A Mathematical Models to Assessment Pollution of Water and Sediments of Auda Marsh

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Abstract
A study was carried out to investigate the quality of water and sediments of Auda marsh, Amara, southern Iraq. Used some mathematical models for assessment water and sediments quality. Values of Sodium Adsorption Ratio (SAR) ranged between 2.63 to 7.31 meq.l^{-1}. It was observed that all sites were good for irrigation (SAR<10). The mean concentration of metals (Fe, Pb, Zn and Cu) ranged between 1365-3735, 6.00-7.70, 4.50-10.50 and 4.15-8.15 mg.kg^{-1} respectively. Values of Enrichment Factor (EF) varied from 12.5 to 38.0, considered to be contaminated with that particular elements (EF>5). Values of Contamination Factor (CF) ranged from 0.037 to 0.385, this mean low contamination factor and low degree of contamination at all sites (Cd< 7). The calculated CFs were found to fall in the following sequence Pb>Cu>Fe>Zn. Values of Pollution Load Index (PLI) and Metal Pollution Index (MPI) were ranged between 0.095 to 0.145 and 583.21 to 1333.09 respectively. The lower values of PLI indicated that it is lied between perfection and only baseline levels of pollutant present (PLI=0-1), while MPI values indicated that it is a considerable contamination (MPI>2). Values of Geoaccumulation Index (Igeo) varied from -3.42 to -1.44, these indicated that unpolluted situation for all stations (Igeo<0). Metal enrichment index (SEF) values varied from 0.029 to 0.385 this indicated unpolluted stations (SEF<1).
Keywords: pollution, Auda marsh, contamination indices, water & sediment quality.

1. Introduction

The Iraqi marshes are freshwater wetland of unique ecosystem. The biome mostly include plants, and many animals, which inhabit this rich environment (Al-Saad *et al.,* 2010). The Iraqi marshlands are one of the finest and most extensive natural wetland ecosystems in Europe and western Asia (Evans, et al., 2002). About 85% of the Mesopotamian Marshlands have been lost mainly as a result of drainage and damming ((UNEP, 2002).Auda marsh consider one of the important marshes in Iraq, lies in Amara city about 60 km to the south of city Centre, its part of the Al-Hawizeh marsh.

Humans have always depended on aquatic systems for drinking, food and materials as well as recreational and commercial purposes such as fishing and tourism (Phuong *et al.,* 1998). Pollution of natural environment especially aquatic systems by different pollutants such as heavy metals is a worldwide problem because these metals are indestructible and most of them have toxic effects and will give adverse effect to the aquatic organisms and human (Elias *et al*., 2011).

Heavy metals in sediments and aquatic systems have natural and anthropogenic origin, distribution and accumulation of metals are influenced by mineralogical composition, adsorption, sediment texture, desorption process and oxidation-reduction state and physical transport (Abdul Aziz *et al*., 2010 ; Hasan *et al*., 2010).

Trace amounts of heavy metals can be found in fresh waters from different sources such as weathering of rocks resulting into geo-chemical recycling of heavy metal elements in these ecosystems (Zvinowanda *et al*., 2009). Marsh sediments are normally the final pathway of both natural and anthropogenic components derived to the environment. Quality of sediments is a good indicator of pollution in water (Praveena *et al*., 2007).

The marshes of the middle and lower basin of the Tigris and Euphrates River in Iraq are the most extensive wetland ecosystems in the middle East. These to great rivers have created a vast network of wetlands, which is known as Mesopotamian marshes, covering about 15,000 to 20,000 km^2 (Al-Saad *et al*., 2010).

Water quality is a good expression used to assessment of water for drinking, industry, agriculture etc. Water is the major source for irrigation in Iraq. The quality of water depend on the nature composition of the soil, depth of water table, topography, climate, etc. (Anant, 2012).

The present work aimed to investigate the pollutants levels including the accumulation of some heavy metals (Iron, lead, Zinc and Cupper) in sediments of Auda marsh as well as to assessment of water quality for agricultural purposes.

Materials and Methods

Water sampling:

Water sampling were collected monthly, during summer season (June, July and August), 2015. This study was carried out involving 5 fixed stations as shown in Fig.(1) in Auda marsh, southern Iraq.

