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Turbidity Changes in the Tigris River Using Satellite Data During the COVID-19 Related Lockdown

Omar H. Obaid
Department of Physics, College of Education for Pure Science (Ibn-AL-Haitham),University of Baghdad, Baghdad,Iraq.
omar.hajoob1204a@ihcoedu.uobaghdad.edu.iq

Inbethaq M. Ali Abdulameer
Department of Physics, College of Education for Pure Science (Ibn-AL-Haitham),University of Baghdad, Baghdad,Iraq.
Inbethaq.m@ihcoedu.uobaghdad.edu.iq

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Abstract

In the present study, an attempt has been made to study the change in water quality of the river in terms of turbidity during lockdown associated with COVID-19. Iraq announced the longest-ever lockdown on 25 March 2020 due to COVID-19 pandemic.

In the absence of ground observations, remote sensing data was adopted, especially during this period. The change in the visible region's spectral reflectance of water in part of the river has been analyzed using the Landsat 8 OLI multispectral remote sensing data at Tigris River, Salah al-Din province (Bayji / near the refinery), Iraq. It was found that the green and red bands are most sensitive and can be used to estimate turbidity. Furthermore, the temporal variation in turbidity was also analyzed through a normalized difference turbidity index NDTI at each location. The NDTI decreased by 7.14% in April 2020 (lockdown period) as compared to November 2020 (6 months after lockdown), when it was observed that the turbidity in the river (near Bayji oil refinery) had drastically decreased.

The study confirmed that the remote sensing approach can be used to make qualitative estimates on turbidity, even in the absence of field observations. It was concluded that the water quality of Tigris River has improved and has shown signs of restoration.

Keywords: Tigris River, remote sensing, turbidity, NDTI, COVID-19 lockdown.

1. Introduction

River water quality assessments are essential to provide effective and sustainable management of drinking water resources, where natural processes can increase the impact of pollution on river water [1]. Land use and anthropogenic changes in land cover tend to cause increased pollution levels. Pollution is the most important challenge facing water nowadays, where water quality, now and in the future, is classified as an un-renewable resource because it is difficult to return back to its original status before pollution. Its purification is also slower than its deterioration [2].

Turbidity is an important optical characterization parameter of the water body. The turbidity increases by increasing water's suspended solids and sediment concentration [5]. The change in the concentration of suspended matter will change the light propagation direction in the water and cause the attenuation of light energy [3,4]. Both climate change and human activities can cause changes in turbidity [6]. In recent years, remote sensing technology has been widely used to observe this characteristic of the river by analyzing how suspended sediment concentration affects water's optical elements .

Compared with in situ measurement data, remote sensing techniques offer enticing possibilities for estimating and monitoring river turbidity and spatiotemporal patterns. Several researchers are now using the spectral bands (especially the green and red bands, where the reflectance increases with increasing water turbidity) remote sensing technology found in the Landsat satellite system for this purpose [7].

COVID-19 is considered a global pandemic as one of the deadly diseases that affect human life. To protect the population from this deadly disease, the government of Iraq announced a complete closure in March 2020. The lockdown brought about the halting of work in factories and reduced the work of oil refineries, where the possible cleansing of the rivers occurred as a natural process. The pollution level of rivers has been reduced, and it has become much cleaner [8].

In this study, to explore the impact of lockdown on the water environment, the visible band reflectance and the normalized difference turbidity Index (NDTI) of Landsat8 data were used to analyze the changes in Tigris River (near Bayji oil refinery) quality before and after the lockdown. Through the monitoring of the water turbidity of the river, it is found that the water quality has significantly changed during the lockdown of COVID-19.

A comprehensive literature review on water quality remote sensing is presented as follows:

Al-Bahrani [9] reported strong negative correlations between digital numbers (DNs) in Bands 1 and 2 of LANDSAT satellite images with water quality indices according to Bhargava and Canadian methods. These two indices were calculated for the Euphrates River from April 2007 to December 2010 for 16 stations along the River inside Iraqi lands, and satellite image models were built to classify the water of the River for irrigation use.

