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Water Quality Assessment for Tigris River through Salah Al-Din Province, Iraq Using Remote Sensing Techniques

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Abstract

The assessment of the quality of running water at specific sites remains of great concern. Water quality indicators were monitored during February of the winter season of 2020. The use of a geographic information system (GIS) in assessing water quality depends on the laboratory results values of water samples and spatial analysis of these values by means of inverse interpolation of the weighted distance. It was possible to map water quality indicators along the Tigris River in Salah El-Din Governorate for thirteen sites and ten water quality indicators. This ensures that trends of specific water quality indicators and the characteristics of pollution spread across the basin are better displayed with differences shown along river courses than with conventional line graphs. The production of water quality maps will improve monitoring and enforcement of standards and regulations for better pollution management and control.

Key words

GIS, interpolation technique (IDW), Tigris river, water quality maps, water monitoring.

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تقييم جودة مياه نهر دجلة في محافظة صلاح الدين، العراق باستخدام تقنيات الاستشعار عن بعد

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الخلاصة

لا يزال تقييم جودة المياه الجارية في مواقع محددة تثير قلقاً كبيراً. تم رصد مؤشرات جودة المياه خلال شهر شباط من فصل الشتاء لعام 2020. إن استخدام نظام معلومات الجغرافية في تقييم جودة المياه يعتمد على قيم النتائج المختبرية للعينات المائية والتحليل المكاني لهذه القيم بطريقة الاستيفاء المعكوس للمسافة الموزونة. فقد مُكن من رسم خرائط مؤشرات جودة المياه على طول نهر دجلة في محافظة صلاح الدين لثلاثة عشر موقعًا وعشرة مؤشر من مؤشرات جودة المياه. يضمن ذلك عرض اتجاهات مؤشرات جودة المياه المحددة وخصائص التلوث المنتشر عبر الحوض بشكل أفضل مع الاختلافات الموضحة على طول مجاري النهر أكثر من الرسوم البيانية الخطية التقليدية. سيؤدي إنتاج خرائط جودة المياه إلى تحسين المراقبة وإنفاذ المعايير واللوائح من أجل إدارة ومراقبة التلوث بشكل أفضل.

Introduction

Water is the fundamental demand of all life on a world. Surface water tends to be significant source of water. And actually, a required resource that is necessary because of the rise in its consumption for drinking, irrigation, water supply, and industrial uses, etc. The rise in population and urbanization requires increases in the agricultural and industrial sectors which need more fresh water [1]. For the purpose of determining the water condition, Information on the state of water quality must be specified, and factors affecting water quality as well as critical locations within the catchment area must be identified. This can be accomplished by collecting water samples at different sites of the river and then analysing the physical and chemical parameters. This will help in identifying sampling sites and areas with a high level of pollution along the river, which in turn will assist in pollution control. Water samples are not usually collected at every point along the river but at specific locations [2]. A change in the quantity and quality of water due to the effects of upstream damming has significantly reduced the water flow to Iraq. In addition, the water quality is continuing to deteriorate in the absence of adequate river basin management programs, the direct dumping of untreated domestic and municipal wastes, (agricultural chemicals, and hazardous industrial substances into the waterways. Such conduct is exerting an immense impact with harmful effects on public health and the environment [3]. The reduction in the world's water bodies, and especially in Iraq, is the most important issue facing us. Home waste, production effluents, and Waste from agriculture can lead to a decline in the quality of river water. Therefore, a monitoring program is necessary to prevent risks of water resource pollution. In situ, sampling site monitoring for preceding laboratory analyses is used to evaluate water quality. These measurements are accurate for a point in time and space [4]. Uses the GIS program and the comprehensive data monitoring environment agency to map catchment water quality [5]. Remote sensing and GIS software, together with computer modelling, are useful resources to provide a solution for future water resource planning and management, in particular water quality control plans [6]. Interpolation being a process of estimating unknown values that falls between known values could be the solution for this challenge. Hence, this research aimed at mapping the water quality of Tigris River in Salah Al-Din province via Inverse Distance Weighted (IDW) interpolation method in order to estimating the water quality status of the none sampled points along the river. Similar studies were carried out in previous years using remote sensing technology, including a study to assess the quality and level of water in the marshes in southern Iraq, Where the seasonal differences and spectral reflectivity of Iraqi rivers waters were studied [3]. In recent years, and in light of what the governorate has suffered from, there has become a scarcity of studies and data that assess the quality of the Tigris River water in Salah al-Din Governorate, In our study, we focused on analyzing and studying most of the most important characteristics that affect water quality, and we obtained river samples in the winter of 2020 with the help and supervision of a cadre from the Ministry of Water Resources / Irrigation and Drainage Projects Department, and they were analyzed laboratory in the Environment and Water Department of the Ministry Science and technology by standard methods.