Fifteen parameters were measured such as (pH, EC, TDS, TSS, T.H, Alkalinity, BOD, Ca, Mg, Na, K, Cl, NO_3, SO_4, and PO_4). All samples were taken from the surface layer (10 cm), all these parameters were analyzed according to APHA (1995).

For assessment of water quality for agricultural purposes, used the express Sodium Adsorption Ratio (SAR).

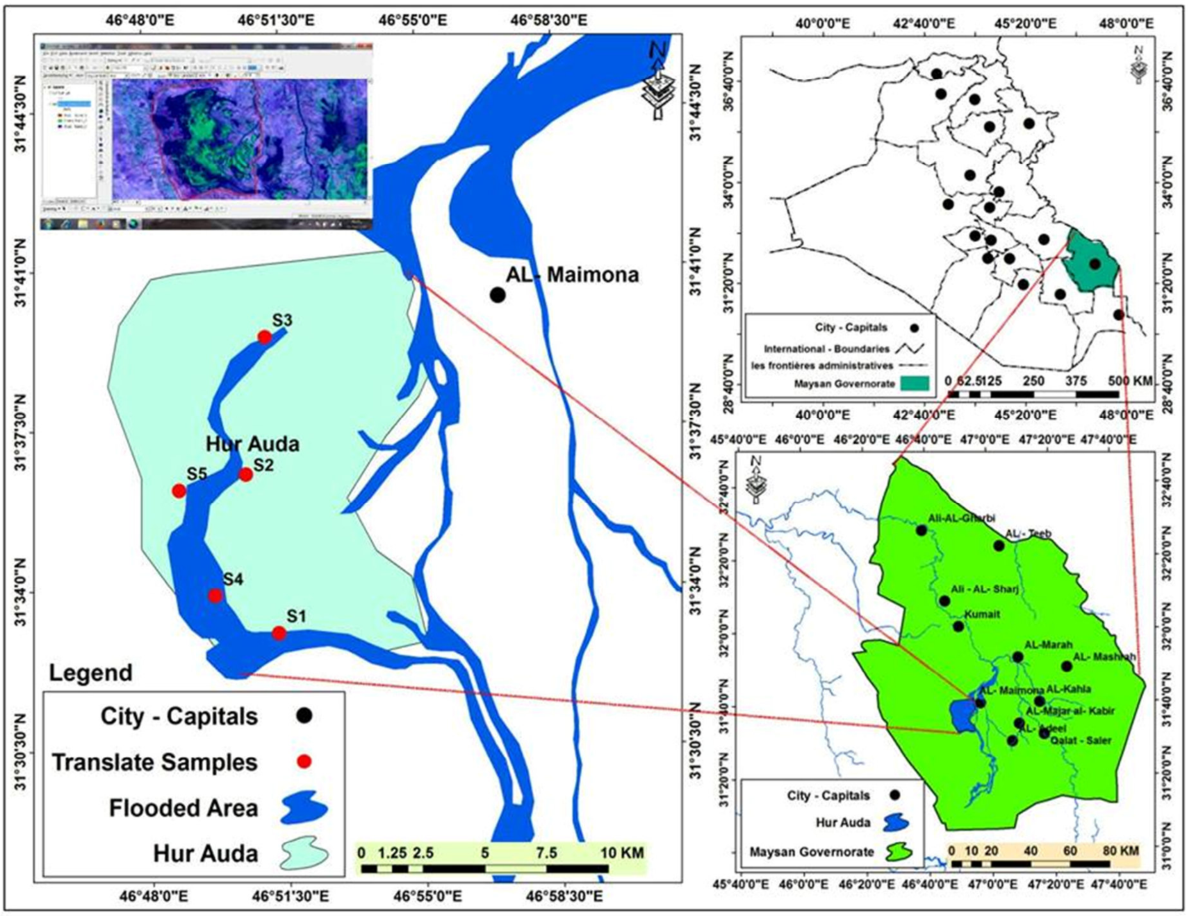

Figure 1. Mapping of study area with the location of sampling points

Sediments sampling

Five sediment samples were collected at the same period (summer season), 2015. Surface sediment samples were taken at a depth of 0-10 cm along the bank which was quickly packed in air tight polythene bags. Sub-samples of the material were oven dried at 45ºC for 48 hours and ground , Then sieved by a sieve (2 mm). The sampling were then stored in a polythene container ready for digestion and analysis (Harikumar and Jisha, 2010) .

