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Spatial Distribution and Partition Coefficient of Nutrient in Water and Sediment of Shatt Al-Basrah Canal, Iraq

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Abstract

The proposed water and sediment quality of Shatt Al-Basrah was assessed by (1) using Geographic Information Systems (GIS) using Inverse Distance Weighting (IDW) method for calculating nutrient concentrations of water and sediment samples, (2) evaluating Partition Coefficient (K_d) and cluster analysis for water and sediment samples. The GIS facilitates the explanations of the spatial relationships among key environmental processes. It employs spatial distribution modeling to analyze the nutrient concentrations of Nitrite as N (NO_2-N), Nitrate as N (NO_3-N), Ammonia as N (NH_3-N), Ammonium (NH_4), and Sulfate (SO_4) in the water and sediment. This paper shows that the results of Partition Coefficient (K_d) is always less than 3 for all sites illustrating that the pollutants are present in liquid phase preferentially which have high solubility and are less sediment-associated.

Keywords: Shatt Al-Basrah, sediment, cluster, Partition Coefficient, GIS.

1. Introduction

Surface waters are contaminated through the received discharge of different resources, which result an elevated significant contaminants' concentrations in river estuaries [1, 2]. The domestic sewage, agricultural run-off, and industrial wastewater are the major sources of pollution in surface water [3, 4]. The aquatic resources management focused on water quality; however, in recent years, the importance of sediments in determining the implications of many contaminants has become clearer [5, 6]. Sediments are important because many toxic substances; present in trace amounts in water; may accumulate to high levels, and also providing a habitat for various organisms [7-9]. Sediments accumulate contaminants and act as sources of pollution to ecosystems. Metals, nutrients, Pathogens, and organic chemicals tend to absorb onto both organic and inorganic materials that finally settle in sedimentation areas [10, 11]. Nutrients are chemicals essential for primary production, can decompose water resources and produce health and environment risks [12, 13]. The degradation of aquatic plants, mixing processes between the sediments and the waters, and terrestrial sources such as domestic sewage, or deposition of particulate matter are the sources of nutrients [14, 15]. In aquatic system, the sediments act as storage reservoirs of nutrient in water. A comprehensive understanding of nutrient behavior requires their study in both water and sediments. Movement of nutrients from sediment to water is a significance process whose depends upon the efficiency of the mixing mechanism, diffusion, internal waves and thermal gradients can induce mixing [16, 17]. Therefore, sediment quality is applied as a sensitive indicator of environmental quality. On the other hand, Geographic Information Systems (GIS) is a powerful tool to assess the water quality, finding water availability and conception the natural environment on a local and/ or regional scale. From GIS, spatial distribution mapping for variety of contaminants can be done. The resulting information is very helpful for policy makers to take correctional measures [18- 20]. The purposes of present study are: (1) applied GIS to assess spatial patterns of water and sediment quality parameters: Nitrite as N (NO_2-N), Nitrate as N (NO_3-N), Ammonia as N (NH_3-N), Ammonium (NH_4), and Sulfate (SO_4) in Shatt Al-Basrah (2) calculate the Partition Coefficient for the parameters to describe the tendency of the element in the canal. (3) Found the cluster analysis for the water and sediment parameters.

2. Materials and Methods

2.1. Site Description

Shatt Al-Basrah is an artificial canal operated in 1983, located on latitude between 30°15' N to 30° 45' N and longitude 47° 30' E and 48° 00' E within Basrah Province in Iraq (Fig.1). It was established to reduce flood and drain the excess water during the flood seasons. The length of Shatt Al-Basrah canal is 37.150 km. The cross section consists of a portion for the purposes of maritime shipping.

2.2. Geo Database

Water and sediment samples were collected from five selected sites (Table 1) at Shatt Al-Basrah during 2014-2015 and illustrating the satellite image of the sampling sites (Fig.2). Water samples were preserved in a polyethylene bottles, and the sediments collected from those water sampling locations (using Van Veen grab sampler) in polyethylene bags, were kept in an ice box during transportation to the laboratory.

In the laboratory, the sediments' samples were homogenized by agate mortar/ pestle, sieved with a 200 µm sieve, and then dried in an oven at 105 Cº.

The water and sediment qualities were analyzed according to the Standard methods for examination of water and wastewater [21].

