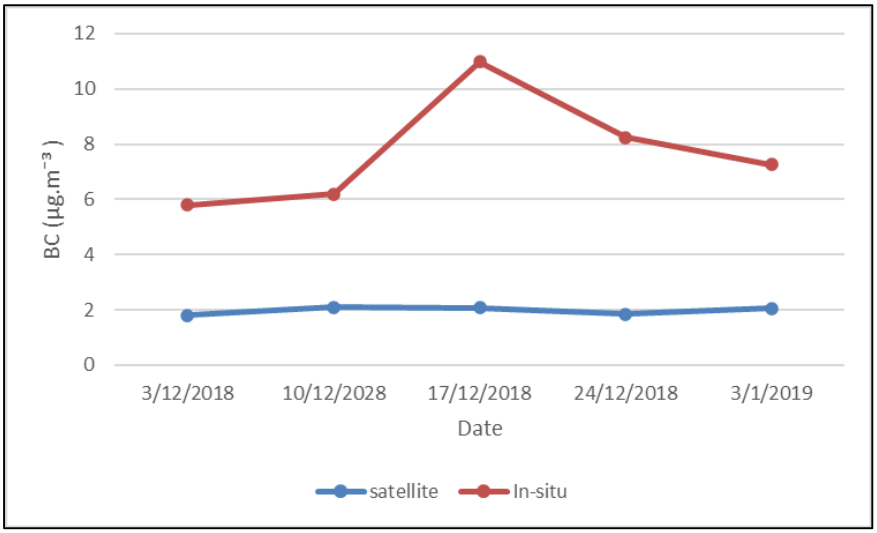

Figure 6 BC concentrations measured by satellite data and stationary monitoring stations from 3/12/2018 to 3/1/2019**.**

Figure 7 shows the NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019. It can be seen that the values measured by satellites increased and decreased simultaneously with the values measured by the fixed ground station, but the values of the satellites were much higher than the values of the fixed station for NO_2.

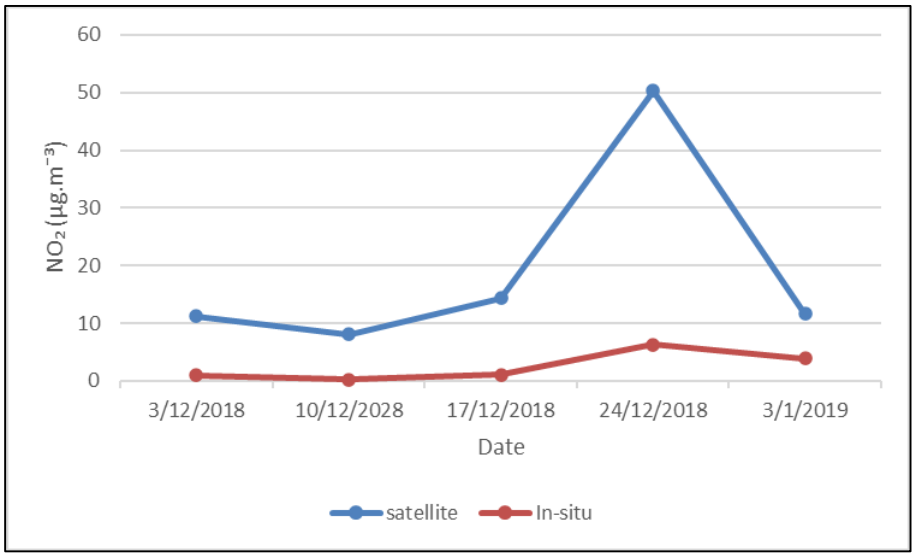

Figure 7 The NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019

Figure 8 shows the NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019, and it was observed that there was a great convergence between the values measured by the satellite and the values measured by the fixed earth station for the concentration of SO2.

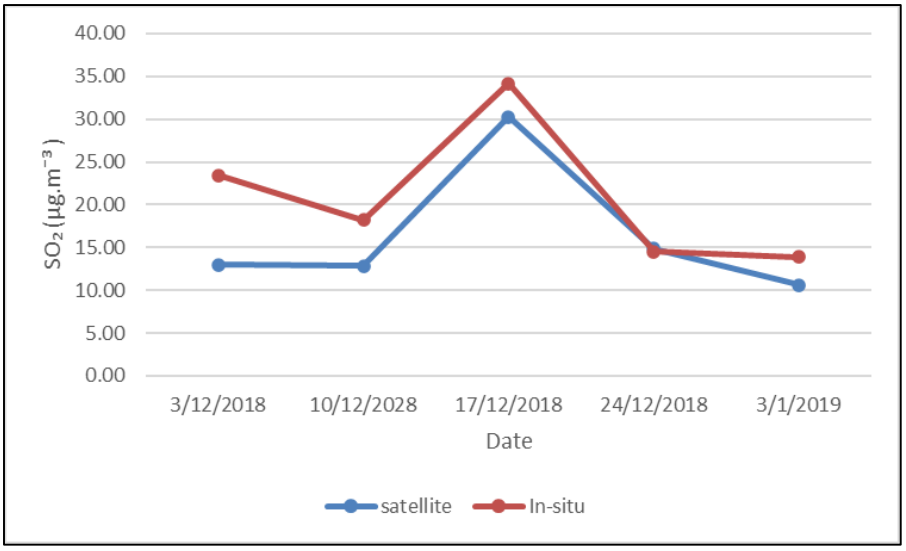

Figure 8 The NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019

4. Conclusions

The objective of this study was to examine and evaluate the prevalence of air pollutants in Basra City from 3/12/2018 to 3/1/2019 using data from fixed environmental stations and satellite observations. The dataset consists of information obtained from satellites and air quality monitoring stations located in various locations within the Basra Governorate. The downloaded data cover a specific period and geographical boundaries of the city of Basra. The results revealed a statistically significant relationship between the concentration of sulfur dioxide values derived from satellite observations and those recorded by ground stations. However, there was little difference between the nitrogen dioxide concentration values obtained from satellite data and measurements from the ground station. In addition, there was a discrepancy in BC concentration values between the satellite data and ground station measurements.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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