Water Pollution Detection of Tigris River by Utilizing Thermal Remote Sensing Techniques: North Baghdad-Iraq Region as a Case Study

Mohammed Mejbel Salih ^{1,2*}

1. Geomatics Engineering Division, Civil Engineering Department, University of Technology-Iraq, Baghdad, Iraq.

2. Laser and Optoelectronics Eng. Dept., University of Technology-Iraq, Baghdad, Iraq.

*E-mail addresses: 40339@uotechnology.edu.iq

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ABSTRACT:

The land on which we live has a tight environmental system, and the elements of life in it must be preserved, as pollution rates have increased in general, including water pollution, and the environmental problems it causes due to population inflation. The development of modern science and technology can contribute greatly to preserving the components of the environmental balance. It was scientifically found that each body has a radiative value that distinguishes it from other bodies and this is called the thermal fingerprint of objects, and therefore the radiation signature of a body is what distinguishes it from other bodies. Accordingly, from here it is possible to reveal what these objects are without direct contact and know their components from distance. This study addresses the aspect of monitoring the spectral footprint of polluted water, especially the waste of hospitals and factories, which causes great damage to the beaches and must be monitored first-hand through the use of a thermal monitoring device and conducting field examinations directly. The study area was determined near one of the wastes of Baghdad hospitals on one side of the Tigris River and compared with the values of the thermal spectral footprint taken from satellites that carry thermal sensors. The results showed the convergence of the measured values with the values taken from the thermal sensors, which confirms the accuracy of the thermal images in the (10-11) beam of the satellite.

Key words: Remote sensing; IR thermometer; Landsat-8; Emissivity.

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1. Introduction

Remote sensing techniques or remote sensing is one of the ancient engineering sciences and is included in all other disciplines, and it is simply possible to define remote sensing terms that are vision for objects that cannot be seen [1-2]. The features of remote sensitivity have been concerned with the search and disclosure of the wealth and natural resources on the earth, which have many different activities between the forties and fifties of the last century. The rapid development of computers led to the development of the field of remote sensing techniques, and was a reason for the increase in exploration and detection of ground resources, especially in the field of radar imaging [3], [4]. These technologies of IR require the use of and employing means and supporting equipment to benefit from them in interpreting aerial photos, in addition to that the most important factor is the experience and skill that the data collector must possess while I interpret the images in a detailed. Pioneering step in discovering natural resources began after the launch of many satellites, especially after 1972, which strengthened the capabilities and skills of remote sensing techniques to the best.

The thermal effects on the surface of the globe in addition to exploration have increased in the last ten years effectively and became Satellite images give important and useful details for large areas, as well as they, take pictures periodically and at any time and are multi-spectral [5,6]. The presence of digital computer technologies helps to improve the efficiency of the interpretation of thermal satellite images[7], [8]. The presence of thermal sensors in the satellites helps a lot in a new classification channel for everything that is in nature[9].

In terms of the thermal footprint, a substance in the universe that has a thermal spectral signature depends on the relationship that links the temperature of the medium of the body and the temperature of the surroundings[10]. The 10 band and 11 band, that monitor the rise of temperature within wide areas and for the distance between the sensor of this temperature in the satellite and the surface of the earth, may

give a certain error rate, that is a widely applied procedure with specialists in this field, especially for those working in the field of remote monitoring and control.

To analyse thermal images directly using special programs to then calculate the thermal emissivity at any point and for the results to be acceptable the specialists need to conduct checks at the same time that the satellite takes thermal images presence device RF power meter in the same area for the purpose of knowing the accuracy and efficiency of the thermal sensors of any satellite that gives images of the thermal beams.

On this basis, the researchers designed and built the temperature measurement systems within An infrared beam that gives high accuracy in calculating the temperature difference or contrast between the body and its surroundings. To calculate the emissivity of this object and compare it with the emissivity issued by the thermal sensors, they are converted into thermal images that are entered into the computer to be processed digitally to know the emissive value of the same objects and to know the of the objects accurately. A very advanced temperature measuring device for objects and the surrounding medium with a low error rate. It has been used reading data from device to mathematical relations to determine the accuracy of the convergence of the results. The Tigris River is one of the largest rivers in Iraq and the Arab world, and it divides the city of Baghdad into two halves, namely the Karkh and Rusafa sides. This study use the Remote sensing technique and aim to provide an indication of the thermal behaviour of wastewater and to measure the amount of energy emitted from it. The study site near the Imams Bridge was chosen at coordinates 44.355140 degrees east and 33.372618 degrees north as shown in Fig. (1).