Table 1: Coordinates of the water and sediment sampling sites by GPS (Garmin navigator)

Site code	Easting (m)	Northing (m)
S_1	762798	3376223
S_2	764413	3372715
S_3	765287	3370531
S_4	766073	3368567

S_5	767264	3366352

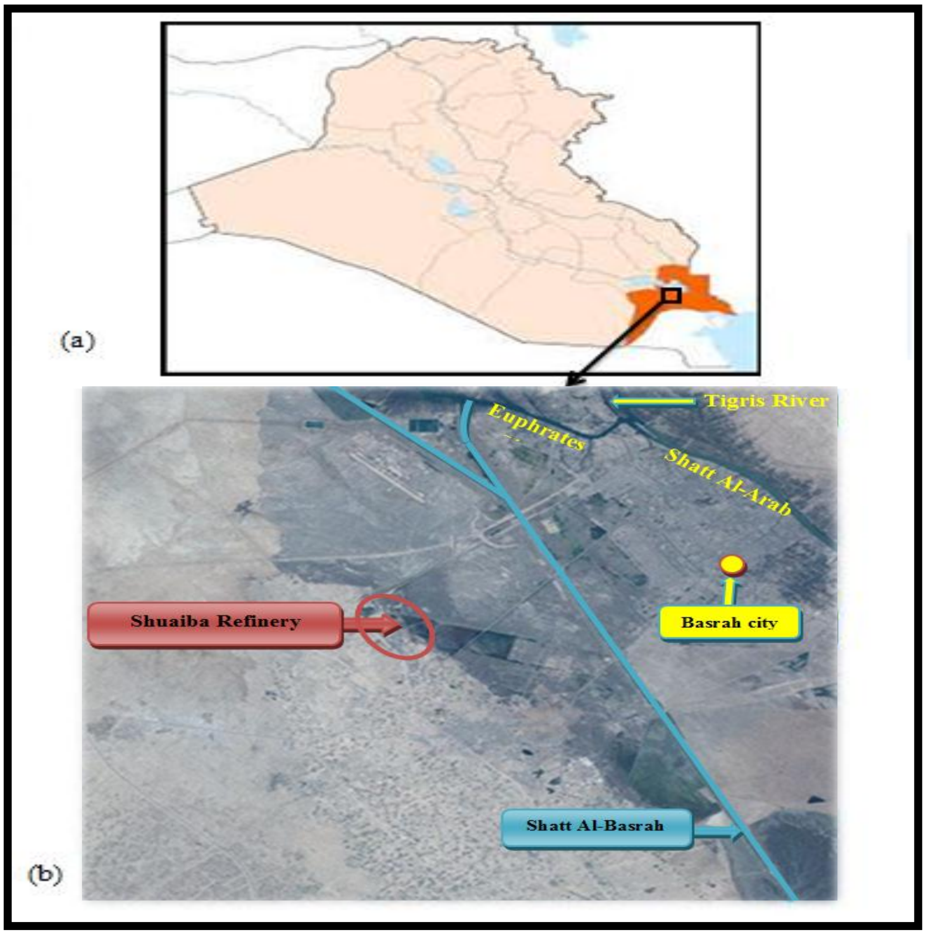

Figure 1: It includes the following: (a) Map of Iraq showing the location of Basrah Governorate. Also map showing the locations of cities in Basrah Governorate. (b) Satellite image with high resolution 0.6m (Quick bard) of the study area.

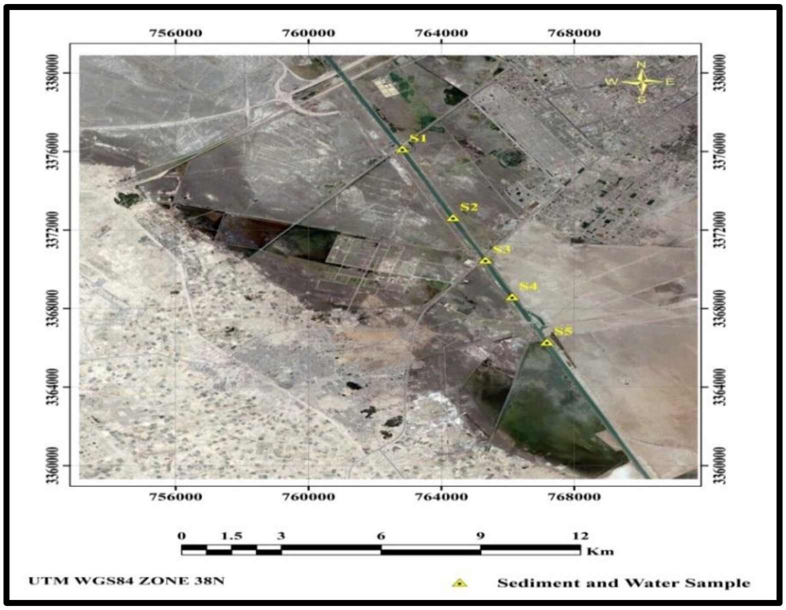

Figure 2: Water and sediment samples locations on satellite image of study area.

