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Research paper

Study of the Relationship Between Spectral Reflectivity and Water Quality Index in Hilla River

Zahraa M. Kadhum Al-Bayati[1], Israa H.Nayle[2], Basheer S. Jasim[3]

[1-3]Babylon Technical Insitute, Al-Furat Al-Awsat Technical University, 51015 Babylon, Iraq.
Corresponding author E-mail: mk_zahraa@yahoo.com

Abstract

The overall objective of this study was to use field spectro-radiometers for finding possible spectral regions for some physical and chemical parameters, The study area was divided into 20 stations on part of the Euphrates River, in Hilla city taking samples and studying the physical and chemical parameters and compared them with the standard specifications parameters:(Ph, TSS, E.C, T.D.S, CL) to calculate water quality indicators (for irrigation purposes) and a spectral reflectivity measurements to find the necessary the relationship of the reflectivity and water quality analysis. A GIS data base was conducted for mapping ,documenting and analyzing the Resources of pollution and water quality within the area of study, then Comparison of the spectral, bands of, the field S,pectro-radiometer, with those of the Landsat 8 depicted that are suitable spectral regions for monitoring water quality. Based on the results from this study and by, matching. the spectral, bands of the field spectro-radiometer with those of the Landsat 8 satellite sensor (or any other antenuptial), it has been found that suitable spectral regions for monitoring water quality in water treatment reservoirs are the following: Ph., EC and CL, at the spectral range of (0.851–0.87) µm and (2.107–2.294) µm (TM, band5 and band 6), TSS, , TUR, at the spectral region of (0.533–0.590) µm (TM, band 3), and for TDS, the region,(1.566–1.561) µm (TM, bands 6).

Keywords: *WQI, Spectro-radiometer, GIS*

1. Introduction

Water sources may be essential in the form of rivers, lakes, glaciers, rain water, ground water etc. Water quality of any specific area or specific source can be assessed using physical, chemica,l and biological elements. The values of these elements are harmful for human health, if they appeared more than defined limits [1,2,3,4]. WQI was developed, by Horton (1965) [5] in United States by selecting 10 most commonly used water quality variables such as dissolved, pH, coliforms, specific conductance, alkalinity chloride and oxygen,. In Iraq, the quality of water used for drinking and agriculture is poor and violate, both Iraqi National Standards and World Health Organization instructions, The rivers or lakes in nature containing varying quantities of the relationship and dissolved substances such as pollutants present in water, whether agricultural, Industrial or household contains additional waste, which is certainly that these various waste cause water pollution or change its quality depends on degree of pollution the quality and concentricity of impurities of the physical, climatologic and hydraulic source water conditions. Study of water quality through the use a modern technologies, such as remote sensing technology and geographic information system (GIS) with use of modern satellite images (Landsat 8) can provide new methods for monitoring the environment and water bodies, thus this technology Played a significant roles in providing accurate and faster information's of resources of the earth's surface, then try to link between water quality indicators that are calculated with data satellite images to get to the models can be used to predict water quality information through satellite images. Where they will search for the best and the strongest correlation between spectral image (Landsat 8) and indicators of water quality. Radiometer is a device to measure emissions and reflections It divided into two types according to the method and put it on the ground, the first evidence on the ground By unilateral tripod legs or triple and the second can be carried by hand, In both types are reflection data from floor space to capture ranging from (1to1.5 meter). Spectrometers, or spectro-radiometers are a good way to collect spectral data [13]. Reflectance spectroscopy is a readily growing technique used to analyze the spectral data in the VNIR and SWIR wavelength regions (0.4–2.5 µm) and to identify the different materials based on the basis of their reflectance characteristics [7]. ASD FieldSpec3 portable spectroradiometer is essentially designed for field environment to acquire visible near-infrared (VNIR) and short-wave infrared (SWIR) spectra in the 0.35–2.50 µm spectral range [6]. The research objectives of this study are the following:

• To identify the spectral region in which chemical parameters and compared them with the standard specifications parameters can be reversion by using field spectroscopy.

