ISSN: 0067-2904

Hydrochemical Characteristics and Seasonal Variations of Al-Hammar Marsh, Southern Iraq

Hadi Salim Al-Lafta*, Firas Mudhafar Abdulhussein
Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

Abstract

Devastated by the combined impact of massive drainage works and upstream damming since the 1980's, Al-Hammar Marsh, Southern Iraq, has completely collapsed with 94 % of its land cover transformed into bare land and salt crusts by 2000. After a policy initiated to restore the Iraqi marshes again in 2003, the marsh recovered about half of its former area. As a part of the ecological recovery assessment of this newly inundated marsh, it is important to investigate the extend impact of desiccation after 3 years of inundation on water quality as the latter plays an important role in the restoration process of the marshes. Therefore, from a restoration point of view, major and trace element distribution and sourcing as well as seasonal variations were studied in the re-flooded marsh of Al-Hammar. First, the Canadian Council of Ministers of the Environment Water Quality Index [1] analyses applied revealed threatened or impaired water quality and conditions in the marsh that depart from natural or desirable levels. Second, multivariate statistical techniques such as Agglomerative Hierarchal Cluster Analyses (AHCA) that were used to analyze the data and identify the possible sources of water pollution in the marsh indicated that some elements such as Ca, SO_4, Mg, TDS, Cl, Na, Co, and Ni are associated with natural sourcing while other elements such as Cd, Zn, Pb, and turbidity indicated a possible anthropogenic sourcing. Third, seasonal variations investigation displayed that the water quality is affected by natural seasonal processes such as evaporation and rainfall as well as biological activities. Dry season exhibited an increase in TDS, Ca, Mg, Na, Cl, SO_4, and Cd due to the concentration by evaporation during the season compared to the dilution by rainfall during the wet season. In contrast, BOD and DO levels showed a considerable decrease in dry season owing to the poor water ability to hold oxygen at high temperature as a result of higher rate of microbial metabolism.

Keywords: Keywords: Al-Hammar Marsh, Restoration, Water quality, CCME WQI, AHCA, Seasonal variations

الخصائص الهيدروكيميائية والتغيرات الفصلية لهور الحمار– جنوب العراق

حادي سالم اللفته*، فراس مظفّر عبد الحسين
قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

هور الحمار، جنوب العراق كان قد دمر من خلال التأثير المشترك لمشاريع التصريف وانشاء سدود اعالي الانهار منذ ثمانينات القرن الماضي مما ادى الى انهيار الهور بشكل كامل وتحول 94 % من غطاءه النباتي الأصلي الى اراض جرداء وقشرة ملحية بحلول عام 2000. بعد تطبيق سياسة لأنعاش الاهوار العراقية

*Email:haoubid@yahoo.com

مجددا في عام 2003، استعاد الهور نصف مساحته الاصلية تقريبا". كجزء من تقييم الانتعاش البيئي للهور المغمور حديثا"، من المهم دراسة تأثير التجفيف− بعد 3 سنوات من الغمر− على نوعية المياه لان الأخيرة تلعب دورا" مهما" في عملية انعاش الأهوار. لذلك ومن وجهة نظر اعادة انعاش الهور تمت دراسة توزيع ومصادر العناصر الاساسية والثقيلة بالاضافة الى التغيرات الفصلية في مياه الهور. اولا"، تم استخدام مؤشر جودة المياه الموضوع من قبل المجلس الكندي لوزراء البيئة [1] اذ كشف المؤشر عن نوعية مياه مهددة ومتضررة كما ان ظروف الهور بعيدة عن تلك الطبيعية والمرغوب فيها. ثانيا"، تم استخدام أساليب الأحصاء المتعددة المتغيرات مثل تحليلات الهيكل العنقودي التجمعي وذلك لغرض تحليل البيانات وتحديد المصادر المحتملة للتلوث في مياه الهور حيث دلت هذه التحليلات على ان بعض المكونات مثل الكالسيوم، الكبريتات، المغنسيوم، المواد الصلبة الذائبة الكلية، الكلور، الصوديوم، الكوبالت والنيكل تكون ذات مصادر طبيعية في حين ان الكادميوم، الزنك،الرصاص، والعكرة كانت ذات مصادر بسبب الانسان. ثالثا"، فحص التغيرات الفصلية اظهر ان نوعية المياه تتأثر بالعمليات الفصلية الطبيعية كالتبخر والامطار بالاضافة الى الفعاليات البايولوجية. الفصل الجاف اظهر زيادة في المواد الصلبة الذائبة الكلية ، الكالسيوم، المغنسيوم، الصوديوم، الكلور، الكبريتات، والكادميوم وذلك نتيجة زيادة تراكيزها بسبب التبخر في ذلك الفصل مقارنة" بالتخفيف الذي يحصل بسبب تساقط الامطار في الفصل الرطب. على النقيض، فأن مستويات طلب الاوكسجين البايوكيميائي (BOD) والاوكسجين المذاب (DO) اظهرت انخفاضا" في الفصل الجاف الأمر الذي يعزى الى قدرة الماء القليلة للاحتفاظ بالاوكسجين عند درجات الحرارة العالية بسبب النسب العالية نسبيا" لعمليات الأيض المايكروبي في الفصل الجاف.

Introduction

The Mesopotamian marshlands are part of a major international river system, the Tigris and Euphrates; one of the great ‘cradles of civilization’ and the largest river system in southwest Asia [2,3]. A rare aquatic landscape in a desert milieu, the marshlands are home to ancient communities rooted in the dawn of human history [4]. They also provide habitat for important populations of wildlife, including endemic and endangered species. The key role played by the marshlands in the inter-continental flyway of migratory birds, and in supporting coastal fisheries endows them with a truly global dimension [5]. For these reasons, the Mesopotamian marshlands (called Al-Ahwar in Arabic) have long been recognized to constitute one of the world’s most significant wetlands and an exceptional natural heritage of the Earth.