2.3. Geology of Study Area

Basrah province represents the area that extends at south Iraq, originally, the lower part of the Mesopotamian basin. Its topographic feature is quite simple with approximately 26.7 cm/km regional slope and a general southeast trend toward the Arabian Gulf [22]. Basrah area is characterized by six geomorphological units; river levees, estuarine river levees, silted tidal flats, Tidal flats, Marshes and swamp deposits, and Dune sand [23] based on the tectonic subdivision of Iraq and occur with the Zubair Subzone [24].

The area is generally arid; with extremely dry and humid summer and cooler, yet mild, cold winter. Irregular winter rainfall may result to 140 mm annual precipitation rates, while the evaporation ranges from 50–250/600 mm a month during the interval; January–July [25].

The soil salinity, at the area, is so high as a result of the low level of Basrah surface and the high evaporation rates of the dominant surface waters (Arabian Gulf, Marshes, Shatt Al-Basrah, and Shatt Al-Arab River and its tributaries) [26]. Basrah soils are exceptionally calcareous composed of 20 to 30% lime, and highly saline. Compared with other fluvial plains in the world, Basrah soils' characters are completely different [27]. The soil of Mesopotamia could be categorized into three groups; torrifluvents which occur on river levees, torrents occur in low land areas, and salorthids common in the lower Mesopotamian plain [28].

2.4. Geostatistics

Geostatistics is a sort of statistics focusing on spatial datasets. It's so useful technique for handling spatially distributed data; such as soil and water pollution, Geology, Hydrology, and Environmental Sciences, and improving solutions for water resources problems [29, 30]. There are two main elements in GIS system; the database and the geographical base, assessing in visualization the data in a map format. The spatial analysis modeling includes explanation and searching for the relations, associations among GIS data for a specific geographic location [31].

2.5. Sediment–Water Partitioning

It is significant to investigate the sediment–water partitioning between dissolved and solid phases, to understand the transport and fate of contaminants. The mobility of contaminants in aquatic sediments is usually expressed as distribution Coefficients, K_d [32, 33]. The K_d value (l/kg) is defined as:

$$K_d = \frac{concentration\ (sediment)}{concentration\ (water)} \qquad (1)$$

Then, K_d was transformed into the natural logarithm form, if the values of log K_d>5 indicate that pollutants are preferred binding to solid phases and migrate to liquid phases just a little bit, while values of log K_d<4 characterize pollutants are more easier released from solid phase and log K_d<3 pollutants are present in liquid phase preferentially [34].

3. Results and Discussion

Statistical evaluation of the Mean and Relative Standard Deviation (RSD) were calculated for each parameter's concentration in water and sediment for all sites, as shown in Table 2.

Table 2: Concentrations of parameters (Mean ±RSD) in water and sediment samples.

Parameters	Water (mg/l)				
	S_1	S_2	S_3	S_4	S_5
Nitrite as N, NO_2-N	0.013±0.006	0.196±0.226	0.948±1.068	0.032±0.001	0.038±0.01
Nitrate as N, NO_3-N	3.383±0.543	2.921±0.271	2.993±0.267	2.896±0.142	2.815±0.455
Ammonia as N, NH_3-N	7.42±4.923	1.593±0.393	1.78±0.026	1.608±0.344	1.445±0.435
Ammonium, NH_4	9.383±6.27	2.050±0.43	2.205±0.033	2.198±0.30	1.913±0.53
Sulfate, SO_4	3494.7±1129	4279.5±342.7	4292.7±270.3	4444.5±347.4	4427.5±374.4
	Sediment (mg/Kg)				
Parameters	S_1	S_2	S_3	S_4	S_5
Nitrite as N, NO_2-N	0.180±0.156	0.075±0.087	0.250±0.346	0.045±0.066	0.255±0.338
Nitrate as N, NO_3-N	0.975±0.896	4.156±8.246	0.025±0.05	2.875±5.106	9.375±15.883
Ammonia as N, NH_3-N	3.557±1.03	1.213±1.40	4.523±4.485	1.624±2.129	6.723±4.420
Ammonium, NH_4	4.6000±1.3	1.563±1.80	5.825±5.806	2.100±2.75	8.688±5.69
Sulfate, SO_4	4550±850.4	2350±2791	4875±921.5	2425±2814.69	4175±699.40

3.1. Spatial Distribution

The analysis results have been clarified using ARC GIS 10.3 by Inverse Distance Weighting (IDW) method.