Nelson et al. [10] developed a regression model to estimate water clarity measured by Secchi disk transparency (SDT) from LANDSAT data calibrated using 93 lakes in Michigan, USA. They correlated the natural log of the SDT with the range of LANDSAT DNs of (Band 1/Band 3). They discovered that using LANDSAT to measure water clarity is sensitive to the distribution of water clarity used in the calibration set.

Selman et al. [11] have employed remote sensing with GIS to study the hydrochemical properties of water at Himreen Dam Reservoir, located on Diyala River in Iraq. An analytical study on the spectrum reflectance value of the study area was performed using satellite images taken by LANDSAT.

Al-Rubai'i [12] used a thermal technique of remote sensing to evaluate its capability to detect and identify water pollution that results from petroleum-related pollution. A mathematical model was developed using DNs of thermal satellite images to measure water temperature.

2. Study Site

The Tigris River is one of the largest rivers in the Middle East, with more than 1,900 km, of which 1,415 km are inside Iraqi territory [13]. The Tigris River enters Salah al-Din Governorate in (369320.077 E), (3878592.11 N), and the length of the Tigris River in Salah al-Din Governorate is estimated to be more than 200 km [14]. The water quality mainly affects the production and lives of residents of the surrounding areas. The study area is in the north of the city of Salah al-Din (Bayji / near the oil refinery). **Figure (1)** shows the studied area.