Modern water works and associated agricultural schemes, however, have led to extensive environmental changes in the Mesopotamian marshlands. These changes have not only restructured human activities, but also have drastically transformed the landscape and hydrology of the river system itself by dams and drainage projects as well as deliberate desiccation during the eighties and nineties of the last century [6].

Al-Hammar Marsh situated south of the Euphrates River (30 45'-30º 59' N, 46º 25'-47º 15' E) has an area range from 2800 km^2 of contiguous permanent marsh and lake to a total area of over 4500 km^2 during periods of seasonal and temporary inundation [7]. Fed primarily by the Euphrates River, Al-Hammar Marsh drains into Shatt Al-Arab River. A considerable amount of water from the Tigris River, overflowing from the Central Marshes, also nourishes Al-Hammar Marsh. Groundwater recharge is another likely source of replenishment [7]. Being desiccated for more than a decade, Al-Hammar Marsh had recovered almost 51% of its former area in 2005 after a policy initiated to restore the marshes again in 2003 [8].

Many studies have performed an environmental assessment of the Mesopotamian marshes after the restoration period (i.e. after 2003) and reported considerable contamination levels [9-12; and 7]. However, few studies have applied new tools to analyze the large amount of data collected during the restoration period to investigate the possible sources of contamination in marshes. Therefore it becomes very important to systematically study the water quality status of Al-Hammar Marsh. Specific research questions addressed here are: What are the level and distribution of major and trace elements in Al-Hammar Marsh? What are the possible sources of contamination? And what are the seasonal variations in water quality? With this work as a background, a more comprehensive picture of these vast wetland resources should emerge which is not only essential to safeguard the lifeblood of millions of human beings, but also to sustain the health and productive potential of plants, wildlife, and natural systems.

Methods

Water samples were collected in July and August 2006 where water levels are the lowest (dry season) and January and February 2007 where water levels are the highest (wet season) from 4 stations Figure-1. Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Water Temperature (WT), turbidity, and pH of the water samples were measured on site. Biochemical Oxygen Demand (BOD) measurement required taking two water samples at each station. One is tested immediately for dissolved oxygen, and the second is incubated in the dark at 20° C for 5 days and then tested for the amount of dissolved oxygen remaining. The difference in oxygen levels between the first test and the second test, in part per million (ppm), is the amount of BOD. Water samples were transferred to the laboratory and divided into aliquots for major elements and heavy metals analyses. The samples were kept in polyethylene bottles that were filtered through 200 µm and acidified with suprapur HNO_3 (pH) for heavy metals measurement, and the other unfiltered samples collected in polyethylene bottles for measuring major contents of anions and cations. ICP-MS (Inductively Coupled Plasma Mass Spectro-

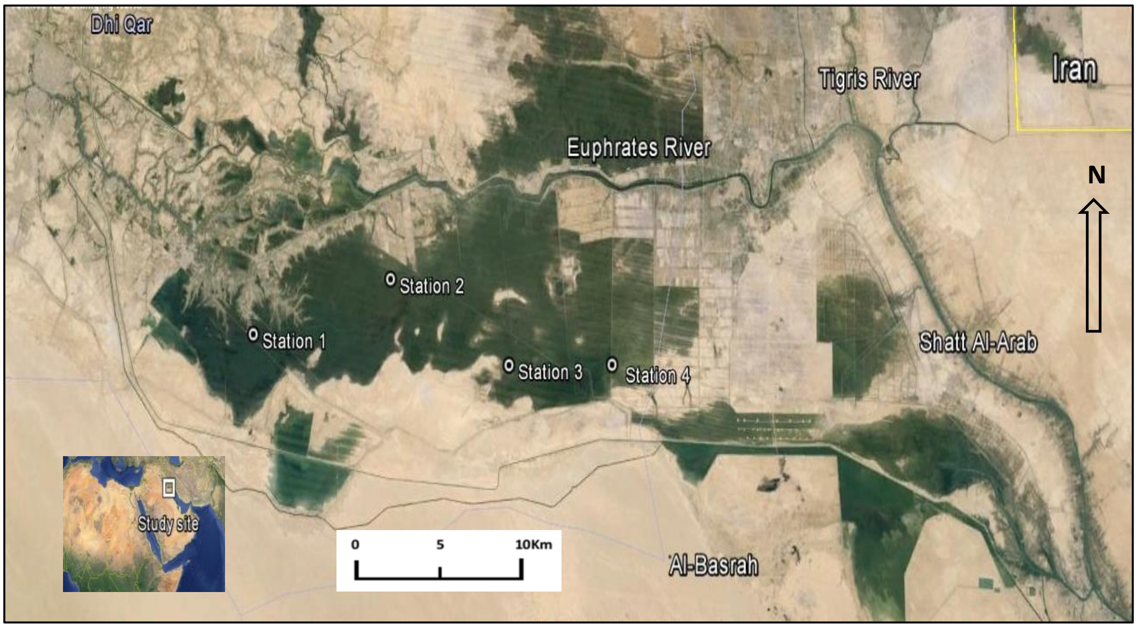


Figure1- Study site and sampling locations

metry) is used to measure heavy metals concentrations in water samples. All the parts of ICP-MS are under software control, provided by the ELAN software on all perkinElmer SCIEX ICP-MS instrument. Metrohm device was used to measure the major contents of anions and cations.