3.1.1. Nitrite as N (NO_2-N)

Nitrite occurs in aquatic systems as an intermediate compound in the microbial reduction of Nitrate or in the oxidation of Ammonia. In water, NO_2-N value was found a higher concentration at point S_3 with mean value of 0.948 mg/l while a less concentration was found in points S_1 with mean values 0.013 mg/l (Fig.3). In sediment, the higher concentration values were found in points S_3 and S_5 with mean values 0.250 mg/l and 0.255 mg/l, respectively, while the less value was found in point S_4 with mean value 0.045 mg/l (Fig.4). A high concentration may be due to the agriculture excess, sewage discharges, or penetration of pollutants from various sources.

3.1.2. Nitrate as N (NO_3-N)

In an aquatic system, Nitrate is the final oxidation product of Nitrogen compounds and is considered to be the only stable oxidation level of Nitrogen. High content of Nitrogen (present as Nitrate) is an indicator of organic pollution. The decomposition of dead animals and plants, animal urines, etc. is oxidized to Nitrate by natural processes. Figure 5 show that Nitrate concentration in the surface water has high value in point S_1 with mean concentration 3.383 mg/l and less concentration 2.815 mg/l in point S_5, while in (Fig. 6) indicate that Nitrate concentration in the sediment has high value in point S_5 with mean concentration 9.375mg/l and less concentrations 0.975 and 0.025mg/l in points S_1 and S_3, respectively.