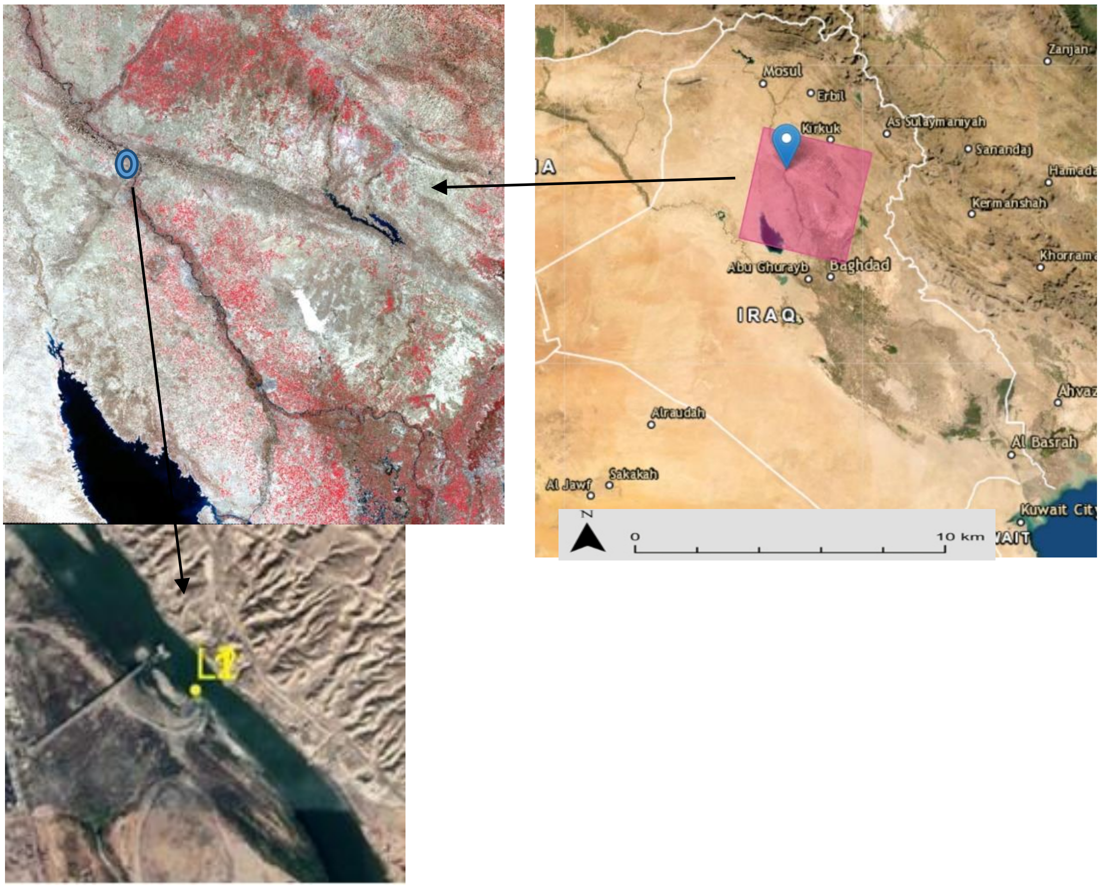

Figure 1.(up) Landsat 8 image of path 169, row 36, showing the Location of study site in the Tigris River, Salah al-Din, Iraq.(down)Turbidity monitoring station location Bayji, near the oil refinery (Study area satellite images were taken in 5/04/2020 by Landsat 8) (Google Earth).

3. Methodology

3.1. Imagery Data and Preprocessing

Landsat-8 is the eighth member of the Landsat series; its system consists of 11 bands of different wavelengths, where this satellite consists of two independent working sensors: the operational land imager (OLI) and the other one is the thermal infrared (TIR) [15]. The OLI sensor has been used to collect the information from the visible range of the EM spectrum. All cloud-free data are downloaded from the USGS Data Center. All data in this study have been geometrically corrected. The data used is shown in **Table 1.** ENVI 5.3 software processes radiometric correction, calibration, band combination, and algorithm input. Convert the digital value of the satellite images to the top of atmosphere (TOA) radiance and reflectance values. Radiometric calibration is used to convert image pixels into reflectance values. The radiometric corrections are sun angle corrections to fix error reflectance values caused by sun positioning [16].

Table 1. List of the satellite image datasets used.

Satellite sensor	Date of the image acquisition
Landsat-8	**15/4/2020**
Landsat-8	**2/5/2020**
Landsat-8	**19/8/2020**
Landsat-8	**26/11/2020**

3.2. Determination of Turbidity by NDTI

The turbidity has been calculated by using NDTI. The NDTI formula uses red and green bands, and its values vary between -1 and +1. The formula for NDTI is:

$$\mathbf{NDTI} = \frac{\mathbf{R_R - R_G}}{\mathbf{R_R + R_G}} \qquad (1)$$

where R_R, R_G are the reflectance in the red and green bands respectively. The reflectance in the green band higher than that in the red band for pure water, but for turbid water, the red band shows higher reflectance compared to green band. When the turbidity is high, the NDTI value also increases and vice versa [17].

4. Results and Discussion

The temporal study of the Landsat-8 data has been performed for the lockdown time frame. Cloud-free satellite images have been considered for this study. For the processing of the image, ENVI software has been used. Furthermore, as no field data were present for this period (during lockdown), the results are represented in river Normalized Difference Turbidity Index (NDTI) values. Existing algorithms for calculating the river water NDTI from equation (1) have been used in this analysis.

The result has been presented as a box plot for river NDTI during the time of lockdown. Different months have been chosen for this study to cover the remaining period during and after the lockdown. For the NDTI representation, April 2020, May 2020, August 2020, and November 2020 have been considered.

NDTI during the lockdown in April 2020 shows a significant decrease compared to November 2020, with a slight upward trend in May 2020 compared to April 2020. Then in August 2020, the NDTI showed an increase compared to April 2020, and the NDTI parameter indicates an upward trend until it reached the highest value in November 2020 for the considered stretch.