Description of study area

Salah al-Din Governorate is located in central Iraq, north of Baghdad, on $33^{\circ}58^{\prime}$ 28.90”N and $43^{\circ}53'$24.60 E. It has an area of 24.363 km^2 and has a population of 1,595,000 people Fig.1. Topographically, it is a semi-flat area with the presence of some elevated local features represented by the deposits of river terraces and several depressions. Geologically, most of the area is covered with sediments such as mud, sand and gravel [7].

The study area represents the path of the Tigris River in Salah al-Din Governorate. The Tigris River runs in a relatively narrow valley within the undulating area from the beginning of the study area until the strait of Fath, which separates the heights of Hamrin and Makhoul. And it continues to run through the river terraces until the sediments of the sedimentary plain near the Balad region, and the river’s slope gradually decreases towards the city of Baghdad, reflecting the suspended and bottom load in the river.main cities of Salah Al-Din province: Tikrit, Aldor, Samarra, Balad, Baiji and Dejail [8].

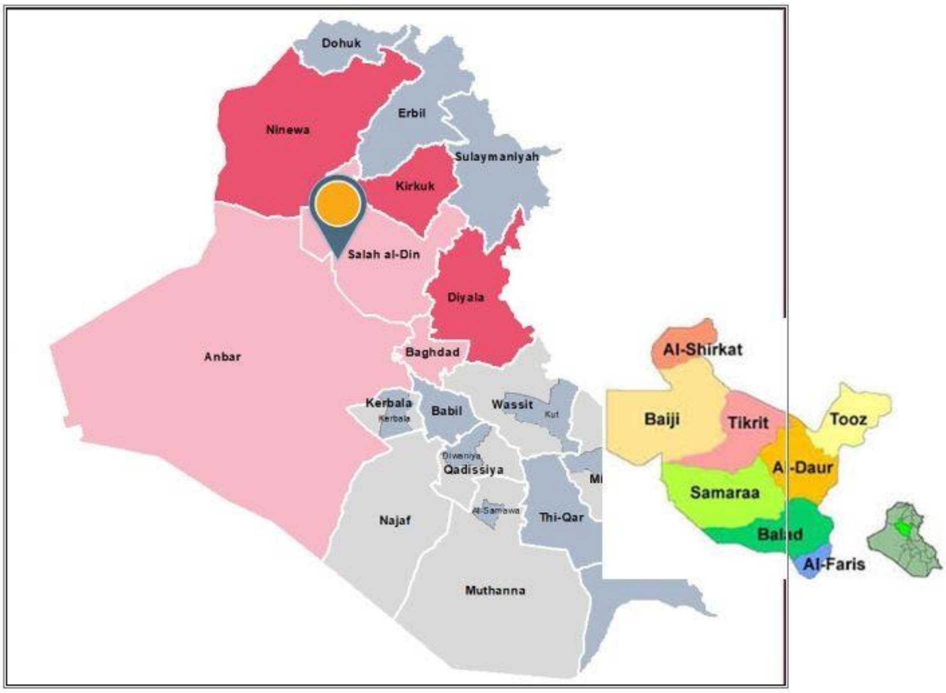

Fig.1: Map of province of Salah ad din [9].

Samples collection and analysis

Thirteen water samples were taken from thirteen sites along the Tigris River in Salah al-Din province during February 2020. Ten physical and chemical parameters (pH, TDS, EC, Turbidity, TSS, Alkalinity, NH3, Cl, SO4, and NO3 ions) They were chosen as toxic minerals to represent a wide range of sources of physical and chemical contaminants in river waters and are very relevant for the assessment of water quality. Water samples were taken Using a simple hand tool consisting of a plastic bottle, after collecting samples, they were sent to the Environment and Water Laboratory at the Ministry of Science and Technology to analyze all the physical and chemical parameters. Standard methods were used to perform these tests. Then, with GIS, the spatial distribution maps for the selected parameters were prepared and evaluated . Resultes were compared with standard values suggested by Iraqi and WHO standards. The sampling locations are shown in Table 1, while Fig.2 shows the selected points along the Tigris River in Salah al-Din Province.