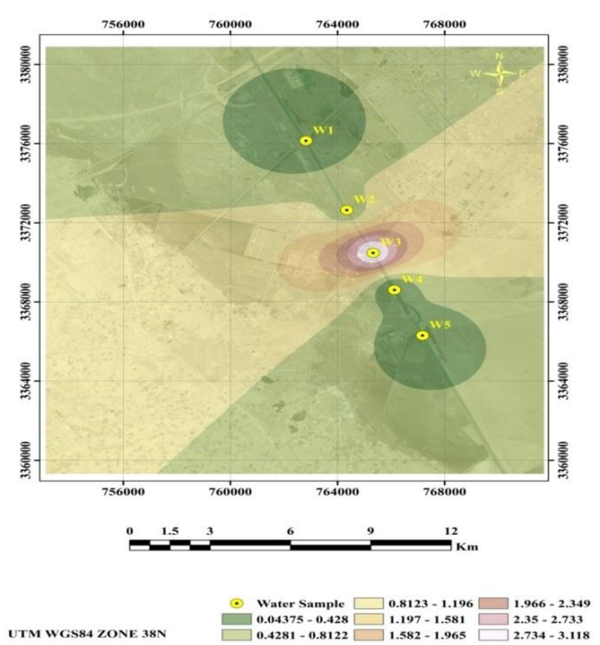

Figure 3: The mean NO_2 concentrations of water sampling sites

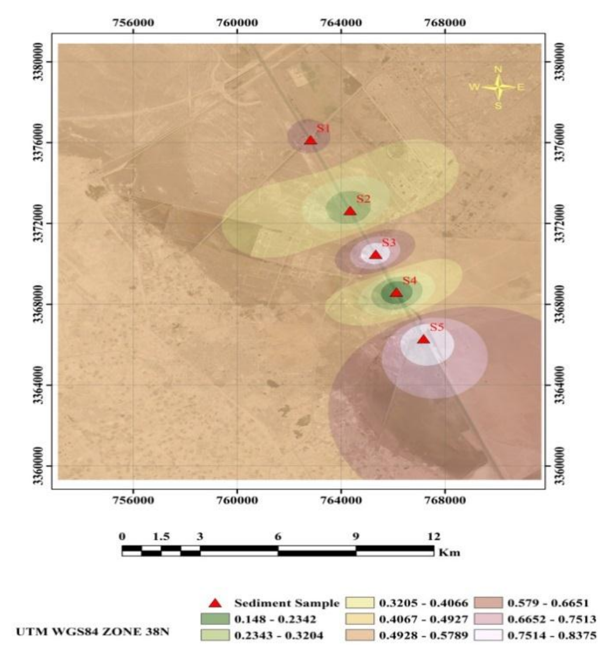

Figure 4: The mean NO_2 concentrations of sediment sampling sites

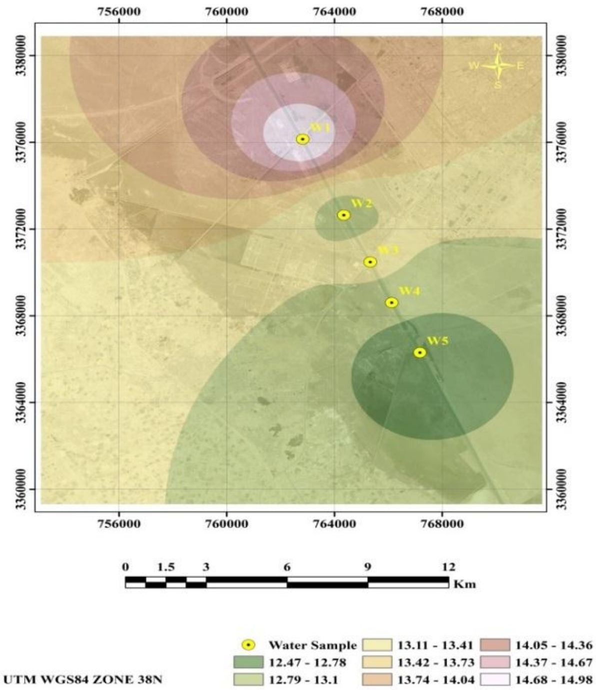

Figure 5: The mean NO_3 concentrations of water sampling sites

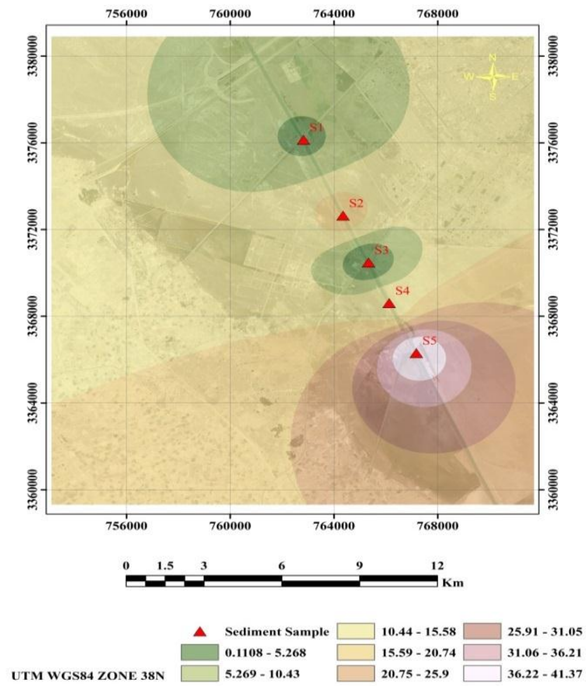

Figure 6: The mean NO_3 concentrations of sediment sampling sites

3.1.3. Inorganic Nitrogen

Ammonia as N (NH_3-N) and Ammonium (NH_4) are usually affected by many factors includes streams, surface overflow from the surrounding area, and wastewater treatment plants discharge, agricultural fertilizers, and industrial wastes. In this study, inorganic Nitrogen (NH_3-N and NH_4) concentrations affected by agricultural surplus and industrial discharge like the effluents of Shuaiba (Basrah) Refinery which is a major sources of Ammonia. In water samples, the Ammonia and Ammonium concentrations in point S_1 have higher values more than others; the mean values of NH_3-N and NH_4 concentrations were 7.42 mg/l and 9.383 mg/l, respectively, as shown in (Fig. 7) and (Fig. 9). While in sediment samples, the higher values of NH_3-N and NH_4 concentrations were found in point S_5 with mean concentration 6.723 mg/l and 8.688 mg/l, respectively, and less value was found in points S_2 and S_4. The less mean concentration in point S_2 was 1.213 mg/l of NH_3-N and 1.563 mg/l of NH_4, and in point S_4 was 1.624 mg/l of NH_3-N and 2.1 mg/l of NH_4, as shown in (Fig.8) and (Fig.10).