In the Tigris River stretch, near Bayji oil refinery in early April 2020, the NDTI ranges between 0.011 and 0.033, and in early May 2020, the NDTI value is between 0.041 and 0.054. The NDTI shows a slight increase in later May 2020 when it ranges between 0.072 and 0.094. The NDTI depicts an almost similar range for the river near and stretching the refinery. In the early period of August 2020, it was 0.12, but later the NDTI value increased to 0.154. For early November 2020, the NDTI ranges between 0.17 and 0.18, and for later November 2020 period, it ranges between 0.189 and 0.19. The NDTI value was considerably high **Figure (2).**

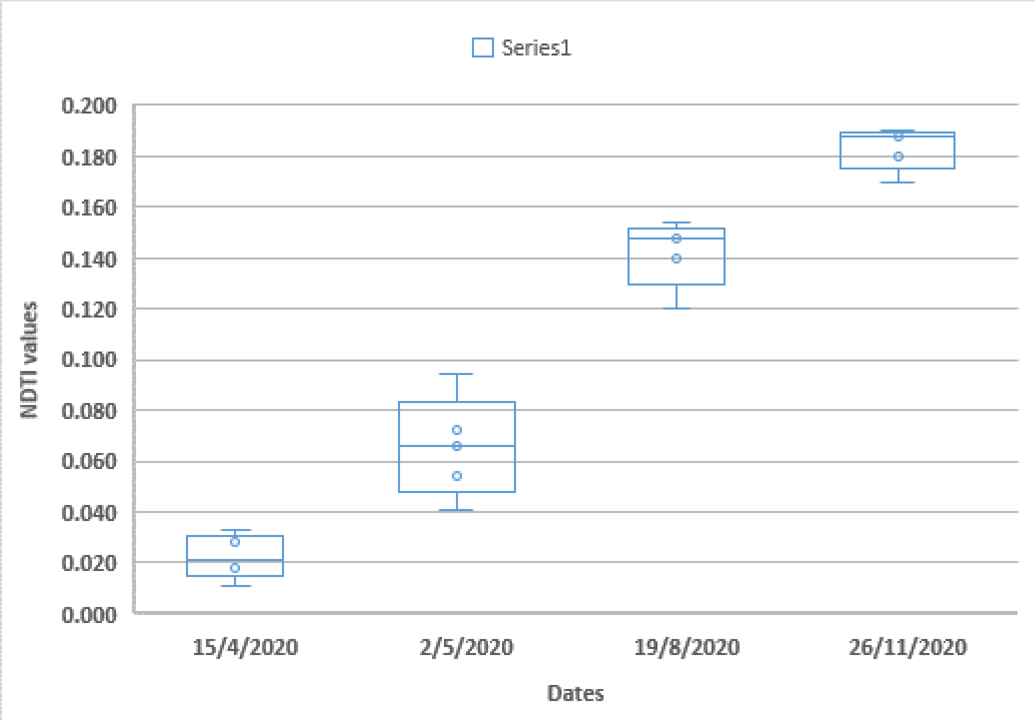

Figure 2. Box-plot representation of the NDTI values for the analysis of the COVID-19 lockdown effect using Landsat8 datasets for the Tigris River, Salah al-Din (Bayji / near the oil refinery).

Turbidity is a significant optical property of water that diminishes the energy required for aquatic growth. An increase in turbidity can hinder the growth of aquatic cora and fauna. With decreasing the photosynthesis which in turn depletes the productivity of the aquatic system, the effect of lockdown has become a blessing in disguise for aquatic ecosystems. Due to this, domestic the industrial and domestic waste discharge in the river has drastically reduced. So, this can also act as an additional factor for lowering the turbidity.

Most factories were closed during the lockdown, and minimal industrial waste was discarded into the river. This leads to a decrease in river turbidity (April 2020), which immensely enhances this region's aquatic ecosystem. Even during the post-lockdown period (May 2020), most industries remained closed, and significantly fewer anthropogenic activities occurred. Therefore, Tigris River near the Oil Refinery was moderately turbid.

The river turbidity value for the oil Refinery region was high in August 2020 compared to April 2020 because of the industrial waste discharged near the Oil Refinery, Wastewater and anthropogenic activities are the main reasons for increasing the turbidity. Rainfall in November 2020 is also resulted in increasing the turbid water in this region, as shown in figure (3).

Figure 9. NDTI values for the Tigris River stretch, Salah al-Din (Bayji / near the oil refinery) using Landsat 8 datasets for the period of (a) April 2020, (b) May 2020, (c) August 2020, and (d) November 2020.

