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EVALUATION OF WATER QUALITY OF DIYALA RIVER FOR IRRIGATION PURPOSES

Nahida H. Hamza
Civil Department Engineering - Diyala University
E-Mail: Nahida_mml@Yahoo.com
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ABSTRACT:- The study comprised suitability evaluation water of quality of Diyala river for irrigation uses. Four stations were selected along Diyala river which are Jalawlah station (DI2) before Jalawlah Bridge, Saadiyah station (DI3) before inter to Hamren Dam, Muqdadia station (DI4) after Diyala Dam, and Baqubah station (DI5) at Iron Bridge, besides wand river station in Khanaqin (DIW) Before Dam. Water samples were collected and analyzed for pH, electric conductivity (EC), TDS, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, HCO_3^{-}, CO_3^{2-}, SO_4^{2-}, Cl^{-}, and NO_3^{-} one sample monthly were taken from these stations during January to December 2010. In addition, to classifying water quality and evaluation its suitability for irrigation purposes, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP) and Residual Sodium Carbonate (RSC) were calculated following standard equations and found experimentally as (0.985), (20.027), (-4.404) respectively. According to the EC and SAR plotted on the US salinity diagram, it is illustrated that water samples of DIW and DI5 fall in the class of C3-S1 indicating high salinity with low sodium water, which can be used for irrigation on almost all types of soil with only a minimum risk of exchangeable sodium, while water samples of other stations fall in the class of C2-S1 indicating medium salinity with low sodium water, which can be suitable to salt tolerant plants with probability developed permeability problem of soil when Lime is not existing. RSC values are negative at all sampling sites, indicating that there is no complete precipitation of calcium and magnesium. All other parameters were within standard levels. The results of the study revealed that the quality of Diyala river water can be classified as suitable for irrigation with few exceptions.

Keywords: Diyala River, Irrigation, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP).

INTRODUCTION

Diyala River is one of the main water resources of Iraq and one of the most important tributaries of Tigris River in Iraq, draining an area reaching 32600 km^2. It covers a total distance of 445 km (275 miles). The river is controlled by the Diyala Weir on the lower Diyala valley, which controls floods and irrigates the area northeast of Baghdad. The river catchments were divided into four parts; Derbendikhan, Upper Diyala, Middle Diyala and Lower Diyala, It finally feeds into the Tigris river below Baghdad (1).

Diyala city depends mostly on Diyala river for its supply of water for domestic, municipal, agriculture and other purposes. Agriculture is not only the greatest water user of the world in terms of volume, it is also a relatively low value, low efficiency and highly subsidized user . Irrigation agriculture is dependent on an adequate water supply of usable quality. Irrigation water quality is a key environmental issue faced by the agricultural sector as well as it is very important for every agricultural use, passing through such activities as irrigation to livestock watering, from safe household family drinkable water on farms, etc. Agricultural water sources may be of poor quality because of natural causes, contamination or both, and often require treatment before it is acceptable for a given use (2,3). The water quality in watershed is directly affected by vegetative cover and agriculture and other management practices (4). The suitability of water for irrigation depends on a variety of factors, most relevant and important are; (salinity) concentration of Total Dissolved Solid (TDS), expressed in EC unit, in irrigation water, which mainly affects crop yields,(element toxicity) concentration of certain ions, which may be toxic to plants or have unfavorable effects on crops, soils and public health and (sodicity) concentration of cations, which may cause de-flocculation of clays in soils resulting damage to soil structure and permeability (SAR). The suitability of water for irrigation varies according to crops, types and permeability of soils and climate. Therefore irrigation water quality criteria developed by US salinity laboratory has received acceptance in many countries. (5,6).

There have been numerous studies and reports on assessment of surface water, ground water and treated wastewater quality for irrigation in various states of the country. Jain and Chaurasia (7) found the surface and subsurface water in upper Urmil river basin suitable and hazard-free for the crops grown. Issac et al (8) investigated the water available from all the sources in the Chaka block can be used for irrigation purpose without any harm. Haritash et al (North India villages) (9), Khodapanah et al (Eshtehard District ,Iran)(10) and Kacmaz and Nakoman (Koprubasi, Turkey)(11) found that most of the ground water samples are not suitable for irrigation uses. Anwar [12] found the wastewater qualities from both Karak and Mutah wastewater treatment plant are suitable for irrigation purposes in term of salinity and its high sodium content. Alobaidy et al [13] found the treated wastewater of Baghdad city can be used for irrigation on almost all types of soil.

The present study was mainly conducted to measure and analyze the irrigation water quality parameters of Diyala River such as EC, TDS, Sodium adsorption ratio, percentage sodium, magnesium and chloride hazard, pH, Residual Sodium Carbonate, that could potentially impact food safety of irrigation crops.

