Utilizing Satellite Data and GIS Technologies for Air Pollution Analysis in Basra Province, Iraq

Hussein T. Khreebsh and Nayyef M. Azeez*

Department of Ecology, College of Science, University of Basrah, Basra, Iraq
Email: hussain.t.k1997@gmail.com (H.T.K.); nayyef.azeez@uobasrah.edu.iq (N.M.A.)
*Corresponding author
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Abstract—Satellite remote sensing, despite its relatively brief history, is poised to play a pivotal role in fields related to geography and spatial analysis. This technological innovation enables real-time monitoring and mapping of dynamic phenomena on Earth's surface. This study investigates and evaluates the dispersion of air pollutants in Basra City from December 3, 2018, to January 3, 2019, utilizing data from stationary environmental monitoring stations and satellite sources. Data for the specified dates was obtained from air quality monitoring stations located throughout Basra Province and satellite sources. The results revealed a strong correlation between sulfur dioxide (SO_2) concentration values obtained from satellites and ground stations. Additionally, a slight convergence was observed in nitrogen dioxide (NO_2) concentration values between satellite and ground station data. However, a notable discrepancy was found in Black Carbon (BC) concentration values between satellite measurements and those recorded by ground stations.

***Keywords*—satellite, Geographic Information System (GIS), air pollutants, Basra, Iraq**

I. INTRODUCTION

Air pollution is a critical issue that presents a significant threat to human health and the environment [1]. Ambient air pollution comprises a complex mixture of solid, liquid, and gaseous components, including over 40 toxic substances from various anthropogenic and natural sources [2]. Among the most prevalent atmospheric pollutants are particulate matter (PM), black carbon (BC), nitrogen dioxide (NO_2), tropospheric ozone (O_3), carbon monoxide (CO), and sulfur dioxide (SO_2) [3]. Sulfur dioxide has detrimental effects on the human respiratory, cardiovascular, and nervous systems. While some evidence suggests that sulfur dioxide at certain concentrations may not have adverse health effects, its synergistic interactions with other air pollutants can be significant [4].

Nitrogen dioxide (NO_2) is of considerable concern because of its negative effects on both the environment and human health [5]. Prolonged exposure to NO_2 is associated with various diseases such as hypertension, reduced pulmonary function, and Chronic Obstructive Pulmonary Disease (COPD) [6], in addition to increasing the risk of viral infections [7]. Black carbon (BC) is a major component of PM2.5 in the atmosphere and is a significant constituent of carbonaceous aerosols, which are among the most critical segments of airborne particles [8]. Current scientific studies indicate that BC exposure can lead to severe health issues, including non-cancerous conditions (such as respiratory and cardiovascular diseases) and cancerous diseases (such as lung cancer) [9].

To address the challenges posed by air pollution, satellite data and Geographic Information System (GIS) services can be leveraged to monitor and study air pollutants, particularly in regions such as Basra Province.

The utilization of satellite data and Geographic Information System (GIS) technologies offers critical insights into the distribution and concentrations of pollutants in specific regions. By analyzing satellite imagery, researchers can identify pollution sources, monitor temporal changes in pollutant levels, and evaluate the impact of air pollutants on local communities and ecosystems [10]. Satellite data also facilitates the tracking of the movement and dispersion of pollutants, highlighting areas most affected by air pollution [11]. Moreover, GIS services can integrate 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 [12]. This comprehensive approach can inform decision-making processes and support the development of effective strategies to mitigate air pollution in the 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 pollutant distribution. These maps can identify air pollution hotspots, thereby informing the development of targeted intervention strategies to mitigate their impact on public health and the environment. Additionally, integrating satellite data with GIS services allows for continuous monitoring of air quality over time, enabling researchers and policymakers to assess the effectiveness of mitigation measures and environmental policies [13].

Furthermore, 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 at-risk groups. Jumaah *et al.* [11] reported that using satellite data and GIS services can reveal intricate patterns and correlations among pollution sources, meteorological conditions, and local topography, providing deeper insights into the factors influencing air quality in the region [10].