Table 1: Coordinates of water samples taken from the river.

No. of samples	Longitude	Latitude	City
1	43 16 13.2239 E	35 29 29.4237 N	Shirqat
2	43 22 0.6151 E	35 20 38.8652 N	Al Zab
3	43 25 14.7011 E	35 14 19.0050 N	Azawi city
4	43 31 6.9487 E	35 16 10.5451 N	Alabbasi
5	43 41 52.1046 E	35 24 12.2093 N	Hawijja
6	43 41 52.1046 E	35 24 12.2093 N	Biji
7	43 31 10.4702 E	34 55 46.7259 N	Hjjaj
8	43 37 51.3984 E	34 44 53.5646 N	Tikrit
9	43 42 0.9328 E	34 35 45.5099 N	Al Dor
10	43 46 44.6796 E	34 28 40.0356 N	Mukeshefa
11	43 47 10.0107 E	34 20 45.9723 N	Samarra
12	43 50 58.6467 E	34 11 52.6462 N	Ishaqi
13	43 50 58.6467 E	34 11 52.6462 N	Balad

Fig.2: Google satellite image showed the selected points along the Tigris River in Salah Al-Din Province.

Mapping of water quality parameters

This Relates to the Inverse Distance Weighted Interpolation (IDW) meaning which indicates the closer sample point is the considered cell that will be calculated, the closer the value of the cell will resemble the value of the sample point, in other words, the underlying concept of IDW is the first geography rule of Waldo Tobler's first law of Geography which states that "everything is related to everything else, but near things are more related than distant things". IDW uses linear combination of weights at known points to estimate unknown location values. That is, values at unknown locations $\hat{Z}$ (S_0) were determined by the weighting value (λ_i) and values at known locations (S_i) expressed mathematically as shown in Eq.(1) [10].

$$\hat{Z}(S_0) = \sum_{i=1}^{n} \lambda_i (S_0) . Z(S_i) \qquad (1)$$

However, the weight λ_i (S_0) were estimated through inverse distance from all points to the new points by applying Eq.(2)

$$\lambda_i(S_0) = \frac{\frac{1}{\beta d(S_\circ . S_i)}}{\frac{1}{\sum_{i=0}^{n} \frac{1}{\beta d(S_\circ . S_i)}}} \quad \beta > 1 \qquad (2)$$

where: λ_i is the weight for neighbour *i* (the sum of weights must be unity to ensure an unbiased interpolator), d(S_0.Si) is the distance from the new point to a known sample point, β is the coefficient used to adjust the weights, and n is the total number of points in the neighbourhood analysis.

It was used all the measured points (water quality data) in the calculation for each interpolation cell (water quality grid). The feature dataset (river network) was utilized for the mask where cells within the specified shape of the feature dataset (river network) only received the values of the first input raster (water quality grid) on the output raster (water quality result).The output raster is the extraction of the cells of the water quality grid (input raster) that corresponds to the routes defined by the mask. These illustration for IDW method of mapping in ArcGIS 10.4 are shown in Fig.3 [11].