• To develop a novel methodology for measure the reflectance at the water surface through field spectroscopy.

• To develop regression models on the basis of the spectral features to monitor the water quality in Shatt Hilla River using satellite imagery acquired during water sampling;

2. Materials and Methods

2.1. Study Area

Shatt Al-Hilla River considered one of the most important water resource within Babil Governorate, where it passes within its wide areas and several small streams courses came out of it to supply water to the agricultural land within the governorates. The area of study is located around the City of Hilla , 100 km south of city of Baghdad city between, Longitude (44º26º55" & 44º31º10”) E and Latitude (32º26º30" & 32º31º33") N covering an area of about 100 km², Figure (1).. The Euphrates River is ramified into two rivers namely Hindia and Shatt Al-Hilla at its middle region. Shatt Al-Hilla is passing through numerous towns and villages, with the exception of effluents from domestics, agriculture and industries wastewater. Its total length is about 103 km with a disc arching 250 m^3/sec. The river is gradient 7 cm to each 1 km overall fall. Shatt Al-Hilla has received less attention by the competent authorities than those other region of Euphrates River. In our previous study different physical and chemical parameters were used to evaluate the quality of river water and most of the observed results revealed a deviation from the national standards.

2.2. Resources

A powered boat, a Fieled,Spec of ASD spectro-radiometer with associated equipment and tools and a GPS were used in the measurement campaign. The major task of the ground measurements was to determine the reflectance of the water surface. And observing, twenty five stations along Shatt Al-Hilla river by using GPS (Garmine type) and Collecting water samples from the monitoring stations.

2.3. Experimental work

Monitoring water quality typically involves costly and time consuming in situ boat surveys12 March, 2014, where water samples are taken and returned to a laboratory. the samples are analyzed and water quality indicators such as ***Ph, TSS, E.C, T.D.S, and CL)***,The program adopted for Experimental work that used to find The water quality index for irrigation use included 25 stations distributed on shatt Al Hilla river Within Babylon city. Spectral reflectance measurements were carried out using a *Spectroradiometer* device company ASD from FieldSpec 3 covering the UV, visible and near infrared. Comparison of these data with water quality measurements shows that this high reflectance occurs due to high turbidity of water and presence of pollutants and industrial wastes at these stations.The deterministic interpolation techniques called Inverse Distance Weighted (IDW) was used. The geo-statistical interpolation techniques are based on statistics and they can be used for more advanced prediction surface modeling.

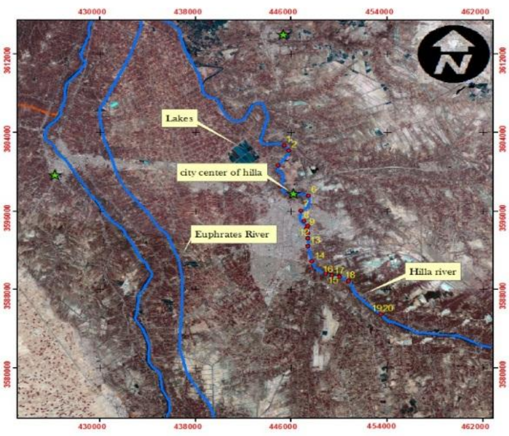


Fig 1. Location of the study area((Landsat-8 image acquired on 13 March, 2014 displayed in true color combination with key locations and feature labeled.).