Remote sensing technologies also enable the accurate identification of specific types of air pollutants such as particulate matter, nitrogen dioxide, and sulfur dioxide [14]. Integrating socioeconomic data with satellite-derived pollution information through GIS services allows researchers to assess the social and economic disparities associated with air pollution impacts [15]. 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, applying satellite data and GIS services to study air pollutants in Basra Province provides crucial insights into the sources, distribution, and impacts of air pollution [12]. This information supports evidence-based decision making for implementing effective air pollution control measures, improving public health outcomes, and protecting the environment in Basra Province.

II. Materials and Methods

A. Study Area

Basra is the southernmost major city of Iraq. With a population more than 1.5 million it is very densely populated, congested and a hub of commercial and industrial activities [16]. Basra province lies between latitudes (31° 30´–29° 00´) and longitudes (30° 48´–46° 30) [17]. Fig. 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.

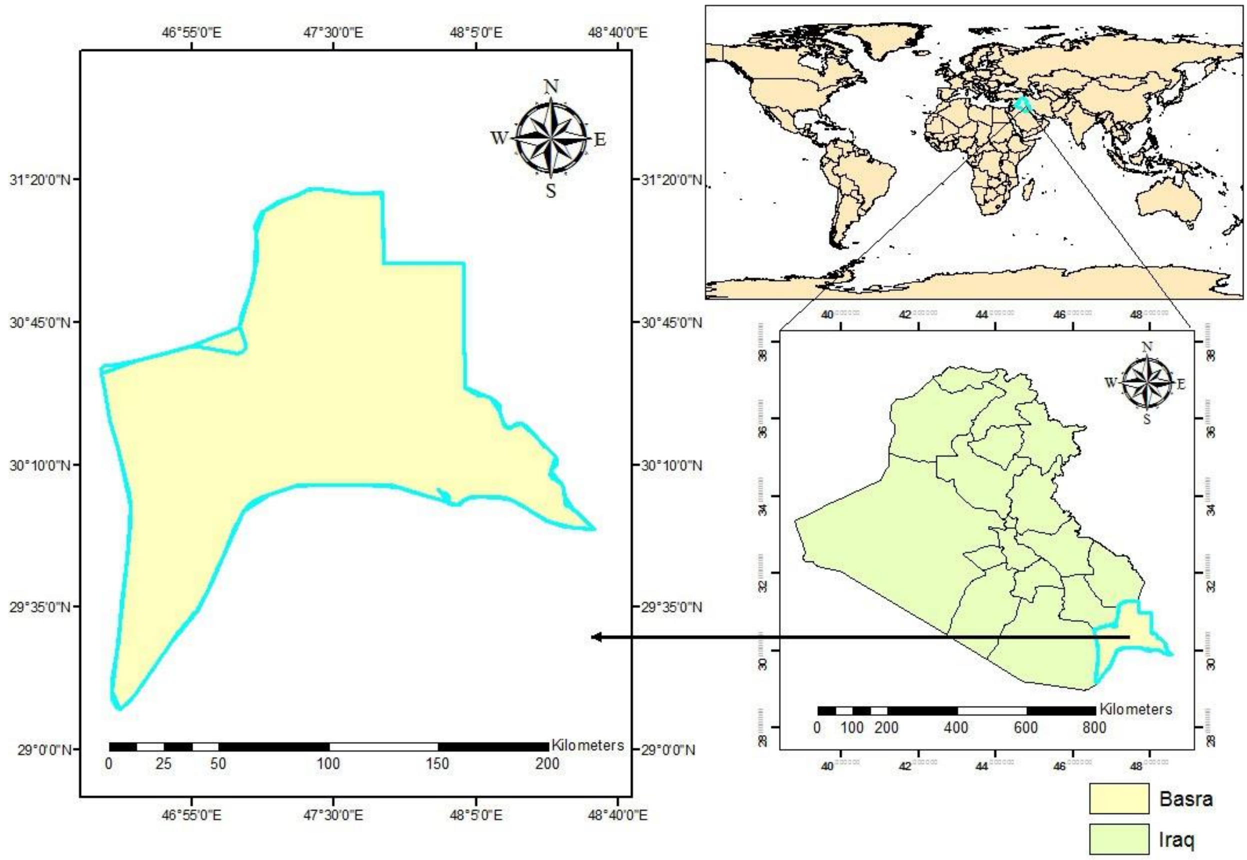

Fig. 1. Map of the Study area.