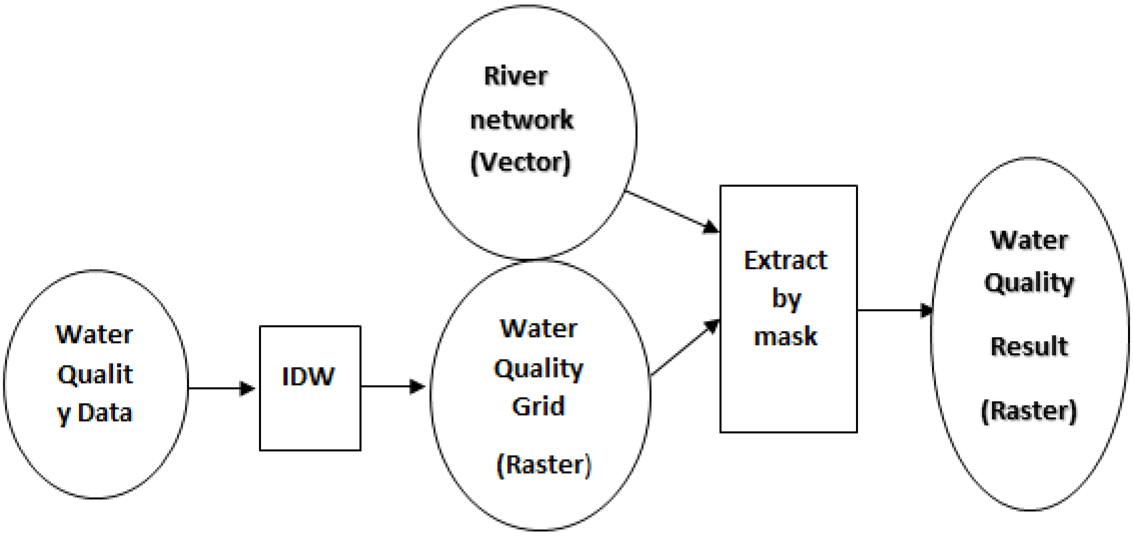

***Fig.3**: Diagram of IDW mapping procedure in ArcGIS 10.4.*

Predicting the distribution of pollutants has proven useful in evaluating, controlling, and implementing water management engineering programs. Contaminant concentration maps played an important role in the assessment of water quality. Several sources were used for the present study to formulate the appropriate map layers within the GIS. Digital maps (shapefile) were the individual Tigris River shape map specified according to the laboratory tests that we carried out on the river samples in addition to the satellite imagery from USGS and Google maps. The laboratory research experimental findings were imported into GIS as features and then converted them into a shapefile using the "export data" function to produce the shapefile map for physiochemical contaminants (Turbidity, T.D.S, T.T.S, PH, EC, Alkalinity, Cl, NH_3, NO_3, SO_4).The GIS extension tool "IDW" was used to construct an interpolation (predicted value) for the unmeasured Tigris River parts at Salah Al-Din.

Results and discussion

The digital pollutant concentration map for the physio-chemical contaminants has been generated. The mean, minimum and maximum values of different selected physic-chemical parameters are shown in Table 2, while the WHO standard values of water quality parameters are arranged in Table 3.

Table 2: Statistics of Physio-Chemical water parameter.

Parameters	Min.	Max.	Mean	Median	Standard Deviation
Turbidity (mg/l)	1.67	28.9	13.36	13.7	8.7
TSS (mg/l)	16	42	38.6	40	12.9
PH (mg/l)	7.8	8.3	7.9	8	0.13
EC (µS/cm)	483	1543	739.2	566	330.9
TDS (mg/l)	285.6	864	413.8	316.3	185.3
Alkalinity	55	130	90.4	96	22.3
Cl (mg/l)	9.67	77.55	29.3	16.52	21.9
NH_3 (mg/l)	3.92	10.64	6.8	6.72	198
NO_3 (mg/l)	0.52	7.15	4.55	4.8	1.9
SO_3 (mg/l)	63.4	437.2	156.3	107	111.5

Table 3: Iraq and WHO standard values of water quality parameters.

Parameters	Iraq and WHO Standard Values
Turbidity (mg/l)	5.0 mg/l
TSS (mg/l)	200 mg/l
PH (mg/l)	7.5 mg/l
EC (µS/cm)	250.0 µS/cm
TDS (mg/l)	500 mg/l
Alkalinity	100.0
Cl (mg/l)	250 mg/l
NH_3 (mg/l)	0.5 mg/l
NO_3 (mg/l)	50.0 mg/l
SO3 (mg/l)	200mg/l

1. Turbidity

Turbidity is considered one of the biggest reasons affecting the poor quality of water by polluting it and causing many diseases. The maximum and minimum concentrations ranged between (1.675-28.894) mg/l whereas the internationally permitted standard value is 5 mg/l [8]. Maximum concentrations can be noted in (azawia city, Al-Alam, Tikrit, Baiji and AL Abbasi), while the minimum concentrations are mainly in (Samarra, Balad, Ishaqi, Aldor and Mukeshefah). The high turbidity rate is due to human, animal and agricultural activities in addition, the erosion-prone areas lead to pollution of the surrounding water. Turbidity is dangerous in water, as it may protect pathogens from sterilizers during water treatment [12].

2. TSS

Turbidity monitoring allows us to assess TSS flows [10]. In this study, the value of all suspended solids in water ranges between (16-64) mg/l as clarified in Fig.4. This is a good indicator especially for irrigation projects as the standard value of its concentration in water according to the Iraq standard is 60 mg/l. Maximum value was in (Al-hawijja and Samarra). The suspended material consists of granules of clay, silt, sand, and decomposition materials, as well as microorganisms. Increased suspended solids reduce the biodiversity in the water because they block sunlight [13].