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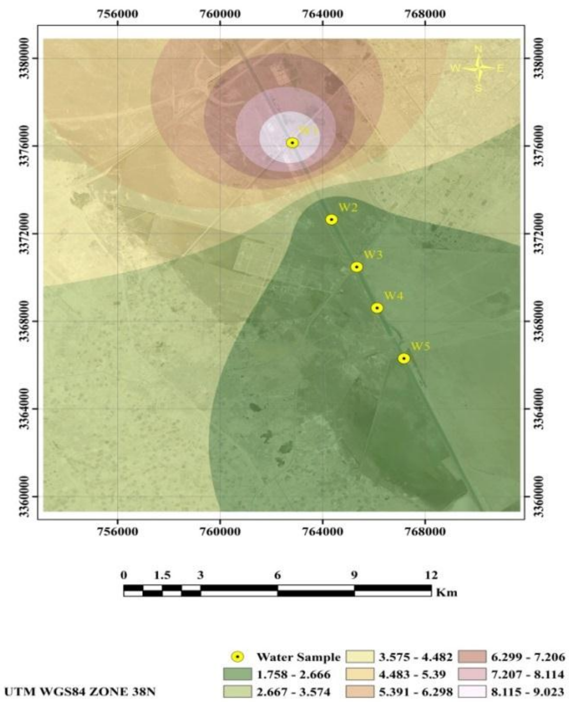