Fig. 1. Baghdad City (Case study area)

2. Methodology and Data Set

The methodology of this study is based on the principles of the infrared remote sensors and its application in water quality studies. Thermal infrared sensors and more recently differentiation of very subtle shifts in spectral responses due to waste using a data-intense high-resolution spectrometer (HRS). Unlike earlier systems, (HRS) has the potential to identify specific materials based on molecular structure, but this is generally difficult due to complex atmospheric interferences. In this paper we will focus on the thermal techniques and applications for measuring and monitoring of wastewater, generally, the work can be divided into two main processes:

2.1. The process of direct measurement of the surface temperature

Using the typical temperature measuring devices. Such as the IR-video Thermometer which is a device that can be used to measure the surface temperature of the objects that is improper to be measured by traditional (contact) thermometer, it is capable of non-contact (infrared) temperature measurements with the visual camera at the touch of a button [11]. The process of identifying the surface temperature using satellite image and image processing and manipulating applications. In this paper, it has used data thermal map from a satellite image of the area under study. The data captured on the 9 of December 2016 and

downloaded from United State Geological Survey (USGS) website. The software used for image processing and interpretation is ArcGIS by Esri.

2.2. Land Surface temperature

The purpose from make a comparison to the thermal fingerprint of land surface temperature LST. The heat value was taken through the bands. (10 and 11), the readings were taken from the red band (4) and near-infrared band (5) represented the Normalized Difference Vegetation Index (NDVI) using the term in any extraction of natural differences to vegetarians and by using the equations of digital conversion from satellites. to the thermal spectral radiance (L_λ) by using equation [1]:

$$L_\lambda = M_L Q + A_L \quad (1)$$

Where M_L = multiplicative rescaling factor from data, Q_{cal} = Quantized standard digital number DN value of pixels, A_L = Band- additive rescaling factor from the dataset.

From equation number (2) we can calculate the brightness temperature (BT) taken from the thermal sensor in satellite [12].

$$BT = \frac{Kt_2}{\ln \left[\left(\frac{Kt_1}{L_\lambda} \right) + 1 \right]} - 273.15 \quad (2)$$

(Kt_1 and Kt_2) thermal infrared bands (10 and 11). in Celsius ($^{\circ}C$) by adding absolute temp. (0 to 273). NDVI values (-1 to +1) ranges from (-1 to +1) taken from (RED) band (0.656 - 0.674 μm) and near-IR band (0.852-0.876 μm) of images by using equation (3).

$$N. D. V. I = \frac{(near\ IR - RED)}{(nearIR + RED)} \quad (3)$$

Where NIR is the near-infrared band value of pixel and RED is the band of the same pixel. The NDVI(Normalized difference vegetation index) is essential to calculate proportional plants (PP) and emissivity [13,14].

From NDVI values obtained in the previous step calculate proportional plants (PP). This proportional plant gives the estimation of the area under each land cover type. The plant and bare soil proportions are acquired from the NDVI of the pixels.

$$PP = \left(\frac{N.DVI - NDVI_s}{N.DVI_v - NDVI_s} \right)^2 \quad (4)$$

Where (s) the soil and (v) vegetation

TABLE 1. Data of LANDSAT-8 Satellite image

Symbols	Descriptions	Value of Band10	Value of Band11
K_{t1}	Thermal constant	774.8853	480.8883
K_{t2}		1321.0789	1201.1442
M_L	A.RADIANC-EMULT	0.000 33420	0.000 33420
Q_{ual}	D.N value		
A_L	RADIANCE-ADD	0.1	0.1

3. Results and dissection

The objective of this research is to make an indication of the thermal behavior of the wastewater and measuring the amount of energy emitted from it in the principles of the surface temperature, because of the surface temperature is a function of the emissivity of the body. It can make a prediction of the emission for that body represented by an emissivity curve along the day time and by comparing this curve with the emissivity curves of different bodies measured by the thermal remote sensing sensors we can distinguish the wastewater from the other objects in the same single satellite image. This approach provides the following advantages:

- a. A very convenient way for non-contact identification of the earth features from the satellite imagery.
- b. Facilitate the monitoring process for the earth's features at night and bad weather conditions based on thermal of the water and wastewater using the thermal sensor in the Landsat-8, the thermal sensor in the satellite depends on the rays emitted from the objects and the effect of the clouds at night and day is relatively weak and it is possible for the thermal contrast gas of surfaces and people to use the thermal sensor easily.
- c. Facilitate the processes of wastewater management and water quality issues.