3. PH

The PH function is an important criterion for estimating the suitability of water for different uses. In our results, we notice that the maximum value was 8, the value tends slightly towards alkaline. The reason for value is this value due to human waste and wastewater. As the pure water at 25 degrees Celsius gives a pH of 7 [14]. The standard value according to the WHO is 7.5 [15].

4. Electrical conductivity

The electrical conductivity expresses the amount of salts dissolved in water and increasing its value causes the unpalatable taste of water when it exceeds the permissible limit (2000) µS/cm. the results indicate that values did not exceed the allowed limit, the higher values (1543-1185) µS/cm was in (Samarra and Tikrit) as shown in Fig.4. This is due to the high value of the dissolved solids in these samples and the high percentage of salts and the high percentage of mineral pollutants due to the high population density and the spread of human and industrial activities [16].

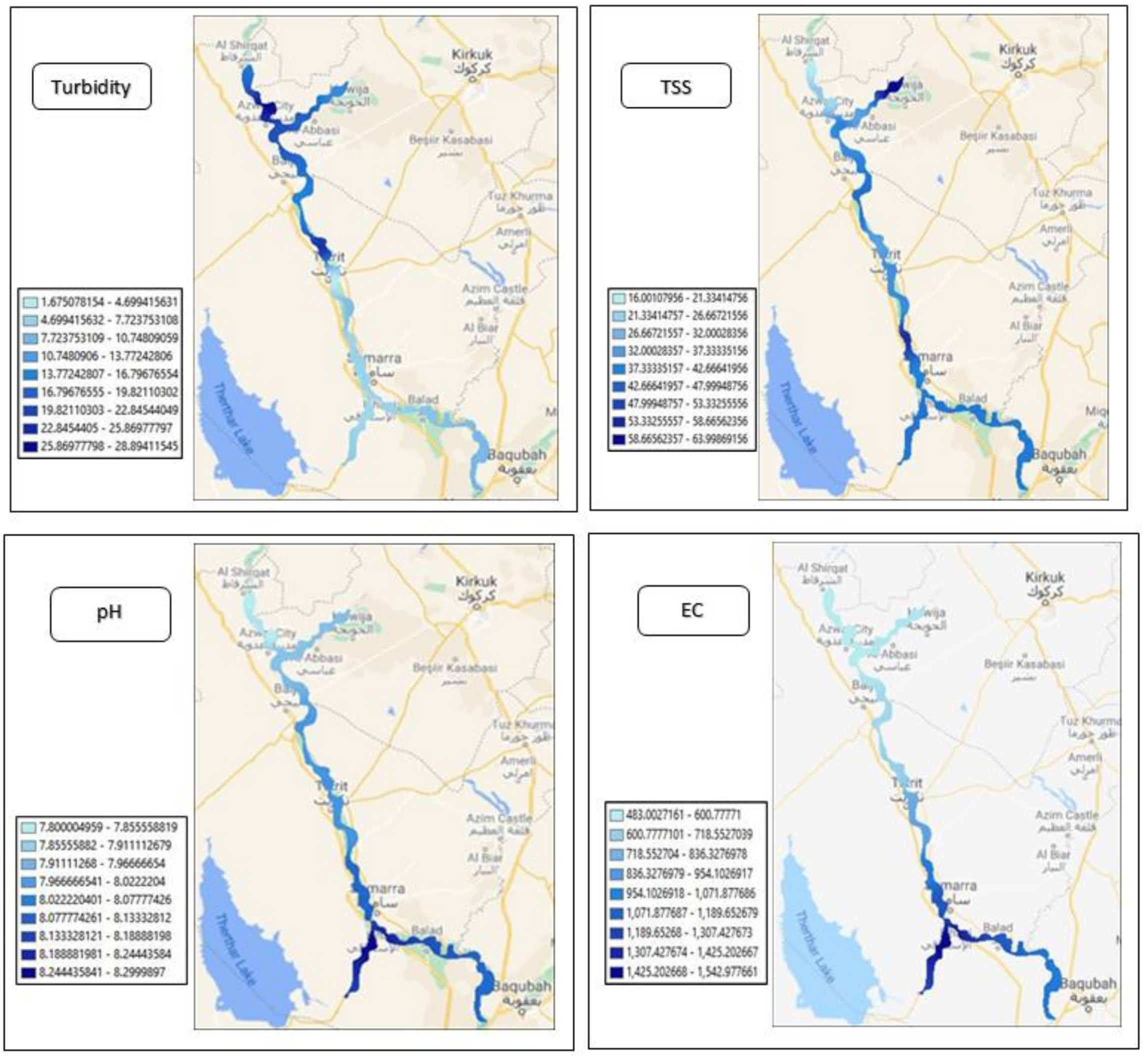

Fig.4: Spatial maps of concentration distribution for Turbidity, T.S.S., PH and EC.

5. Total dissolved solids

When water evaporates, gases, liquids, and some easily-volatile substances will fly, and only solid, non-volatile substances will remain, which are often salts. Thus, it gives an initial estimate of the suitability of the water for use without the need for sophisticated analyses. The relationship between solids and electrical conductivity is determined by a direct relationship, where the electrical conductivity values rise with the rise in the values of dissolved solids, which depend on the behaviour of ions in the water. Micro-organisms that survive longer with fresh water than in salt water [13]. The resulting values ranged between (270.4-863.9) mg/l. the allowable limit is 500 mg/l according to World Health Organization (WHO) standard values. Note that the Maximum Values was in Samarra then Tikrit, Ishaqi and Balad. Its source is