Figure 7: The mean NH_3 concentrations of water sampling sites

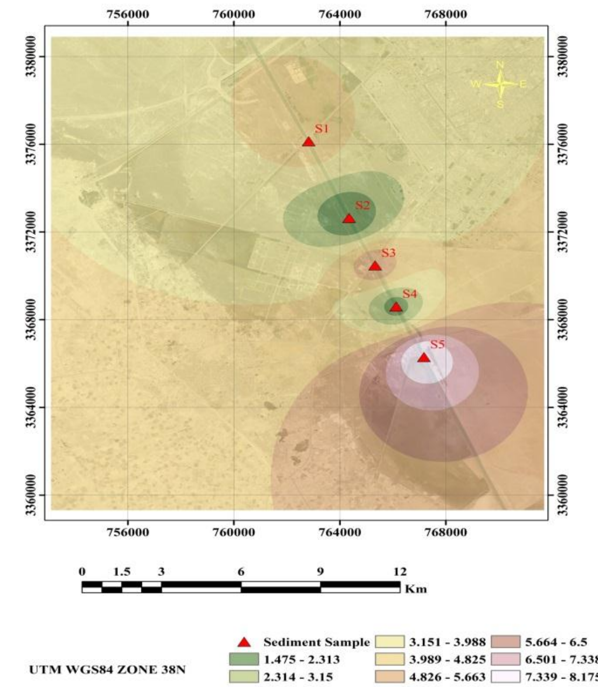

Figure 8: The mean NH_3 concentrations of sediment sampling sites

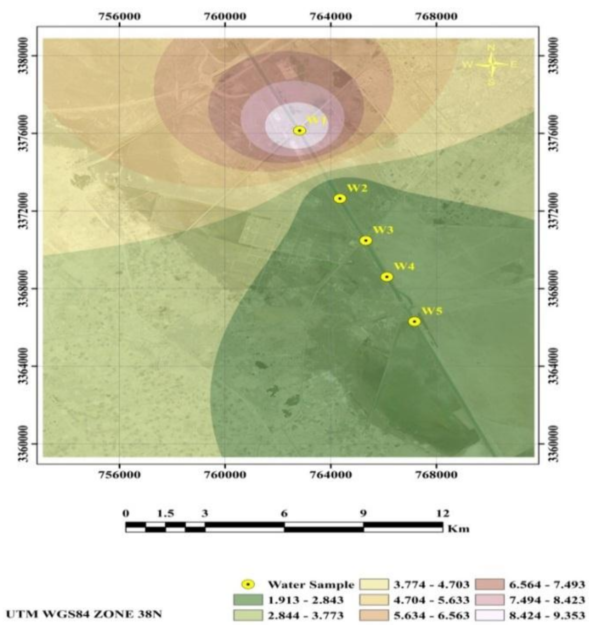

Figure 9: The mean NH_4 concentrations of water sampling sites

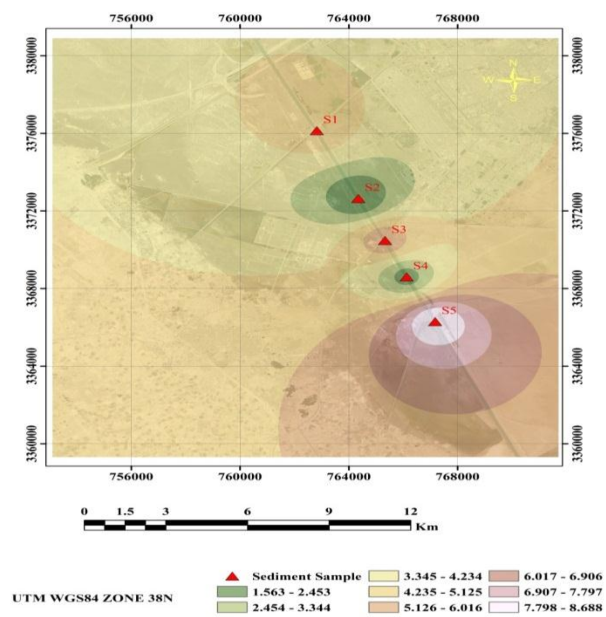

Figure 10: The mean NH_4 concentrations of sediment sampling sites

3.1.4. Sulfate (SO_4)

In water samples, Sulfate concentrations in the five sampling point ranged between 3494.7 and 4444.5 mg/l. point S_1 showed the lowest concentration, while the highest level of Sulfate was observed at points S_4 and S_5 (Fig.11). In sediment samples, Sulfate concentrations in the five sampling point ranged between 2425 and 4875 mg/l. points S_2 and S_4

showed the lowest concentrations, while the highest level of Sulfate was observed at point S_3 (Fig.12).

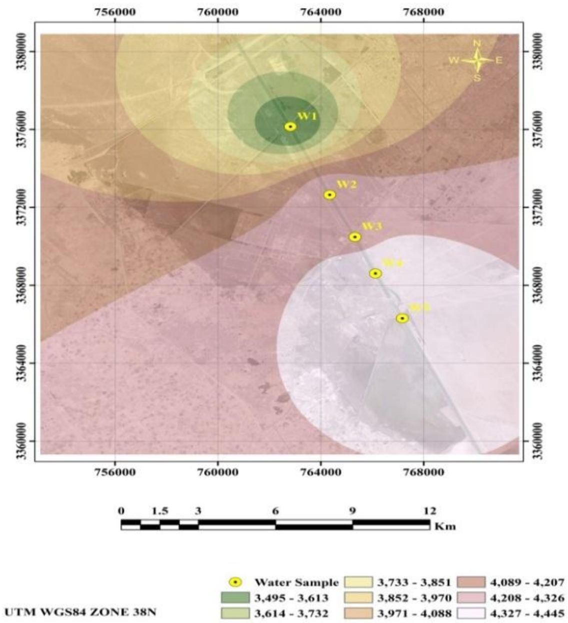

Figure 11: The mean SO_4 concentrations of water sampling sites

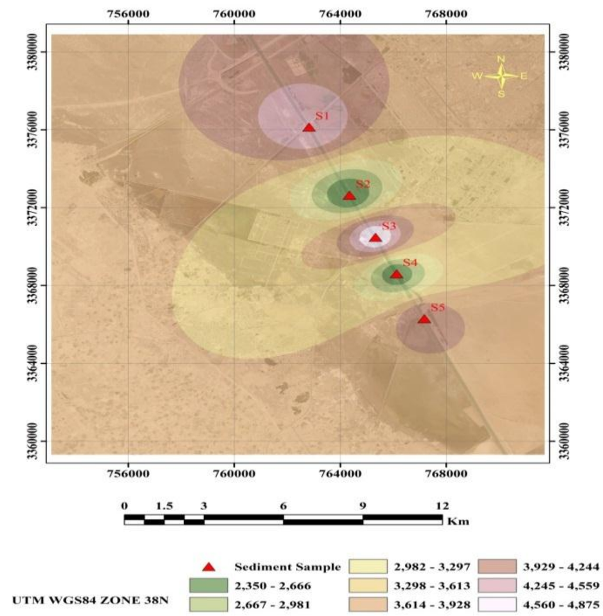

Figure 12: The mean SO_4 concentrations of sediment sampling sites

3.2. Distribution Coefficient (K_d)

Distribution Coefficient is the ratio between; parameters concentrated in sediment and those in water, used to describe the tendency of the element to be retained by the sediment or to remain in the water and consequently to be available for transport and biological uptake [35]. The Partition Coefficient (log K_d) depends on the main chemical-physical properties of the sediments, e.g. pH and different texture. The results show that K_d in this study is always less than 3 for all sites, meaning that the pollutants are present in liquid phase preferentially which have high solubility and are less sediment-associated (Table 3).