2.4. Spectro-Radiometric Measurements

Spectral reflectance measurements were carried out using a spectro radiometer FieledSpec of ASD covering the UV, visible and near infrared. Spectroradiometer, the US is one of newest devices universally where it records a spectral reflectance, values through the wavelength (350-2500) nanometers with spectral resolution 3 nm for wavelength (350-1000) and 10 nanometers for wavelength (1000-2500). Reflectance spectroscopy is a widely growing technique used to analyze the spectral data in the VNIR. and SWIR wavelength regions (0.4–2.5 μm) and to identify the different materials based on the basis of their reflectance characteristics [7]. The collection of spectro-radiometric data was implement at a number of locations during an extensive measurement campaign on the Shatt Al-Hilla river. ASD FieldSpec3 portable spectro radiometer is2.50 μm spectral range [ASD, 2007]. For instrument details, refer to Table (1) [ASD, 2007]. water bodies are identified sites with data sensing is more easily with wave infrared. Pure water absorbs a small amount of the same wave length of less than about 600 nm energy means less reflectivity, while the turbid water that contains amount of suspended solids has higher reflectivity as shown in Figure (2). According to the recorded measurement, it can be seen that there is a high reflectivity within the spectral region of wave length from 500 to 700 nm., This high reflectance was measured high reflectance occurs due to high turbidity of water and presence of
pollutants and industrial wastes at these stations. The collection of spectro-radiometric data was performed at a number of locations during an extensive measurement campaign on the middle and south of the river, Field spectroscopy has previously been applied to obtain radiance, irradiance and reflectance values of freshwater, sea-water and pure water [6-12]. Spectrometers or spectro-radiometers are widely used to collect spectral data [13]. It has been shown by several other researchers, who studied the actual relationship between water properties (*i.e.*, water quality) and satellite data for several types of water bodies, that satellite remote sensing techniques show more important advantages than traditional sampling [14,15].

2.5. Conversion of Digital Number to Reflectance

The Arc map 10.3 was used to implement and apply a model for converting digital number (DN) of Landsat 8 OLI
Image to reflectance based on equations (1) and (2) and using all the necessary factors,

$$L_{\lambda} = M_L Q_{cal} + A_L \quad (1)$$

where:

L_{λ} = TOA spectral radiance [Watts/(m2 * srad * μm)]
M_L = Band-specific multiplicative rescaling factor from the metadata
A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)
Q_{cal} = calibrated standard and Quantized product pixel values (DN)
then convert DN values to TOA reflectance for OLI data as follows:

$$p_{\lambda'} = M_P Q_{cal} + A_p \quad (2)$$

where:

$\rho\lambda'$ = TOA planetary reflectance, for solar angle without correction. Note that $\rho\lambda'$ there's no correction for the sun angle".
M_{ρ} = Band-specific"multiplicative rescaling factor from the metadata (REFLECTANCE_ FOR MULT"_BAND_x, where x is the band number)
A_{ρ} = Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x", where x" is the band number)
Q_{cal} = Quantized an'd calibrated standard product pixel values (DN).

Table 1: Details of the ASD FieldSpec® 3 spectroradiometer (ASD,2007.)

Spectral range.	350–2500 nm
Detectors.	VNIR (350–1000 nm) SWIR1 (1000–1830 nm) SWIR2 (1830–2500 nm)
Spectral resolution.	3 nm at 700 nm 10 nm at 1400 nm &at 2100 nm
Sampling interval.	1.4 nm for 350–1000 nm 2 nm for 1000–2500 nm
Field of view	8, 18, 28 degrees

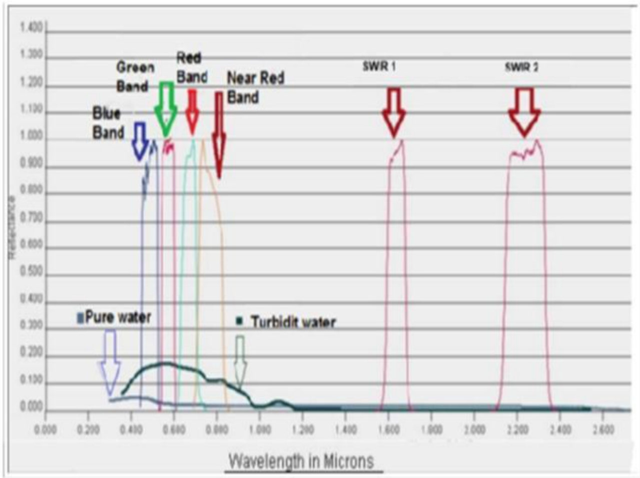


Fig 2: Curve of perfect reflectivity spectrum for pure and turbidity water from [Spectral Library of USGS