The Water Quality Index that has been adopted by Canadian Council of Ministers of the Environment [1] was used in the current study to provide a tool for simplifying the reporting of water quality data. There are three factors in the index, each of which has been scaled to range between 0 and 100. The values of the three measures of variance from selected objectives for water quality are combined to create a vector in an imaginary ‘objective exceedance’ space. The length of the vector is then scaled to range between 0 and 100, and subtracted from 100 to produce an index which is 0 or close to 0 for very poor water quality, and close to 100 for excellent water quality. The three factors are: First, Factor 1 (scope) represents the extent of water quality guideline non-compliance over the time period of interest:

$$F1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) X\ 100 \ldots\ldots\ldots\ldots (1)$$

Table 1- Physical and chemical water quality parameters of Al-Hammar Marsh (July and August 2006; January and February 2007) for 4 stations

Parameter	Station															
	1				2				3				4			
	JUL	AUG	JAN	FEB	JUL	AUG	JAN	FEB	JUL	AUG	JAN	FEB	JUL	AUG	JAN	FEB
WT (˚C)	27.9	20.8	13.5	22.2	27.5	23.6	13.8	21.8	29.1	24.3	13.8	20.5	30.3	23.5	14.7	21.5
pH	7.5	7.4	8.5	7.8	7.65	7.47	8.8	8.04	7.6	7.7	8.2	7.9	7.47	7.6	8.15	7.8
Turbidity	9.4	4.7	4.09	4.8	6.05	4.39	4.9	4.58	8.3	12.1	12.9	15.1	18.3	19.2	9.08	13.5
TDS (ppm)	2311	1463	1770	1382	2840	1886	2056	1230	2296	1503	1921	2438	2517	1422	1908	2264
Na (ppm)	532.0	466.0	452.0	422.0	708.0	584.0	476.0	411.0	543.0	501.0	478.0	489.0	556.0	421.0	432.0	499.0
Ca (ppm)	139.9	148.0	122.4	72.7	130.8	189.4	144.3	56.0	140.6	152.6	121.8	97.9	140.4	145.5	79.0	100.5
Mg (ppm)	130.3	107.9	94.4	55.5	150.5	149.5	102.1	42.0	112.4	96.9	104.2	46.0	112.2	96.1	138.2	54.1
Cl (ppm)	719.4	544.6	532.2	508.6	1134.3	815.0	579.0	484.4	849.8	601.6	696.1	802.6	802.3	483.4	577.9	755.3
SO4 (ppm)	726.5	808.0	414.4	524.5	731.7	971.6	512.8	439.3	606.7	834.2	530.2	473.5	619.8	823.0	410.2	390.7
Cd (ppm)	0.19	-	0.15	-	0.21	-	0.18	-	0.31	-	0.24	-	0.44	-	0.33	-
Pb (ppm)	5.01	-	4.39	-	5.5	-	5.04	-	7.1	-	6.9	-	8.8	-	7.87	-
Co (ppm)	1.52	-	1.46	-	3.1	-	2.58	-	1.39	-	1.26	-	3.92	-	3.46	-
Zn (ppm)	4	-	3.67	-	4.4	-	4.13	-	5.9	-	5.5	-	6.6	-	5.49	-
Ni (ppm)	1.1	-	1.08	-	1.25	-	1.09	-	0.82	-	0.55	-	1.62	-	1.59	-
DO (ppm)	4.90	7.00	6.90	4.70	3.49	5.18	7.20	5.20	5.50	6.70	9.20	6.70	7.60	7.50	10.06	6.60
BOD(ppm)	1.7	1.9	3.55	12	1.84	2.21	13.93	14.16	3.4	0.99	6.1	4.5	5.94	1.7	6.3	4.8

Where variables refer to water quality variables with objectives that were tested during the time period for the index calculation. Second, Factor 2 (frequency) represents the percentage of individual tests that do not meet objectives (failed tests):

$$F2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right) X\ 100 \ldots\ldots\ldots\ldots (2)$$

Third, Factor 3 (amplitude) represents the amount by which failed test values do not meet their objectives. F3 is calculated in three steps.

(i)The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows. When the test value must not exceed the objective:

$$\text{excursion}_i = \left(\frac{\text{Failed Test Value}_i}{\text{Objective}_j}\right)-1 \ldots\ldots\ldots\ldots \quad (3a)$$

For the cases in which the test value must not fall below the objective:

$$\text{excursion}_i = \left(\frac{\text{Objective}_j}{\text{Failed Test Value}_i}\right)-1 \ldots\ldots\ldots\ldots \quad (3b)$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or nse, is calculated as:

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{number of tests}} \ldots\ldots\ldots\ldots \qquad (4)$$

iii) F3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100:

$$F3 = \left(\frac{\text{nse}}{0.01\text{nse}+0.01}\right) \ldots\ldots\ldots \ldots \qquad (5)$$

The CCME WQI is then calculated as:

$$\text{CCMEWQI} = 100 - \left(\frac{\sqrt{F1^2+F2^2+F3^2}}{1.732}\right) \ldots\ldots\ldots \quad (6)$$

Next, Agglomerative Hierarchal Cluster Analysis (AHCA) was performed using JMP 8.0 (SAS System) to determine the sources of major elements as well as heavy metals. After standardizing the data, I conducted AHCA by constructing a dendrogram that displays the cohesiveness and correlations among the variables [13]. Clustering begins by finding the two samples that are most similar, based on the distance matrix, and merging them into a single group. This procedure of combining two samples and merging their characteristics is repeated until all the samples have been joined into a single large cluster [14].

Furthermore, physical and chemical water parameters (i.e. pH, turbidity, DO, BOD, TDS, Ca, Mg, Na, Cl, SO_4, Cd, Pb, Co, Zn, and Ni) were compared in dry and wet seasons across our study sites in order to examine the seasonal variations in water quality parameters.

RESULTS

The data show that the water parameters of concern (i.e. exceed the objectives) are WT, DO, TDS, Mg, Cl, and SO_4 as they tend to consistently exceed the objectives. Ca concentration is out of the objectives in one occasion only. However, pH tends to fall within objectives range (Table-2). By applying the equations described above the values of F1, F2, nse, and F3 were 90, 53.75, 0.241, 19.41 respectively (Table-2; bolded values represent variables not meeting the objectives). Once the factors have been obtained, the index itself could be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors. Accordingly, the final WQI value was calculated to be 38.45, which reflects threatened or impaired water quality and conditions usually depart from natural or desirable levels*.

AHCA highlighted 5 specific element response patterns (R1, R2, R3, R4, and R5) (Figure- 2). The degree of relationship between clusters is represented by the distance of the centroid of one cluster to another, where clusters with smaller or shorter distances between them are more similar to each other than clusters with larger or longer distances between. Here, cluster R4 has the shortest distance (4.08), and highest similarity to cluster R5, whereas cluster R1 is the least similar and has the greatest distance to R4 (9.19) Figure-2.