Table 3: Partition Coefficient (K_d) for water and sediment samples

Parameters	S_1		S_2		S_3		S_4		S_5	
	K_d	log K_d	K_d	log K_d	K_d	log K_d	K_d	log K_d	K_d	log K_d
NO_2-N	13.531	1.131	0.383	-0.417	0.264	-0.579	1.420	0.152	6.713	0.827
NO_3-N	0.288	-0.540	1.423	0.153	0.008	-2.078	0.993	-0.003	3.330	0.523
NH_3-N	0.479	-0.319	0.761	-0.118	2.540	0.405	1.010	0.004	4.651	0.668
NH_4	0.490	-0.310	0.762	-0.118	2.642	0.422	0.956	-0.020	4.542	0.657
SO_4	1.302	0.115	0.549	-0.260	1.136	0.055	0.546	-0.263	0.943	-0.026

3.3. Cluster Analysis

Cluster analysis is a suitable method for identifying homogenous groups of data. Data in a specific cluster have many same characteristics, but are dissimilar to data in another cluster. Cluster analysis was accomplished by applying Ward's method, using Squared Euclidean Distance as a measure of similarity [36]. Cluster analysis was applied on the water and sediment data of all sites of Shatt Al-Basrah to find different sub clusters within the water and sediment quality that let us to determine the associations among different parameters and their input source. The results of cluster analysis for the water and sediment data are clarified with a tree dendrogram. Figure 13 show the nutrient in water could be mainly grouped into two main clusters. Cluster I consists of NH_3-N, NH_4 and NO_2-N, while cluster II consists of NO_3-N and SO_4. Figure 14 show the nutrient in sediment could be mainly grouped into two main clusters. Cluster I consists of NH_3-N, NH_4 and SO_4, while cluster II consists of NO_2-N and NO_3-N.

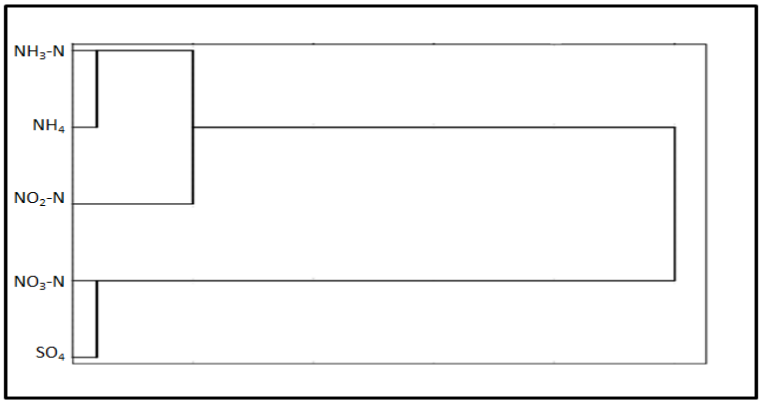

Figure 13: A tree dendrogram for nutrient in water quality for Shatt Al-Basrah

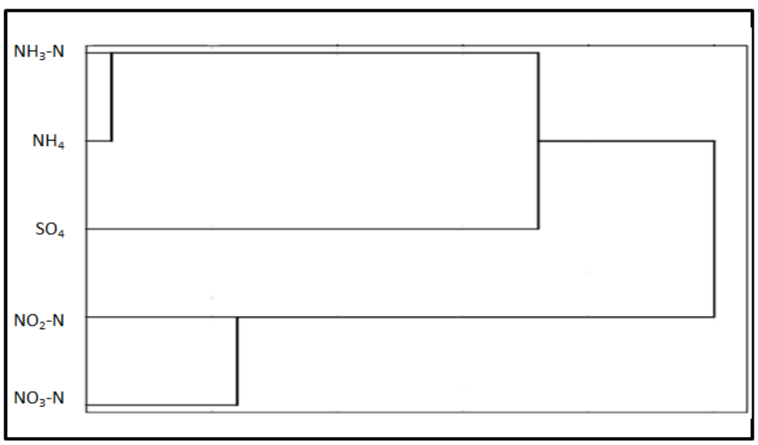

Figure 14: A tree dendrogram for nutrient in sediment quality for Shatt Al-Basrah

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