3.1. IR video thermometer

It is a device that can be used to measure the surface temperature of the objects that is improper to be measured by traditional (contact) thermometer (such as moving object, the surface with electricity current or the objects which are uneasy to be touched). It is capable of non-contact (infrared) temperature measurements with a visual camera at the touch of a button. The built-in laser pointer increases target accuracy while the backlight LCD and handy push-button combined for convenient and ergonomic operation (Fig. 2).

In this process, we simply measure the surface temperature of the area under study which is the wastewater by using a surface temperature measuring device which is called (IR video thermometer). This device allows a remote measuring of the surface temperature and has other capabilities we will talk about it.

Fig 2. IR-video thermometer

3.2. Landsat-8

Using Landsat-8 satellite imagery to gathered the land surface temperature Fig. (3) and Fig. (4) LST for area interested and compared this data with the surface temperature measured directly by using IR-thermometer in time of image from 9/12/2019. For instance, it showed good compatibility between the results of the satellite and IR thermometer [15]. Land surface emissivity give us the radiative absorption ability of a surface in the loge wave [9]. LSE is largely dependent on the target surface top layer such as the type of soil, surface roughness, and nature of vegetation cover [16,17].

$$\varepsilon = \varepsilon_{v\lambda} \cdot P_V + \varepsilon_{s\lambda} \cdot (1 - P_V) + C_\lambda \quad (5)$$

Where:

ε = Land Surface Emissivity,

$\varepsilon_{s\lambda}$ = soil emissivity

$\varepsilon_{v\lambda}$ = plant emissivity

P_V = proportion of plants

C_λ = surface constant (0.009)

The NDVI can be used to estimate the emissivity of different land surfaces in the 10-12 μm range (Sobrino et al., 2008).

$$\varepsilon_\lambda = \begin{cases} \varepsilon_{s\lambda} & NDVI < NDVI_S \\ \varepsilon_{s\lambda} P_V + \varepsilon_{s\lambda} (1 - P_V) + C_\lambda & NDVI_S \leq NDVI \leq NDVI_V \\ \varepsilon_{s\lambda} + C_\lambda & NDVI > NDVI_V \end{cases} \quad (6)$$

for final step using (B.T) of 2 bands (10, 11, and LSE) it is derived from NDVI [16]. using equation (7).

$$LST = \frac{BT}{[1 + \{(\frac{\lambda BT}{\rho}) \ln \varepsilon_\lambda\}]} \quad (7)$$

BT in Celsius ($^{\circ}\text{C}$), (λ) is the wavelength, (ε_λ) is the emissivity that computed at eq. (5), (ρ) is ($h \times \frac{c}{\sigma}$) which is 1.438×10^{-2} MK, ($\sigma = 1.38 \times 10^{-23}$ J/K), (h) Plank low $= 6.625 \times 10^{-34}$ and $c = 3 \times 10^8$ m/s.

The thermal data of land surface extracted from (LST-8) for (10&11) are a camera with the measurement of surface temperature by using the IR-video thermometer camera and the results as shown in Table (2).

Fig. 3 LST_Band10 of the area interested

Fig. 4. LST_Band11 of the area interested

The results are shown in Table (2) uncovered that there is a linear intermediate correlation equation of medium strength between the band 10 of satellite image and measurements taken by the IR_ thermometer camera as in Fig. (5) where $R^2 = 0.396$. Given the convergence of the difference between the temperatures, as well as monitoring the passage of the satellite and taking the image simultaneously on this date, in addition to the field measurements. For this reason, the readings were adopted on this date and they represent the thermal spectrum footprint in this month of the surface of polluted water.