Seasonal variations analyses revealed that Ca, Mg, Na, Cl, and SO_4 have relatively low concentrations in wet season and high concentrations in dry season in all stations. Ca concentrations range from 56.00 ppm in station 2 (February) to 189.40 ppm in station 2 (August) with an average level of 123.86 ppm. Mg concentrations range from 42.00 ppm in station 2 (February) to 150.50 ppm in station 2 (July) with an average level of 99.52 ppm. Na concentrations range from 411.00 ppm in station 2 (February) to 708.00 ppm in station 2 (July) with an average level of 498.12 ppm. Cl concentrations range from 484.40 ppm in station 2 (February) to 1134.30 ppm in station 2 (July) with an average level of 680.40 ppm. SO_4 concentrations range from 390.70 ppm in station 4 (February) to 971.60 ppm in station 2 (August) with an average level of 613.56 ppm Table-1, Figure- 3. Similarly, heavy metals (Cd, Pb, Co, Zn, and Ni) tend to have their highest concentrations in dry season (0.44, 8.8, 3.92, 6.6, and 1.62 ppm) respectively and exhibit lowest concentrations in wet season (0.15, 4.39, 1.26, 3.67, and 0.55 ppm) respectively Table-1, Figure-3. TDS displays low values in wet season and higher levels in dry season in all stations with an average value of 1950.4 ppm Table-1, Figure-3. In contrast, DO, BOD and pH exhibit low values in dry season and higher ones in wet season Table-1, Figure-3.

DISCUSSION

The CCME WQI value of 38.45 indicates that the conditions of the marsh are still often departing from natural or desirable levels; the marsh simply has not recovered yet and remained in poor conditions in respect to the parameters under consideration in this paper. The low WQI value obtained can be attributed to the considerable degradation of marshlands throughout the deliberately drying process which took more than a decade as this process reflected its effects on the physical and chemical properties of the marshlands. The findings are consistent with other studies [eg. 4] who noted that some water chemistry parameters of Al-Hammar Marsh, when compared with historical surveys completed before drainage [15-18], revealed high increases in TDS (140 %), Na (170 %), Mg (158 %), Ca (240 %), and Cl (160 %) during the past 20 years. This considerable increase in major ions is probably related to a rise in salinity in the Euphrates River and to increased flux into the water column of ions concentrated in the soil after more than a decade of drainage and evaporation [7].

Elements clustering in R1 (Mg, Ca, and SO_4) indicate weathering of sulfate minerals. TDS, Cl, and Na that clustered in R2 are associated with weathering of chloride minerals. Chloride in turn can contribute to high TDS concentration as it is one of the most common chemical constituents of TDS [19]. pH, BOD and DO clustered together in R3 as pH can affect the solubility of nutrients and metal compounds and by affecting the solubility, it can change the amount of nutrients available for plant growth. If too many nutrients are available, aquatic plants can grow out of control. When these plants decompose, they can deplete the oxygen of the water [20]. BOD, on the other hand, directly affects the amount of DO as the greater the BOD, the more rapidly oxygen is depleted. This means less oxygen is available to higher forms of aquatic life [21].

Turbidity, Cd, Pb, and Zn that clustered in R4 are associated with anthropogenic sourcing (i.e. residential, industrial, commercial and road land uses). [22-27] found that Cd, Zn, and Pb are mainly of anthropogenic sources. Furthermore, Cd and Zn appear to have the same sources (brake lining

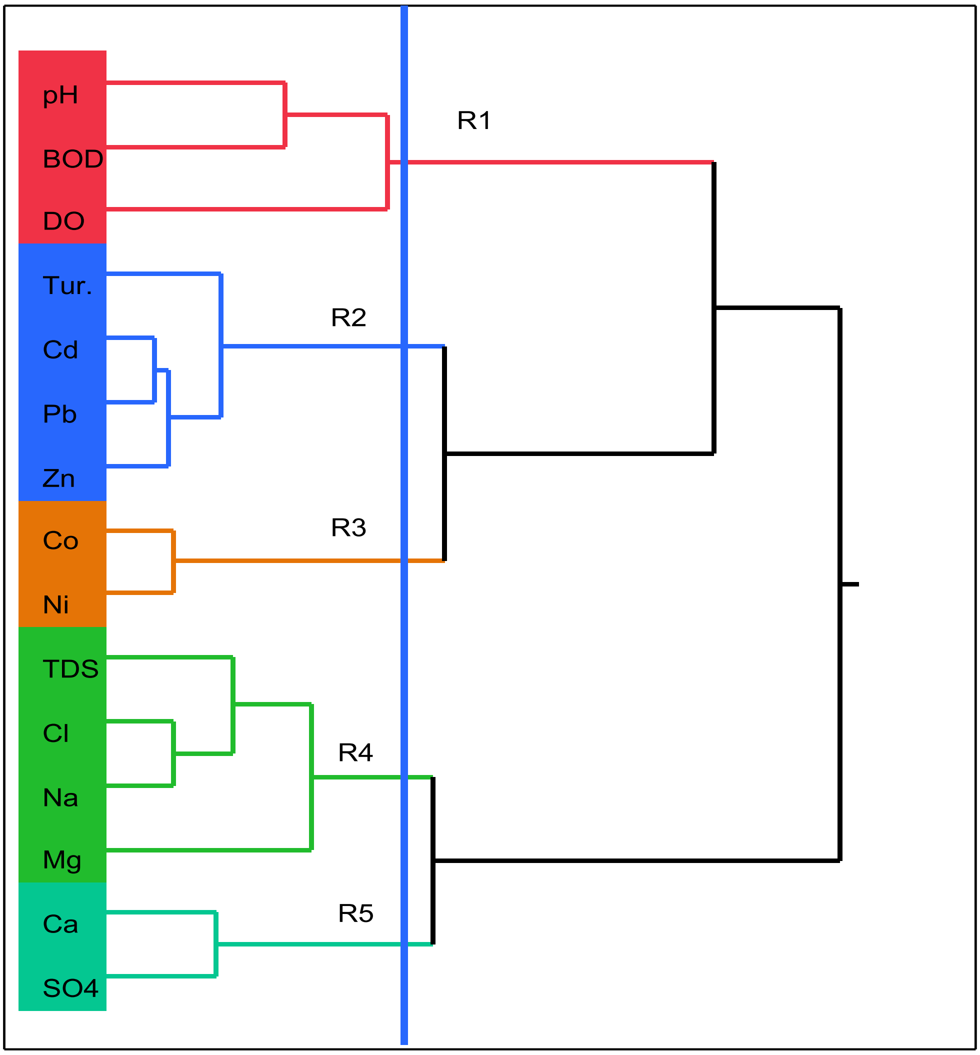
* According to CCME, 2001: WQI value 95-100 represents excellent water quality
WQI value 80-94 represents good water quality.
WQI value 65-79 represents fair water quality
WQI value 45-64 represents marginal water quality
WQI value 0-44 represents poor water quality