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

B. Air Pollutants Data from Ground-Based Station

The air pollutants (Sulphur 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 site of the University of Basrah. The concentration of pollutants was then collected weekly from December 2018 to January 2019. Fig. 2 records the fixed air quality monitoring station (Horiba) located at the University of Basrah site, which is used to measure and monitor pollutants over large areas and continuously.

C. Satellite Data

The NASA Giovanni data analysis system is a well-known and useful tool for analyzing various types of remote sensing data. Air quality is a concern in public health. Aerosol optical depth data products, which are 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 are obtained through OMI [18]. Air pollutant data has been downloaded from the NASA Giovanni data analysis system, which contains satellite data used to monitor air pollutants. 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 OMNO2d 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}.

Fig. 2. Horiba station.

Using the Geographic Information System (GIS), weekly concentrations of BC, SO_2 and NO_2 were distributed spatially. A computer information system known as a geographic information system. GIS provides capabilities for accurate graphical depiction of objects in space as well as data collection, integration, management, analysis, modeling purposes, and data display [19]. 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 [20].

III. Results and Discussion

Fig. 3 shows the spatial distribution of black carbon concentration in 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.* [21], where the average concentrations measured in that study ranged from 0.78 to 0.96 µg m^{-3}. It was noted that the highest concentrations were in the center and north of Basra Governorate, where the oil production fields such as the Rumaila fields, the West Al-Gharna fields, Nahran Ben Omar and the Majnoon oil field are located.

Fig. 4 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.* [18], which ranged from 2.5 to 10.97 µg m^{-3} for the same satellite (OMI). It is noted that the concentration of gas 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 are located.

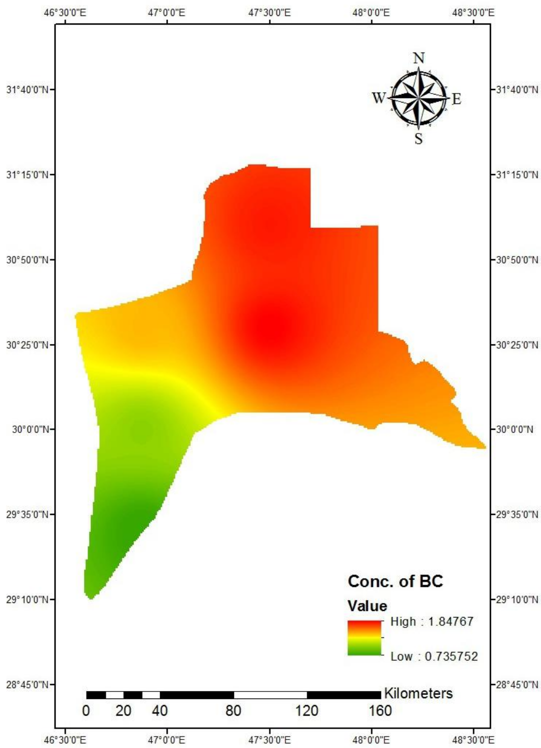

Fig. 3. The spatial distribution of black carbon concentration in Basra Governorate during the measurement period.

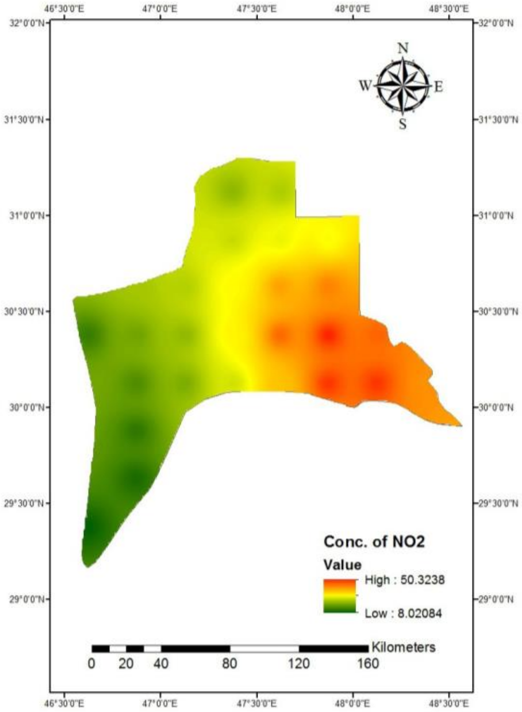

Fig. 4. The spatial conversion of the average NO_2 concentrations in Basra Governorate during the measurement period.