mostly from rocks and soil that the water mixes with or runs out through in its journey in nature, and salts can reach water sources as well as a result of some human activities such as agriculture, industry and mining. One of them may actually be harmful while the other part can be beneficial and wanted in the water [17].

6. Alkalinity

Depending on the fact that the Alkalinity etiology is the presence of bicarbonate ions, carbonates, and hydroxyls, one can attribute the calculated value of PH= 8.3 to the existence of bicarbonate ionic and a little carbonate [18]. Alkalinity values ranged between

(55-129.9) mg/l while the Standard value is 200 mg/l according to WHO. This percentage of Alkalinity does not pose a health risk, but can cause aesthetic problems where the taste of water is bitter [19].

7. Chloride

The high concentrations of chloride mean the presence of pollution resulting from the disposal of civil, industrial and agricultural wastes into river water. This makes it unfit for drinking, irrigation and watering of livestock [20]. The values of Cl ranged between (9.67-77.54) mg/l they are all well below the permissible limit (350) mg/l according to WHO.

8. NH_3 (Ammonium)

Ammonia can get in the aquatic environment by direct means such as municipal effluent discharges and the excretion of nitrogenous wastes from animals, and indirect means such as nitrogen fixation, air deposition, and runoff from agricultural lands [21]. The maximum and minimum values ranged between (3.9-10.4) mg/l while the allowed value is 0.5 mg/l according to WHO. NH3, its value exceeded the limit value in most areas, this is due to the poor drainage of sewage into the river. When ammonia is present in water at high enough levels, it is difficult for aquatic organisms to sufficiently excrete the toxicant, leading to toxic build up in internal tissues and blood, and potentially death. Environmental factors, such as pH and temperature, can affect ammonia toxicity to aquatic animals [22].