TABLE 2. LST Data computed and extracted from Landsat-8 and IR-video thermometer

X m.	Y m.	LST from Band10(C°)	LST from Band11(C°)	Av.	Surface temperature by using IR-video thermometer(C°)	LST10 - IR (C°)	LST1 1- IR (C°)
440416	3693536	11.41	10.92	11.165	12.1	-0.69	-1.18
440342	363367	10.84	10.48	10.66	11.8	-0.96	-1.32
440236	3693250	11.13	10.63	10.88	12.2	-1.07	-1.57
440151	3693166	11.41	10.89	11.15	12.4	-0.99	-1.51
439966	3692843	10.31	10.26	10.285	11.1	-0.79	-0.84
439850	3692843	11.28	10.76	11.02	12.2	-0.92	-1.44
439844	3692742	10.96	10.49	10.725	11.3	-0.34	-0.81
439733	3692615	10.94	10.48	10.71	11.6	-0.66	-1.12
439696	3692499	10.89	10.39	10.64	12.1	-1.21	-1.71
439564	3692340	11.21	10.33	10.77	12.3	-1.09	-1.97
439495	3692086	11.12	10.5	10.81	12.4	-1.28	-1.9
439739	3691271	10.7	10.13	10.415	12.4	-1.7	-2.27
440056	3691261	11.3	10.87	11.085	12.5	-1.2	-1.63
440405	3691388	10.85	10.94	10.895	12.2	-1.35	-1.26

This means that there is an average correlation coefficient of forecasts to measure the surface temperature and the reason behind this correlation is because field measurements were collected within an hour during day time, while the image was captured in an estimated time in seconds or less. Therefore, the differences of measurements are clear using an IR-video thermometer. Also, reason is the relative temperature difference. In general, there are many factors that affect the temperature emitted from objects that is the thermal leakage due to winds and shade areas due to intermittent clouds, which leads to divergence in the results relatively and they have little effect on affinity values.

So, the results revealed a weak correlation coefficient it is about $R^2=0.127$ between the thermal temperature at band 11 of satellite image and the measurements taken by the IR-video thermometer camera as in Fig.

(6), the weak measurements due to the reasons mentioned above, as well as the fact that the band-11 was affected by the lighting of stars.

Fig. 5. The correlation coefficient between the temperature of Landsat-8 band 10 satellite image and IR_camera

Fig. 6. The correlation coefficient between the temperature of Landsat-8 band 11 satellite image the IR_camera

From Fig. (7), which represents the readings of the thermal sensor in the Landsat-8, as indicator gives the exact difference to evaluate whether the other bands, for example, that band- 10 is much better than Band -11.

Fig. 7. The correlation coefficient between surface temperature from Landsat-8 (average bands 10 and 11) satellite image and IR_camera

4. Conclusion

The purpose of this research is to make an indication of the thermal behavior of the wastewater and measuring the amount of energy emitted from it in the principles of the surface temperature, because of the surface temperature is a function of the emissivity of the body, we can make an emission signature for that body represented by an emissivity curve along the day time and by comparing this curves with the emissivity curves of different bodies measured by the thermal remote sensing sensors we can distinguish the wastewater from the other objects in the same single image, this process can be done by measuring the surface temperature directly from the area of study by using the thermometer, this direct measurement is done for both wastewater and the ambient temperature to calculate the emissivity of the marital. The emissivity of the wastewater also calculated from a satellite image taken for the same area and nearly at the same time and gives approximately the same surface temperature which means almost equal emissivity, process Autocorrelation Why is it originally the result of taking readings when combined with field tests of polluted water in the Tigris River to ensure the accuracy of the thermal satellite images and that the comparison process is based on the results of equations implicit in the Excel program and The equations (5),(6) show the calculation of the heat emitted from the bodies, especially from the surfaces of the polluted water, to determine the thermal spectral signature of the general pollution in the river water that Satellite images taken from the thermal sensor .

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List of Abbreviation

HRS	High-resolution spectrometer
USGS	United State Geological Survey
LST	land surface temperature
NDVI	Normalized Difference Vegetation Index
BT	Brightness temperature
DN	Value of pixels
La	Thermal spectral radiance
ϵ , LSE	Land Surface Emissivity
$\epsilon_{s\lambda}$	Soil emissivity
$\epsilon_{p\lambda}$	Plant emissivity
PV	Proportion of plants
C_{λ}	Surface constant (0.009)