Fig. 5 shows the spatial conversion of the average SO_2 concentrations in Basra Governorate during the measurement period, which was between 10.39 to 14.86 μg m^{-3}, which was lower than the average concentrations measured by Soleimany *et al.* [18], which ranged from 4.91 to 25.27 μg m^{-3}. The highest concentrations were observed in the center of the governorate approximately, where the northern Rumaila oil field is located to the west.

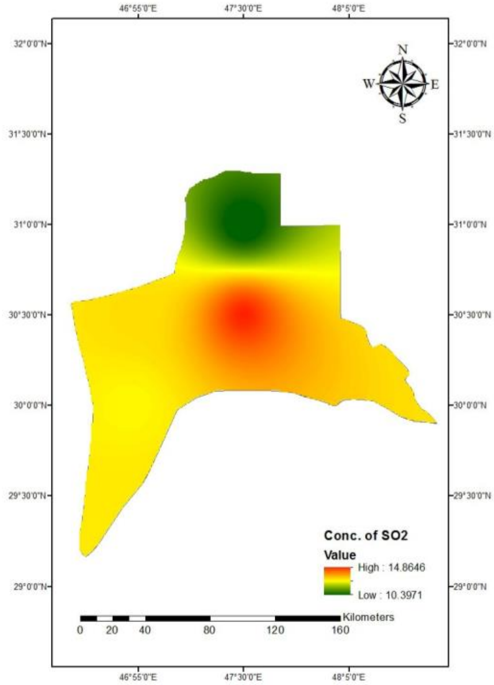

Fig. 5. The spatial conversion of the average SO2 concentrations in Basra Governorate during the measurement period.

IV. Comparison of Satellite Data for BC, NO_2, SO_2 and In-situ Measurements

Fig. 6 shows the BC concentration measured by satellite data and stationary monitoring station 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.

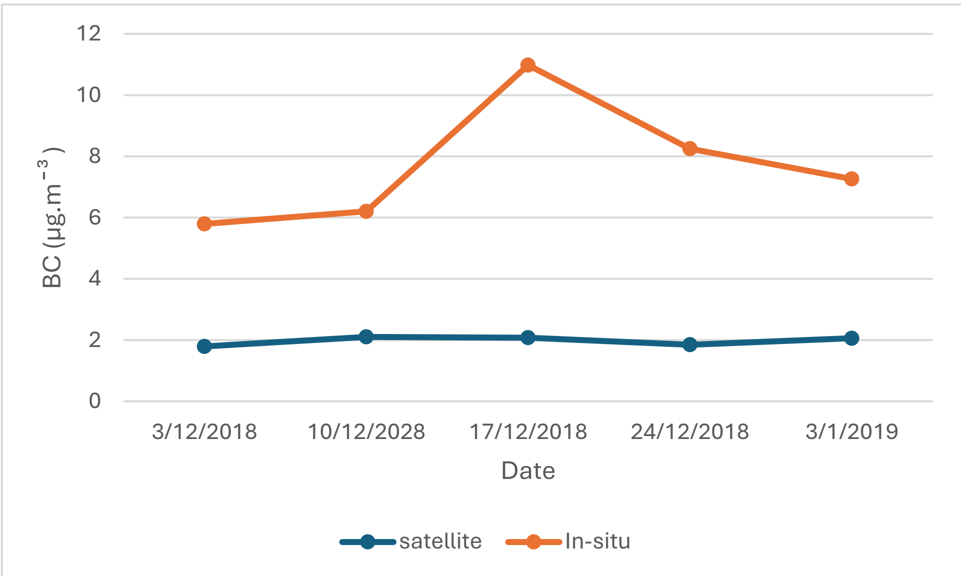

Fig. 6. The BC concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019.

Fig. 7 shows the NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019, Where it was noted that the values measured by satellites increase and decrease simultaneously with the values measured by the fixed ground station, but the values of the satellites are much higher than the values of the fixed station for NO_2.