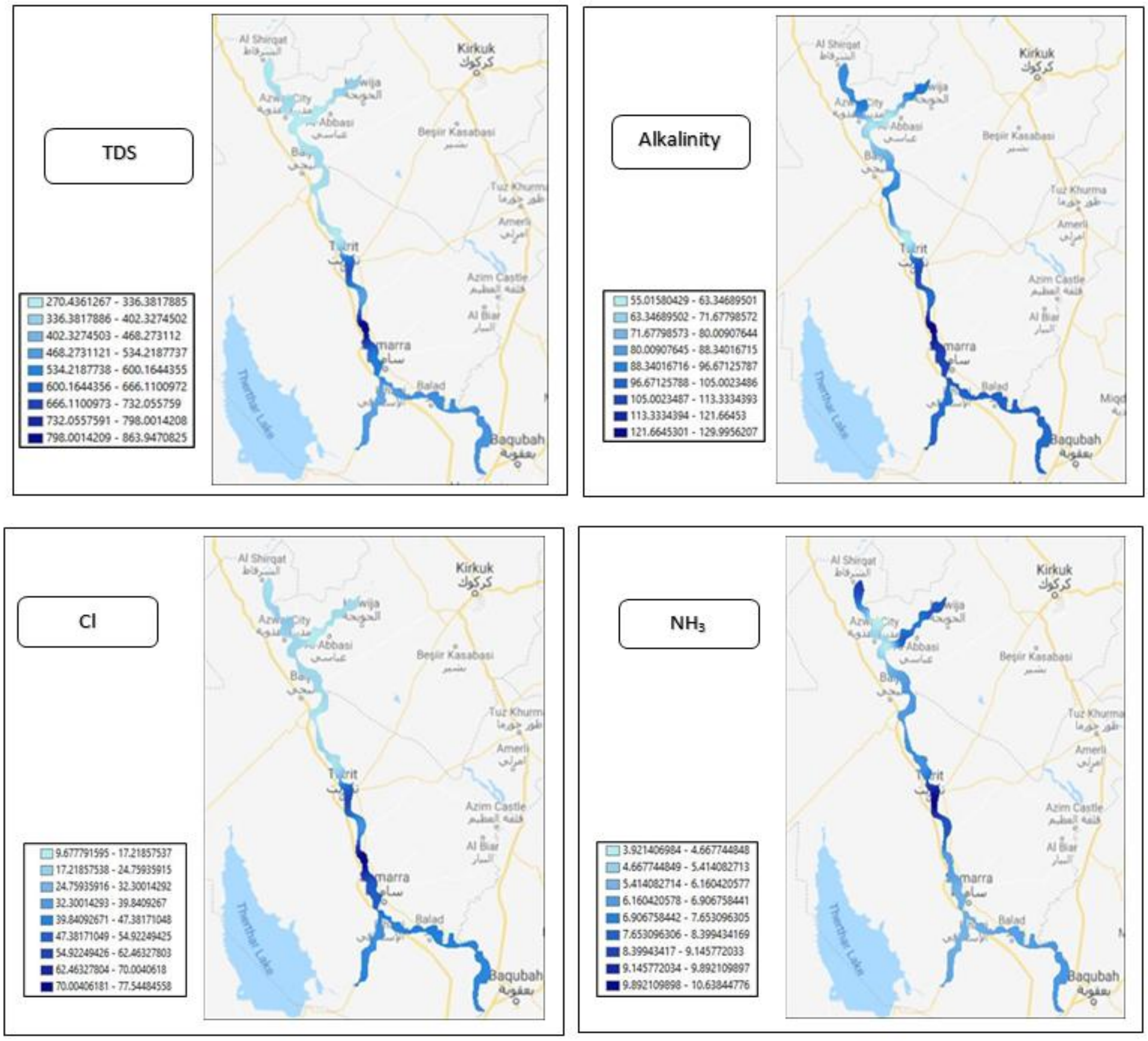

Fig.5: Spatial maps of concentration distribution for T.D.S, Alkalinity, Cl and NH_3.

9. NO_3 (Nitrate)

High nitrate concentrations are not desirable because they have negative effects on public health, as it causes Methemoglobinemia disease for children and some cancerous diseases such as stomach cancer, thyroid gland and brain tumours. We notice that the values ranged between (0.52-7.1) mg/l as shown in Fig.6, and It is much less than the permitted limit by the WHO (50) mg/l according to WHO [23].

10. SO_4 (Sulfate)

The high concentration of sulfate ions causes diarrheal and bitter taste, where its concentration in the water depends on the geological formation for water and on the excesses in the industrial, agricultural and civil wastes disposal which is all reflected on the water of the liquefaction [23]. The values ranged between (63.4-437.1) mg/l as shown in Fig.6, while the value at point (11) is over the allowed limit (400) mg/l according to WHO. The maximum value was in Samarra. Sulphates contribute to the formation of permanent hardness in water, especially if it is found in the form of calcium or magnesium sulfate, and it is included in the elements that cause salinity as it gives the taste salty and contributes to killing fish [24].