Table 2-Physical and chemical properties of water in Al-Hammar Marsh during 2006-2007 as compared to the historical objectives. Bolded values represent variables not meeting the objectives.

	WT (^oC)	pH	DO ppm	TDS ppm	Ca ppm	Mg ppm	Cl ppm	SO_4 ppm
	13.5	8.5	6.91	**1770**	122.4	94.4	**532.2**	414.4
	22.2	7.8	**4.7**	1382	72.7	55.5	**508.6**	**524.5**
	27.9	7.5	**4.9**	**2311**	139.9	**130.3**	**719.4**	**726.5**
	20.8	7.4	**7.0**	1413	148.0	**107.9**	**544.6**	**808.0**
	13.88	8.8	7.2	**2056**	144.3	**102.1**	**579.0**	**512.8**
	21.8	8.04	**5.2**	1230	56.0	42.0	**484.4**	439.3
	27.5	7.65	**3.49**	**2840**	130.8	**150.5**	**1134.3**	**731.7**
	23.6	7.47	**5.18**	**1886**	**189.4**	**149.5**	**815.0**	**971.6**
	13.8	8.2	9.2	**1921**	121.8	**104.2**	**696.1**	**530.2**
	20.5	7.9	**6.7**	**2438**	97.9	46.0	**802.6**	473.5
	29.1	7.6	**5.5**	**2296**	140.6	**112.4**	**849.8**	**606.7**
	24.3	7.7	**6.7**	**1503**	152.6	**96.9**	**601.6**	**834.2**
	14.7	8.15	10.06	**1908**	79.0	**138.2**	**577.9**	410.2
	21.5	7.8	**6.6**	**2264**	100.5	54.1	**755.3**	390.7
	30.3	7.47	7.6	**2517**	140.4	**112.2**	**802.3**	**619.8**
	23.5	7.6	7.5	1422	145.5	**96.1**	**483.4**	**823.0**
Objectives	22.67	7.1-8.3	6.9	1448	179	95	364	502

abrasion, tire abrasion, roof runoff, motorway abrasion, pesticides, plumping, and cosmetics products) [28], therefore it is not surprising that they clustered together in the present study. Furthermore, high Cd, Pb, and Zn concentrations in the present study can be attributed to the suspended solids transported in surface water runoff to the wetlands [29], and that, in turn, can promote high turbidity levels. Our data are consistent with [30] who recorded high concentration of Cd, Zn and Pb in Iraqi marshes and [31] who recorded high concentration of Zn and Pb in the Wolfe Glade and Great marshes in Delaware, US and assigned that to the anthropogenic sources of these solutes that are ultimately trapped into these marshes. Co and Ni that clustered in R5 indicate a possible geologic sourcing as is evidenced by the soil geochemistry of southern Iraq region which is known to be of high Co and Ni concentrations [32].

Water quality of Al-Hammar Marsh is affected by natural seasonal processes such as evaporation and rainfall as well as biological activities. Dry season where evaporation exceeds precipitation exhibited an increase in Ca (49 %), Mg (50 %), Na (18 %), Cl (21 %), SO_4 (66 %), and Cd (28 %). This increase can be attributed to the concentration by evaporation during the dry season compared to the dilution by rainfall during the wet season. In contrast, BOD and DO levels showed a considerable decrease (71 % and 25 % respectively) in dry season. The decrease in DO of water is due to its poor ability to hold oxygen at high temperature as a result of higher rate of microbial metabolism [33 and 34]. BOD levels were found comparatively higher in wet season [35-37] and that can be attributed to the higher organic waste load experienced in the rainy months. [38 and 39] also observed that BOD fluctuation between seasons may be attributed to additional organic matter introduced into the river as a result of runoff and soil erosion caused by continuous rainfall in the rainy season.