Analysis of sediment samples

The pH of the sediments was measured in 1:1 sediment to water ratio (Conyers and Davey, 1988). Electrical conductivity was measured in saturation extract of sediments using an EC meter and organic matter was measured according to Page et al., (1982). Texture of sediments was measured by used the Pipette method (Black, 1965).

The degree of contamination in the sediments is determined with the help of some parameters to assess trace elements concentration (Fe, Pb, Zn and Cu) according to Page et al., (1982), is mathematically expressed as :

Determination of enrichment factor:

$\mathbf{EF = (Ci / Fe)_{sample} / (Ci / Fe)_{background}}$

Where, Ci is the concentration of element i. The background value is that of average shale (Turekian and Wedepohl, 1961).

Determination of contamination factor and degree of contamination:

CF = metal concentration in sediments / Background value of the metal (Hakanson et al., 1980).

$\mathbf{C_d = \sum C_f}$ Where, C_f is the contamination factor. i=1

Determination of pollution load index:

$$PLI= [C_{f1} * C_{f2} * \ldots\ldots * C_{fn}]^{1/n}$$

Where, n is the number of metals (four in this study) and C_f is the contamination factor (Tomilson et al., 1980).

Determination of metal pollution index:

$$MPI= (M_1, M_2, M_3, \ldots\ldots M_n)^{1/n}$$

Where, Mn is the concentration of metal n expressed in mg/kg of dry weight (Usero et al., 1996).

Determination of the geoaccumulation index:

$$Igeo= \log2 (C_n / 1.5 \times B_n)$$

Where, C_n is the measured concentration of element n in the sediment and B is the geochemical background value in average shale of element n and 1.5 is the background matrix correction due to Terrigenous effects (Muller, 1969).

Determination of metal enrichment index:

$$SEF= Ci – Co / Co$$

Where, Ci is the total concentration of each metal i measured in the sediment; Co the heavy metal background level established for the ecosystem studied (Riba, et al., 2002a).

Results and Discussion

The analyzed physic-chemical parameters of water of the Auda marsh are shown in Table 1. The pH values ranged between 8.11 to 8.34 which was in the basic side and its within the recommended ranged (USEPA, 1989). EC values were ranged from 750 to 3220 µmhos.cm^{-1}. Mean values of the alkalinity and total hardness were 100.56 mg $CaCO_3$.L^{-1} and 766.80 mg $CaCO_3$.L^{-1} respectively. High values of alkalinity and total hardness may be attributed to the nature of mineral structure of sediments or parent material (Al-Manssory et al., 2004), and precipitate of carbonates because the high temperature (Bhuvanoswaran *et al*., 1999).

Table 1. Physic-chemical properties of surface water of Auda marsh

properties	locations							
	1	2	3	4	5	Min.	Max.	Mean
pH	8.16	8.18	8.34	8.11	8.22	8.11	8.34	8.20
EC	750	960	3220	770	1750	750	3220	3.20
TDS	1840	2300	963	967	900	900	2300	100.56
TSS	9.3	3.5	9.3	673	0.5	0.5	673	613.20
BOD	1.7	1.8	2.2	6.9	3.4	1.7	6.9	635.20
TH	1080	1440	414	540	360	360	1440	0.119
Alkalinity	105	130	92	117	58.8	58.8	130	4.31
Na	500	637	154.2	201	114.5	114.5	637	766.80
K	7.19	8.56	4.02	5.23	3.93	3.93	8.56	131.02
Ca	180	237.5	79.2	72	86.4	72	237.5	104.92
Mg	150.5	202.1	51.6	86	34.4	34.4	202.1	321.34
Cl	946	1196	301	332	291	291	1196	5.78
NO_3	6.88	6.02	2.87	2.96	2.83	2.83	6.88	17.98
SO_4	1012	1262	328	232	342	232	1262	1394.00
PO_4	0.097	0.104	0.159	0.201	0.036	0.036	0.201	1490.00

* all values in mg.l^{-1} except EC in µmhos.cm^{-1}

Mean values of TDS,TSS and BOD were 1394.00, 17.98 and 3.20 mg.l^{-1} respectively. The mean concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-} and PO_4^{2-} were 321.34, 5.78, 131.02, 104.92, 613.20, 4.31, 635.20 and 0.119 mg.l^{-1} respectively. High concentrations in some of ions may be attributed to the anthropogenic effects as well as the high temperature in sampling period (summer season) which due to the increasing in evaporation (Al-Sabah, 2013).