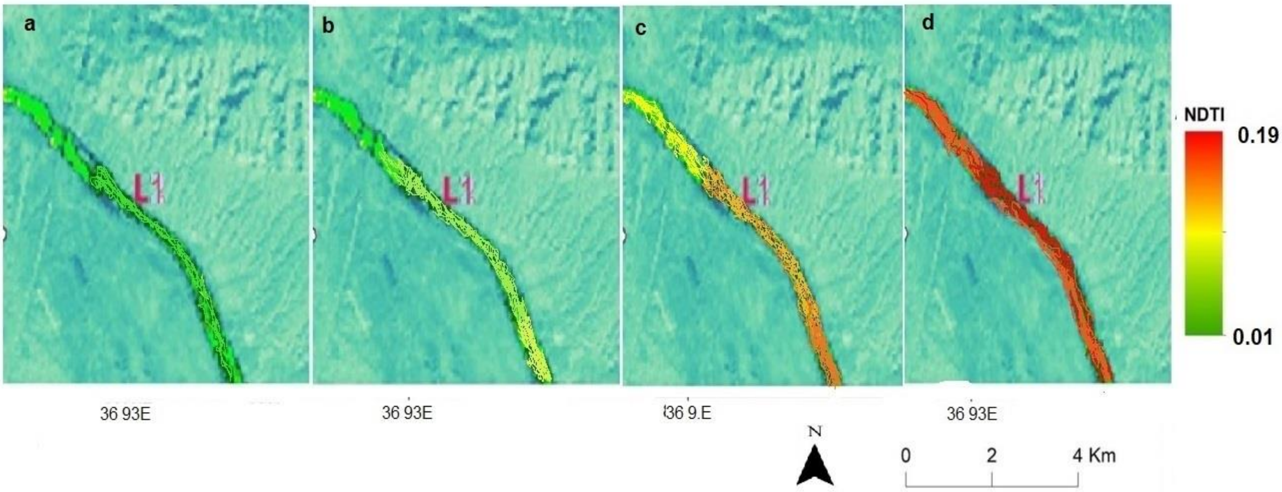

Figure 3. NDTI values for the Tigris River stretch, Salah al-Din (Bayji / near the oil refinery) using Landsat 8 datasets for the time period of (a) April 2020, (b) May 2020, (c) August 2020 and (d) November 2020.

5. Conclusion

Satellite images have been used for the spatiotemporal analysis of the river water quality parameter in the considered study stretch for the lockdown time. Several polluting industries were closed, and anthropogenic activities have also been reduced to a great extent due to the lockdown. A significant impact of the lockdown had occurred on the water quality of the Tigris River stretch in Salah al-Din (Bayji / near the oil refinery) and its nearby regions. The decrease in the NDTI value showed a different trend. The river showed the most significant decrease by 0.26 in April 2020 compared to November 2020. The reduction in the NDTI value was calculated by 0.24 in the river stretch in May 2020 compared to May 2019. For the river stretch, the decline of the NDTI value was 0.22 in May 2020 compared to May 2019.
After a period since the lockdown had begun, the production of oil items and other industries had been allowed by the government. So obviously, there had been more discharge and effluent generation. This situation has given a vast chunk of toxic load to the river. Anthropogenic activities were also carried out, which increased the pollution level of the river. The water quality improvement due to the lockdown phenomenon is delayed. Necessary regulations should be implemented to reduce further deterioration of the water quality while considering the increasing rate of urbanization and pollution load into the river. One of the biggest challenges is to sustain the improvement in water quality.

During the lockdown, the river's water quality has shown progress. The water quality parameters have shown improvement, especially around the oil refinery, industrial clusters, and urban areas. A significant reduction in the river turbidity was also very apparent, and it is evident that the leading cause of water quality degradation is Oil Refinery Wastewater. So, highly polluting industries in the river's catchment areas must be regulated soon.

The COVID-19 global pandemic occurrence plagued the world. Nevertheless, it presents an excellent opportunity to redesign the existing frameworks and implement a robust and dynamic mechanism to clean polluted rivers and other similar watercourses in the country.

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