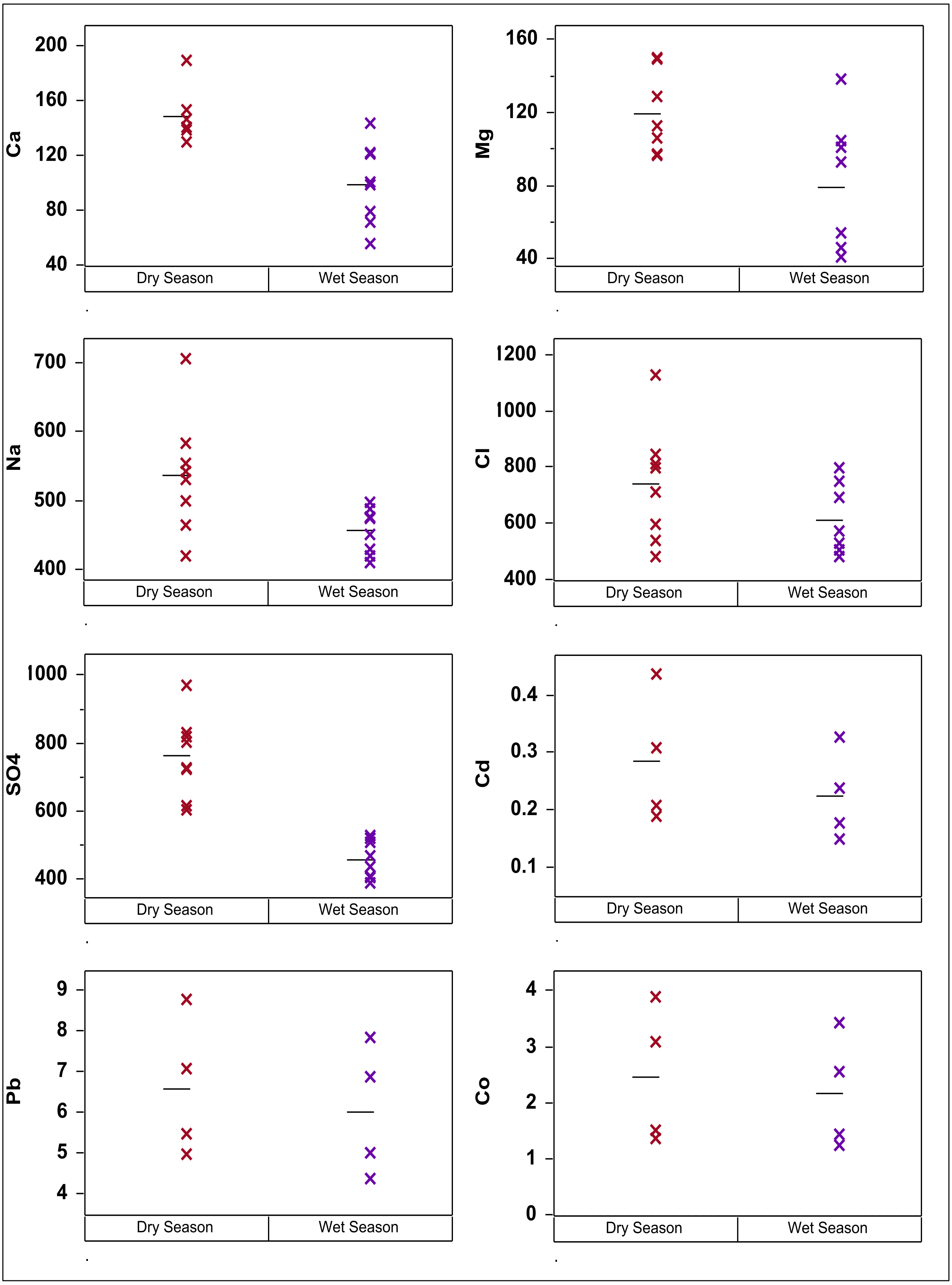


Joiner	Leader	Distance	Number of Clusters
Pb	Cd	0.583	14
Zn	Cd	0.788	13
Na	Cl	0.827	12
Ni	Co	0.839	11
SO4	Ca	1.372	10
Cd	Tur.	1.419	9
Cl	TDS	1.570	8
BOD	pH	2.227	7
Mg	TDS	2.554	6
DO	pH	3.517	5
Ca	TDS	4.087	4
Co	Tur.	4.244	3
Tur.	pH	7.628	2
TDS	pH	9.193	1

Figure 2- Dendrogram showing clustering of physical and chemical parameters using Ward Method

Conclusions

- The outcomes of application of the CCME WQI in the present study indicated poor water quality of Al-Hammar Marsh. The low WQI value obtained can be attributed to the considerable degradation of marshlands throughout the deliberately drying process which took more than a decade. Our results, thus, indicate that more efforts are needed to recover the area, particularly with regard to WT, DO, TDS, Mg, Cl, and SO_4 as they tend to consistently exceed the historical objectives. Therefore, one will not hesitate to state the urgent need to restore the area; plantation, increasing water flow, sustainable management, and firm policy are among the most needed measures to recover the marsh.
- Statistical analysis applied defined the possible sources of contaminants; while some solutes are of natural sources such as Mg, Ca, SO_4, TDS, Cl, and Na, others are of anthropogenic sources such as Cd, Pb, and Zn.
- Seasonal variations monitoring showed that dry season exhibited an increase in Ca, Mg, Na, Cl, SO_4, and Cd and this increase can be attributed to the concentration by evaporation during the dry season compared to the dilution by rainfall during the wet season. In contrast, BOD and DO levels showed a considerable decrease in dry season due to the poor water ability to hold oxygen at summer as a result of higher rate of microbial metabolism.
- The physical and chemical aspects of Al-Hammar Marsh water provide valuable indications of the overall health of the ecosystem of the marsh. The result obtained during this study can establish important background information and a baseline for further restoration work in the southern marshes of Iraq. Continuous monitoring and ecological studies can create main tools to follow up the restoration process and monitoring the successive improvement of the status of the area.


Ca
200
160
120
80
40
Dry Season
Wet Season
Mg
160
120
80
40
Dry Season
Wet Season
Na
700
600
500
400
Dry Season
Wet Season
Cl
1200
1000
800
600
400
Dry Season
Wet Season
SO4
1000
800
600
400
Dry Season
Wet Season
Cd
0.4
0.3
0.2
0.1
Dry Season
Wet Season
Pb
9
8
7
6
5
4
Dry Season
Wet Season
Co
4
3
2
1
0
Dry Season
Wet Season