For assessment water quality of Auda marsh for agricultural purposes, used the express Sodium Adsorption Ratio (SAR), which ranged between 2.63 meq.l^{-1} in site 5 to 7.31 meq.l^{-1} in site 2 (Table 2). The water having SAR <10 is good for irrigation. It was observed that all the sites were good for irrigation (USEPA, 1974 ; Al-Sabah, 2013).

Table 2. SAR values for the water of Auda marsh and its classification (USEPA,1974)

location	EC µmhos.cm^{-1}	SAR meq.l^{-1}	Class
1	750	6.63	C2S1
2	960	7.31	C3S2
3	3220	3.30	C4S1
4	770	3.77	C3S1
5	1750	2.63	C3S1
Min.	750	2.63	
Max.	3220	7.31	
Mean	1490	4.73	

From the results shown in Table 3, the mean values of pH, EC and organic matter (OM) of sediments samples were 7.75, 1490 µmhos.cm^{-1} and 3.16% respectively. High percentage of organic matter can be attributed to the high amounts of plants residues and animals in marshes environment which add high amounts of organic matter to the sediments after decomposition as well as the nature off texture of these sediments (Molisani, 1999).

Table 3. Physio-chemical analyses of study sediments

locations	pH	EC µmhos.cm^{-1}	O.M %	Sand	silt	clay	texture
				gm.kg^{-1}			
1	7.64	2750	3.1	180	430	390	Silty Clay
2	7.67	3250	2.9	179	473	348	Silty Clay
3	7.94	2800	3.3	126	447	327	Silty Clay
4	7.64	3100	3.1	111	461	328	Silty Clay
5	7.87	3300	3.4	191	435	356	Silty Clay
Min.	7.64	2750	2.9	111	430	348	
Max.	7.94	3300	3.4	191	473	428	
Mean	7.75	3040	3.16	157.4	389.8	452.8	

Assessment of Metal Contamination :

Assessment according to Enrichment Factor (EF)

The mean concentration of heavy metals were ranged between 5.79 mg.kg^{-1} for Cu to 2465 mg.kg^{-1} for Fe (Table 4).

Table 4. Concentrations of heavy metals in sediments

locations	Fe	Pb	Zn	Cu
	ug.gm^{-1}			
1	1365	7.50	8.00	4.15
2	1730	6.00	7.50	4.40
3	2160	7.10	5.00	5.00
4	3335	7.00	10.5	7.25
5	3735	7.70	4.50	8.15
Min.	1365	6.00	4.50	4.15
Max.	3735	7.70	10.5	8.15
Mean	2465	7.06	7.10	5.79

The enrichment factor is a convenient measure of geochemical trends and is used for making comparisons between areas . A value of $0.5 \leq EF \leq 1.5$ suggest that traces of metals may be due to crustal materials or natural weathering processes. According to Harikumar and Jisha, 2010, EF values greater than 1.5 have such heavy metals derived from other sources suggesting environmental contamination by those particular heavy metals.

From the results (Table 5) the EF values ranged from 14.00 to 38.00, these values greater than 5 are considered to be contaminated with that particular element (Khan *et al*., 1992).

Table 5. Enrichment Factor (EF) of heavy metals with respect to each location and classification (Sutherland, 2000)

Heavy metal	locations				
	1	2	3	4	5
Fe	34.22	26.99	21.62	14.00	12.50
Pb	34.31	28.83	21.86	14.92	12.87
Zn	34.47	27.06	23.10	14.27	13.33
Cu	38.00	28.22	23.10	14.46	12.82
EF indices	Degree of Enrichment			Heavy metal	
EF ≤ 1	background concentration				
EF 1-2	depletion to minimal enrichment				
EF 2-5	moderate enrichment				
EF 5-20	significant enrichment			Fe, Pb, Zn, Cu	
EF 20-40	very high enrichment			Fe, Pb, Zn, Cu	
EF > 40	extremely high enrichment				

Assessment According to Contamination Factor (FC) and Degree of Contamination (Cd)