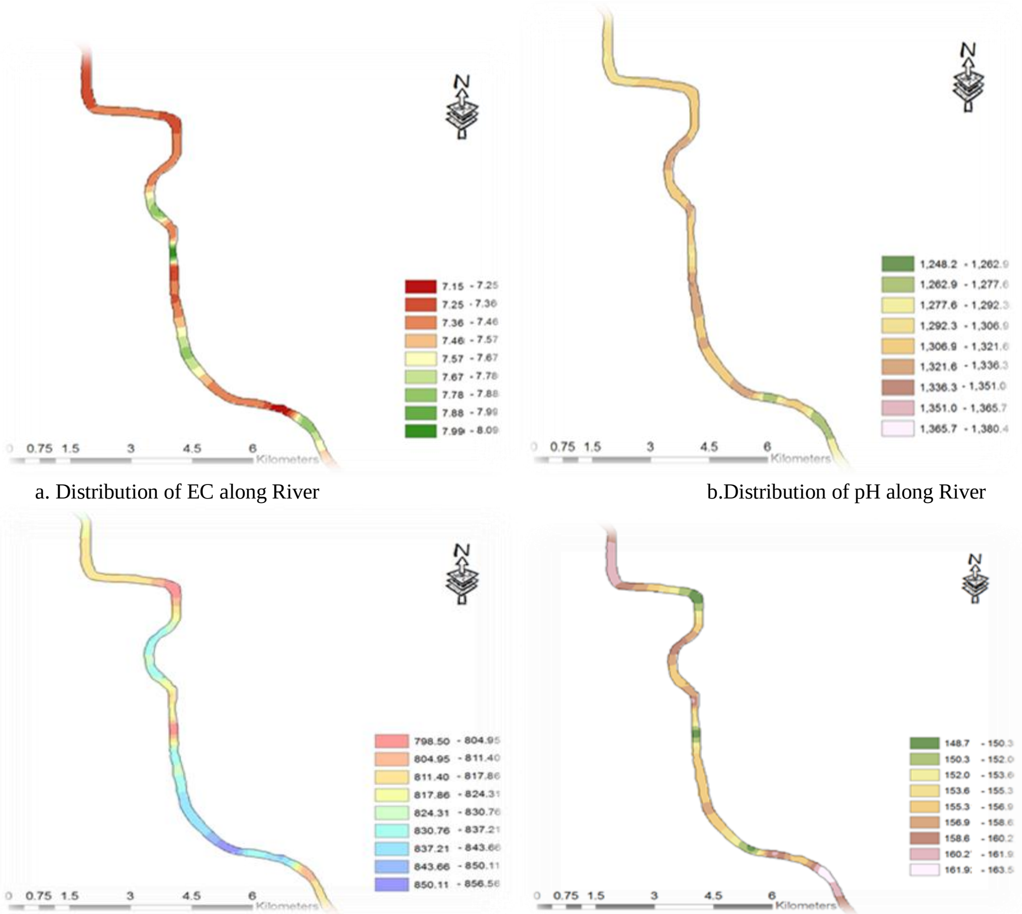
3. Water Quality

Water quality index was calculated by weighted index method for irrigation purposes. The index developed by Tiwari and Mishra (1985) was used. In the present study, seven water quality parameters, namely, pH, chloride, total dissolved solids (TDS), and total subtend solid, were considered for computing WQI. The distribution of WQI along Al- Hilla River is shown in Figure (3). For calculating WQI, the following steps were used: In the first step, unit weight (Wi) by using the following formula pro-posed by Tiwari and Mishra [8].

the overall WQI was calculated by
using formula :

$$WQI = \sum_{i=1}^{i=n} WiQI \tag{3}$$

Fig 3. Distribution IDW of WQI.



a. Distribution of EC along River

b.Distribution of pH along River

c) Distribution of TDS along River.

d) Distribution of CL along River.

Fig 4.: Distribution IDW for parameters.