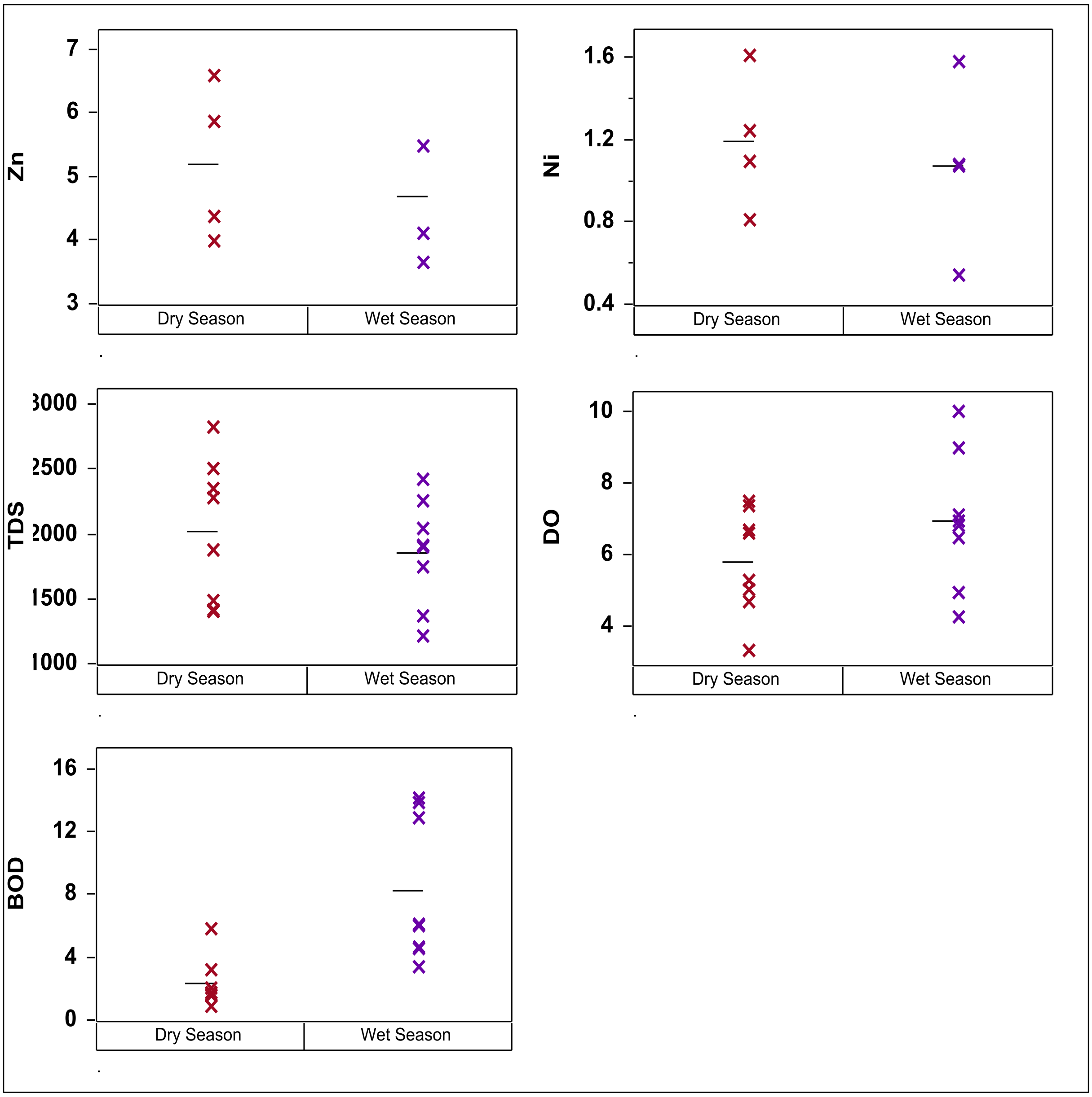


Figure 3- Solute concentrations in dry season (July and August) versus wet season (January and February). The horizontal short lines represent the mean concentration. Unites in part per million (ppm).

References

1. CCME, **2001**. Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, Technical Report. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg
2. Thesiger, W., **1964**. The Marsh Arabs. London: Penguin Classics, 256 pages
3. Nicholson, E. and Clark, P., **2003**. The Iraqi Marshlands: A Human and Environmental Study. London: Politico's Publications, p. 332
4. Richardson, C.J., Reiss, P., Hussain, N.A., Alwash A.J. and Pool, D.J., **2005**. The Restoration Potential of the Mesopotamian Marshes of Iraq. *Science*, New Series, Vol. 307, No. 5713, pp. 1307-1311
5. Maltby, E., **1994**. An Environmental and Ecological Study of the Marshlands of Mesopotamia. Draft Consultative Bulletin. Wetland Ecosystems Research Group, University of Exeter. Published by the AMAR Appeal Trust, London
6. Richardson, C., and Hussain, N., **2006**. Restoring the Garden of Eden: An ecological assessment of the marshes of Iraq. *Bioscience*, 56(6): 477-489

7. UNEP, **2001**. The Mesopotamian Marshlands: Demise of an Ecosystem Early Warning and Assessment. Technical Report, UNEP/DEWA/TR.01-3 Rev. 1 Division of Early Warning and Assessment United Nations Environment Programme Nairobi, Kenya

8. Al-Saboonchi, A., Mohamed, A.M., Alobaidy, A.M., Abid, H.S. and Maulood, B.K., **2011**. On the Current and Restoration Conditions of the Southern Iraqi Marshes: Application of the CCME WQI on East Hammar Marsh. Journal of Environmental Protection, 2, 316-322 doi:10.4236/jep.2011.23035

9. Abdul Jabbar, M.F., Al-Ma'amar, A.F. and Shehab, A.T., **2010**. Change detections in marsh areas, south Iraq, using remote sensing and GIS applications. *Iraqi Bulletin of Geology and Mining*, Vol.6, No.2, p 17- 39

10. Al-Saad, T.H., Al-Hello, M.A., Al-Taein S.M. and DouAbul A.A.Z., **2010**. Water quality of the Iraqi southern marshes. *Mesopot. J. Mar. Sci.*, 25 (2):188-204

11. Al-Mosewi, T.J., **2009**. Water Quality of Al-Hammar Marsh South Iraq. *Journal of Engineering*, Number 3, Volume 15, p 3999-4008

12. Salman, N.A., **2011**. Assessment of environmental toxicity in Iraqi Southern marshes using fish as bio-indicators. *EKOLOGIJA*, T.57. Nr. 1. P. 21–29