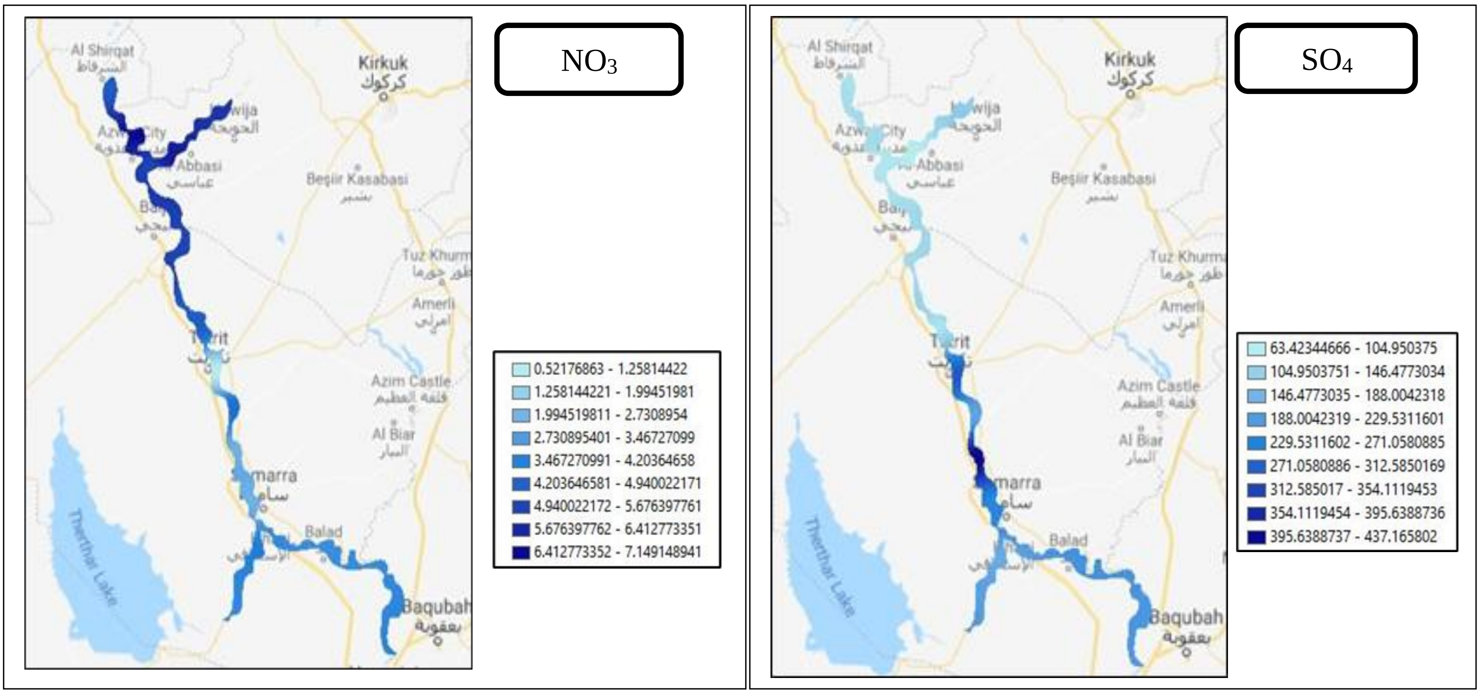

Fig.6: Spatial maps of concentration distribution for (I) NO_3 and SO_4.

Conclusions

A GIS model was applied along the Tigris River in Salah Al-Din province to study the spatial distribution of some water quality parameters. The results obtained can be summarized as follows:

1. The concentration levels of pollution indicators, Alkalinity, Cl, NO_3 and EC were within the allowable limits along the river. As for Turbidity, its value exceeded the limit at azawia city (28.89 mg/l), Al-Alam (17.779 mg/l), Tikrit (25.86 mg/l), Baiji (22.84 mg/l) and AL Abbasi (19.8 mg/l). TSS, its value exceeded at Alhawija (63.9 mg/l) and Samarra (58.66 mg/l). TDS, exceeded the limit value at Samarra (863.9 mg/l) then Tikrit (798 mg/l), Ishaqi (732 mg/l) and Balad 666 mg/l). NH3, its value exceeded the limit value in most areas the highest was in Tikrit, where it reached (10.6 mg/l), this is due to the poor drainage of

sewage into the river. PH values was fixed in the range of 8 and is alkaline and SO4, its value exceeded the standard limit at Samarra.

2. Pollutants increased and exceeding the permissible concentration were most likely in Samarra and Tikrit, this is due to their population density and direct drainage of human waste and sewage water, as well as the presence of electrical stations and laboratories there.

3. The water quality of the river is being altered in a few areas as a result of domestic effluents direct discharge into river and of others human activities along the banks of the river. Moreover, further research and periodic monitoring of river water quality is of importance for the improvement or maintenance of the water of Tigris River.

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