This research identified the following optimal Landsat 8 bands in the visible wavelength region:

- for Ph., EC and CL, at the spectral region of (0.851–0.87) µm and (2.107–2.294) µm (TM band5and band 6)
- for TSS, , TUR, at the spectral region of (0.533–0.590) µm (TM band 3).
- for TDS, the region(1.566–1.561) µm (TM bands 6).

Table 2: Correlation (Pearson Correlation) between Water Quality Parameters and measured spectral reflectance

Correlation Between Water Quality Parameters and Bands of Landsat 8 OLI					
	PH	TDS	TUR	TSS	WQI
Band 1 Coastal	-0.022	0.015	.724**	-.676**	-0.352
Band 2 Blue	-0.064	0.041	.756**	-.716**	-0.327
Band 3 Green	0.033	0.099	.810**	-.762**	-0.261
Band 4 Red	0.167	0.271	.955**	-.919**	-0.102
Band 5 NIR	0.158	0.42	.950**	-.956**	0.115
Band 6 SWIR 1	-0.197	0.333	-0.1	0.017	0.397
Band 7 SWIR 2	-0.226	0.338	-0.064	-0.02	0.369

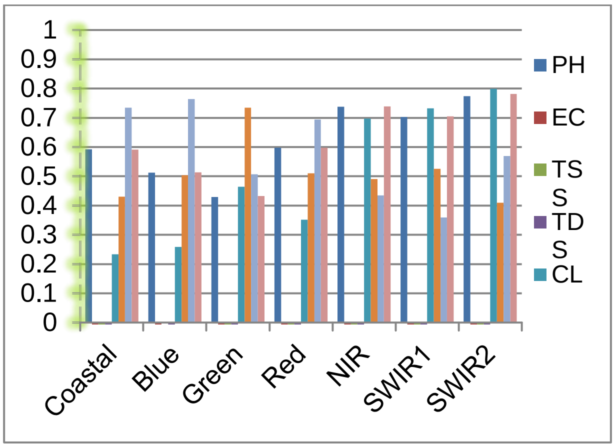
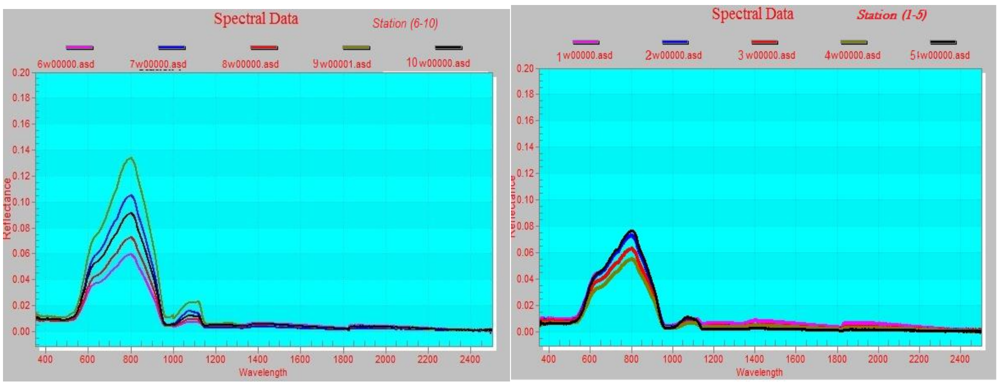


Fig 5: Correlation Coefficient between reflectivity and water parameter for all station.