The contamination factor (CF) and the degree of contamination (Cd) are used to determined the contamination status of sediment in this study. CF values ranged from 0.037 to 0.385 (Table 6). All values were less than 1, this mean low contamination factor (Harikumar *et al*., 2009). The degree of contamination (Cd) was defined as the sum of all contamination factors and these values were given in Table 5. Values of Cd ranged from 0.514 to 0.693 , this mean low degree of contamination at all sites Cd < 7 (Harikumar *et al*., 2009). The calculated CFs were found to fall in the following sequence :

Pb > Cu > Fe > Zn

Table 6. Contamination Factor (CF) of heavy metals in sediments and classes (Hakanson, 1980)

Heavy metal	locations				
	1	2	3	4	5
Fe	0.229	0.037	0.046	0.071	0.080
Pb	0.375	0.300	0.355	0.350	0.385
Zn	0.084	0.079	0.053	0.111	0.047
Cu	0.092	0.098	0.111	0.161	0.181
Degree of Contamination (Cd)	0.580	0.514	0.565	0.693	0.693
EF indices	Degree of Contamination			Heavy metal	
CF < 1	Low contamination			Fe, Pb, Zn, Cu	
1 ≥ CF ≤ 3	Moderate contamination				
3 ≥ CF ≤ 6	Considerable contamination				
CF > 6	Very high contamination				

Assessment According to Pollution Load Index (PLI) and Metal Pollution Index (MPI)

Values of PLI and MPI were ranged between 0.095 to 0.145 and 583.21 to 133.09 respectively (Table 7). The lower values of PLI indicates that it is lied between perfection and only baseline levels of pollutants present PLI= 0-1 (Tomilson et al., 1980). These results agree with many studies (praveena et al., 2007; Mohiuddin et al., 2010). Whereas the high values of MPI indicated that it is a considerable contamination for the previous four metal (MPI > 2) according to the classification of Goncalves et al., (1992).

Table 7. Values of Pollution Load Index (PLI) and Metal Pollution Index (MPI) for Auda marsh sediments

locations	Fe	Pb	Zn	Cu	PLI	MPI
	ug.gm^{-1} dry weight					
1	1365	7.50	8.00	4.15	0.095	583.21
2	1730	6.00	7.50	4.40	0.096	585.26
3	2160	7.10	5.00	5.00	0.099	619.19
4	3335	7.00	10.5	7.25	0.145	1333.09
5	3735	7.70	4.50	8.15	0.127	1027.01
PLI indices	Pollution level					locations
0	Perfection					between
1	Only baseline levels of pollutants present					0 &1
> 1	Progressive deterioration of the site					

Assessment According to Geoaccumulation Index (Igeo)

The geoaccumulation index (Igeo), introduced by Muller (1969) for determining the extent of metal accumulation in sediments. The mean values of (Igeo) ranged from -3.42 to -1.44 (Table 8). These values according to the Muller scale (Table 9) indicated that unpolluted situation for all stations (Igeo < 0), these results agreed with study of (Ahdy and Khaled, 2009; Harikumar and Jisha, 2010).

Table 8. Values of Geoaccumulation index (Igeo) of heavy metals in sediments

locations	*Igeo*			
	Fe	*Pb*	*Zn*	*Cu*
1	*- 3.96*	*- 1.38*	*- 2.87*	*- 2.78*
2	*- 3.70*	*- 1.60*	*- 2.94*	*- 2.73*
3	*- 3.47*	*- 1.44*	*- 3.35*	*- 2.60*
4	*- 3.04*	*- 1.45*	*- 2.60*	*- 2.23*
5	*- 2.93*	*- 1.36*	*- 3.45*	*- 2.11*
mean	*- 3.42*	*- 1.44*	*- 3.04*	*- 2.49*

Table 9. Muller's classification for the Geoaccumulation index (Muller, 1979)

Igeo value	*Class*	*Quality of Sediments*
< 0	*0*	*Unpolluted*
0-1	*1*	*Unpolluted to moderately polluted*
1-2	*2*	*Moderately polluted*
2-3	*3*	*Moderately to strongly polluted*
3-4	*4*	*Strongly polluted*
4-5	*5*	*Strongly to very strongly*
> 6	*6*	*Very strongly polluted*

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