13. Aziz, N.M., Marina, B.A. and Qzar E.A., **2010**. The potential of some snails as bioindicator of trace metals level in East Hammar Marsh, South of Iraq. *Basrah Journal of Scienec*, Vol. 28(2):228-242, 2010

14. Yongming, H., Peixuan, D., Junji, C. and Posmentier, E.S., **2006**. Multivariate analysis of heavy metal contamination in urban dusts of Xian, Central China. *Sci. Total Environ.*, 355(1-3):176 – 186

15. Kaufman, L. and Rousseeuw, P.J., **1990**. Finding Groups in Data: *An Introduction to Cluster Analysis*. Wiley, New York, Print ISBN: 9780471878766, Online ISBN: 9780470316801, DOI: 10.1002/9780470316801, p. 342

16. Maulood, B.K., Hinton, G.C.F., Whitton, B.A. and Al-Saadi, H.A., **1981**. On the Algal Ecology of the Lowland Iraqi-Marshes. *Hydrobiologia*, Vol. 80, No. 3, pp. 269-276. doi:10.1007/BF00018367

17. Maulood, B.K., Hinton, G.C.F., Kamees, H.S., Saleh, F.A.K., Shaban, A.A. and AlShahwani, S.M.H., **1979**. An Ecological Survey of Some Aquatic Ecosystems in Southern Iraq. *Tropical Ecology*, 20(1): 27-40

18. Qassim, T.I., **1986**. Ecological Study on Benthic Algae of Some Area in Southern Iraqi Marshes. M.Sc. Thesis, College of Science, University of Basrah, 203 pp.

19. Banat, K.M., Howari, F.M., and Abdullah, M.B., **2005**. Mineralology and Hydrochemical Characteristics of the Late Marshes and Swamps of Hor Al-Hammar, Southern Iraq. *Journal of Arid Environment*, 65:400-419

20. Weiner E.R., **2000**. Applications of Environmental Chemistry: A Practical Guide for Environmental Professionals, LEWIS PUBLISHERS ISBN 1-56670-354-9 (alk. paper)

21. Bellos D., Sawidis T., and Tsekos I., **2004**. Nutrient chemistry of River Pinios (Thessalia, Greece) *Environment International*, Volume 30, Issue 1, Pages 105-115

22. Tanwar, K., and Mathur, J., **2016**. Analysis and Characterization of Industrial Waste Water, *International Journal of Civil Engineering*, Volume 3, Issue 7

23. Davis, A.P., Shokouhian, M. and Ni, S., **2001**. Loading estimates of lead, copper, cadmium, and zinc in urban runoff from specific sources. *Chemosphere*, 44, 997-1009

24. Gromaire, M.C., Garnaud, S., Saad, M. and Chebbo, G., **2001**. Contribution of different sources to the pollution of wet weather flows in combined sewers. *Water Research*, 35, 521-533

25. Pitt, R., Field, R., Lalor, M. and Brown, M., **1995**. Urban Stormwater Toxic Pollutants Assessment, Sources, and Treatability. *Water Environment Research*, 67, 260-275

26. Tiefenthaler, L.L., Stein, E.D. and Schiff, K.C., **2008**. Watershed and land use-based sources of trace metals in urban storm water. *Environmental Toxicology and Chemistry*, 27, 277-287

27. Van Metre, P.C. and Mahler, B.J., **2003**. The contribution of particles washed from rooftops to contaminant loading to urban streams. *Chemosphere*, 52, 1727-1741

28. Omu A., **2008**. Identification of the Sources of Heavy Metal in Urban Wastewater Centre for Environmental Policy. Imperial College London

29. Peltier, E.F., Webb, S.M. and Gaillard , J.F., **2003**. Zinc and lead sequestration in an impacted wetland system. *Advances in Environmental Research*, 8:103–112

30. Al-Tawash, B.S., Al-Lafta, H.S. and Merkel, B., **2013**. Preliminary Assessment of Shatt Al-Arab Riverine Environment, Basra Governorate, Southern Iraq. *Journal of Natural Science Research*, ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online),Vol. 3, No.13
31. Kim, G., Alleman, L.Y. and Church, T.M., **2004**. Accumulation records of radionuclides and trace metals in two contrasting Delaware salt marshes. *Marine Chemistry*, 87: 87-96
32. Khwedim, K.H., Al-Anssari, H.R. and Al- Bassam, K., **2009**. Study of distribution of some heavy metals in the soil of Basra city- south of Iraq. *Iraqi Journal of Science*, 50(4):533-542
33. Lewis , W.M., **2000**. Basis for the protection and Management of tropical Lakes. *Lakes Reserv. Res. Management*, 5: 35-48
34. Singh M. and Singh S.K., **2014**. Impact of Seasonal Variation on Physicochemical Parameters of Mansi Ganga, Radha and Shyam Kund, Mathura. *Microbiology*, Volume : 4 | Issue : 8
35. Joseph, K.O. and Srivastava, J.P., **1993**. Heavy Metal Load in Edible Oyster, Crassoskrea madrasensis (Fres ton) from the Ennore Estuary in Madras. *J. Environ. Biol.*, 14(2):121-127
36. Clark, R.B., **1986**. *Marine pollution*. 3rd ed Oxford Science Press Publication, Calendon. B, pp. 433-443
37. Ezekiel, E.N., Hart, A.I. and Abowei, J.F., **2011**. The Physical and Chemical Condition of Sombreiro River, Niger Delta, Nigeria. *Research Journal of Environmental and Earth Sciences*, 3(4): 327-340
38. Odokuma, L.O. and Okpokwasili, G.C., **1996**. Seasonal influences on the organic pollution monitoring of the New Calabar River, Nigeria. *Environ. Monitor. Assess.*, 45(1):43-56
39. Anhwange, B.A., Agbaji, E.B. and Gimba E.C., **2012**. Impact Assessment of Human Activities and Seasonal Variation on River Benue, within Makurdi Metropolis. *International Journal of Science and Technology*, Volume 2 No.5