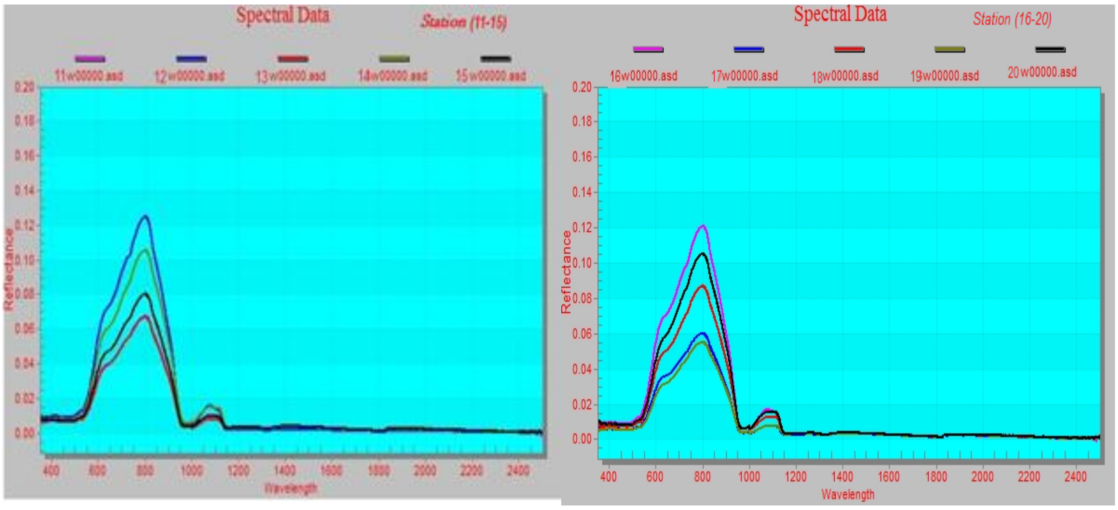
The achieved correlations, presented as r2 against wavelength, indicate the regions with high correlation values for both water quality variables 0.694 to 0.982were found for the following spectral regions as Table (3).
The ASD spectro-radiometer experimental data was relationship between the water quality parameters and the in-band reflectance measured from the ASD spectro-radiometer regression models have been applied and the outcomes as Table (3).filtered through the RSR functions and averaged within the limits (band3,band 5 and band 6), to yield the in- band reflectance values. In order to retrieve the statistical 2, 3, 4, 6 and 7 (which is the Coastal, Blue, Green, Red, Near Infrared (NIR), Short-wave Infrared Test of the correlations between the water quality parameters and the measured spectral reflectance of the spectral bands (SWIR1) and Short-wave Infrared (SWIR2**)** is listed in Table(2) This test shows that there is strong correlation between the water quality parameters and the spectral reflectance of these spectral bands. each of TUR, TSS

table 3::Highest correlations (expressed as r2) achieved when applying regressions parameters against the ASD spectro-radiometer reflectance values.

Model	R	R2
pH (pH Unit) = 8.693 + 0.148 * (ICA B6) - 0.241 (G / R)	.703^{b}	.495
EC (MS) = 204.848 + 69379.870 (Emissivity B5)	.521^{a}	.271
TDS (MS) = 102.424 + 34689.935 (Emissivity B5)	.521^{a}	.271
Temp.(Celcius) = 21.320 - 0.002 * (G + NIR)	.723^{a}	.522
Temp. (Celcius) = 21.791 - 0.016 * (G + NIR) + 1.891 (Band 4 : Float)	.816^{b}	.665
Tur. (NTU) = - 24.389 + 69.481 * (Band 5 : Float)	.991^{a}	.983
Tur. (NTU) = - 26.401 + 55..962 * (Band 5 : Float) +11.701 (R / B)	.999^{b}	.998
TSS (µg/l) = 0.012 - 0.009 (Band 5 : Float	1.000^{a}	1.000
WQI (Unitless) = 48.080 + 21.000 (NIR / B)	.499^{a}	.249
EC (MC) = 195.73 + 0.753 (NIR/B + NIR)	.507^{a}	0.257
TDS (MC) = 97.863 + 0.376 * (NIR/B + NIR)	.507^{a}	0.257
TSS (µg/l) = 0.012 - 0.00003873 (B5)	.956^{a}	0.914
TSS (µg/l) = 0.012 - 0.00004226 (B5) + 0.007 (NIR / B)	.971^{b}	0.943



a) *spectral data measurement for station (1to 5)* b) *spectral data measurement for station (6to 10)*



c) Spectral data measurement for station (16to 20). d) *Spectral data measurement for station (11to 15*)

Fig 6. Reflectivity measurements for stations

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