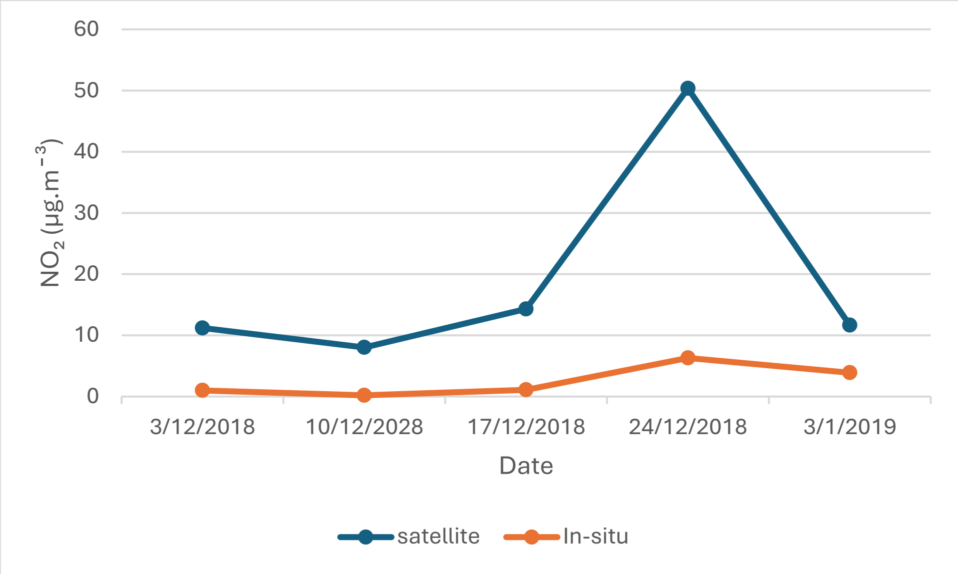

Fig. 7. Shows the NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019.

Fig. 8 shows the NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019, Where it was observed that there is a great convergence between the values measured by the satellite and the values measured by the fixed earth station for the concentration of SO_2.

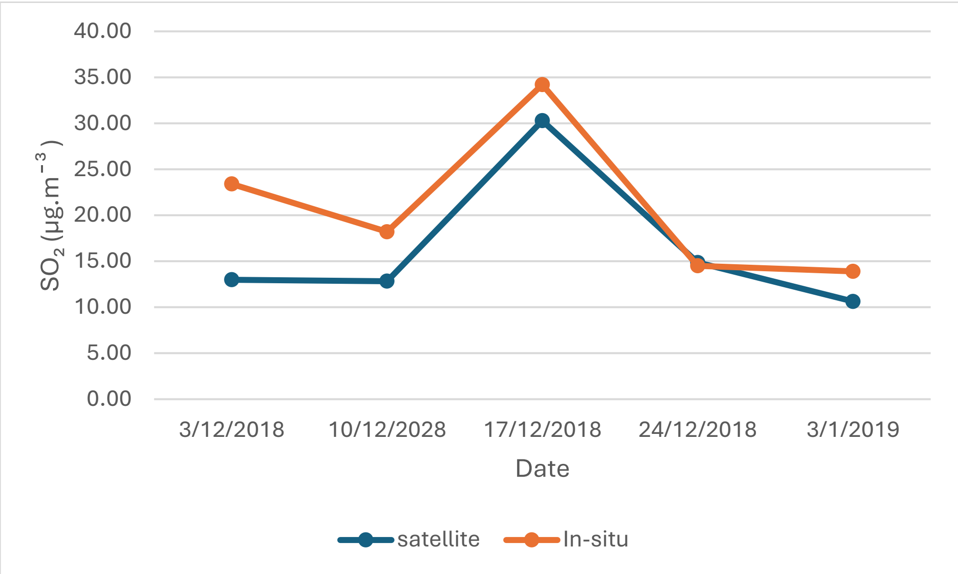

Fig. 8. Shows the NO_2 concentration measured by satellite data and stationary monitoring station from 3/12/2018 to 3/1/2019.

V. 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 Basra Governorate. The downloaded data covers the 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 satellite data and ground station measurements.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Hussein T. Khreebsh carried out the research and performed the data analysis. Nayyef M. Azeez provided supervision and guidance throughout the study and contributed to the writing of the manuscript. Both authors reviewed and approved the final version of the manuscript.

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