MATERIAL AND METHODS

The study area is located within agricultural fields in Diyala governorate. It has an approximate population of 6657768 (0.066578 persons per square meter) and an average elevation of 32 meters above sea levels. Diyala River, with a latitude of 33.23 (33° 13' 60 N) and a longitude of 44.52 (44° 31' 0 E), is a hydrographic (stream) located in Iraq that is a part of Middle East (Figure 1) [14]. Four stations were selected along Diyala River starting from north of the city which are Jalawlah station(DI2) before Jalawlah Bridge, Saadiyah station (DI3) before inter to Hamren Dam, Muqudadia station (DI4) after Diyala Dam and Baqubah station(DI5) at Iron Bridge, besides wand river station in Khanaqin (DIW) Before Dam. Water samples were collected once per month from these stations during January to December 2010 in plastic bottles of 1-L capacity that is rinsed several times with the sample before filling. These samples were kept refrigerated and analyzed within 48 hours after collection in the laboratory of Environmental Department in Diyala city.

Various tests were conducted according to the Standard Methods for examination of water [15]. Water quality parameters which were studied are as follows: total dissolved solids (TDS), electrical conductivity (EC), PH, Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Carbonate (CO_3), Bicarbonate (HCO_3), Nitrate (NO_3), Sulfate (SO_4) and Chloride (Cl).

These parameters mainly consist of certain physical and chemical characteristics of water that are used in the evaluation of agricultural water quality. Numerous water quality guidelines have been developed by many researchers for using water in irrigation under different condition. However, the classification of US Salinity Laboratory (USSL) is most commonly used [3,6,13]. Parameters such as EC, TDS, pH, Sodium Adsorption Ratio (SAR), adjusted SAR (adj SAR) and the Exchangeable Sodium Percentage (ESP), Soluble Sodium

Percentage (SSP) and Residual Sodium Carbonate (RSC) were used to assess the suitability of water for irrigation purposes. The criteria used to evaluate quality of water for use in agriculture are listed in Table 1.

THEORETICAL EQUATION

The characteristics of water for irrigation which are important in determining its quality are:

1. Salinity Hazard :

Salinity hazard is the most influential water quality guideline on crop productivity as measured by electrical conductivity, it reflects the total dissolved solid (TDS) in water [3,16]. The amount of water transpired through a crop is directly related to yield; therefore, irrigation water with high EC reduces yield potential and can result in a physiological drought condition. That is, even though the field appears to have plenty of moisture, the plants wilt because the roots are unable to absorb the water [10,17].

2. Sodium Hazard:

Although plant growth is primarily limited by the salinity EC level of the irrigation water, the application of water with a sodium imbalance can further reduce yield under certain soil texture conditions. Toxicity of sodium occurs with the accumulation of sodium in the plant tissues and exceeds the tolerance limit of crop. Reductions in water infiltration can occur when irrigation water contains high sodium relative to the calcium and magnesium contents, this causes swelling and dispersion of soil clays, surface crusting and pore plugging, almost impermeable to rain or irrigation water and decrease in the downward movement of water into and through the soil, and actively growing plants roots may not get adequate water, despite pooling of water on the soil surface after irrigation [18] .

As sodium ions increase in the soil ,they are adsorbed to the cation exchange sites and displace elements needed for plant growth. The net effect of the sodium ion buildup is a dispersion of soil aggregates, resulting in a soil that has a structure more like that of talcum powder than of a normal soil [19]. In addition there is a different indicator, as SAR, SSP, adj SAR and ESP, can be used to measure the sodium hazard.

Sodium hazard is expressed in terms of SAR (Sodium Adsorption Ratio), it is a measure of the suitability of water for use in agricultural irrigation , as calculated from the ratio of sodium to calcium and magnesium by this formula[3,9]:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2}+Mg^{+2}}{2}}} \qquad (1)$$

where: Na^{+}, Ca^{+2} and Mg^{+2} are in meq/l.

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soils. Continued use of water with high SAR value leads to a breakdown in the physical structure of the soil caused by excessive amounts of colloidally adsorbed sodium. The soil then becomes hard and compact when dry and increasingly impervious to water penetration[10, 17].

The presence of bicarbonate and carbonate ions in the irrigation water increases the permeability hazard as quantified by SAR [20]. The adj SAR measures the water's sodium level against calcium and magnesium, while adjusting for effect from bicarbonates and carbonates ions, these ions cause the Ca ions to precipitate out of water resulting in a high sodicity. Most adj SAR values of irrigation waters are about 10 to 15 percent greater than the unadjusted SAR When pHc less than 8.4 as shown in formula 2 below. The adj SAR should be used when determining if the water is appropriate for irrigation purposes [13, 21]. It can be calculated as in reference[3] by using the following formula:

$$adj\ SAR = SAR\ [1 + (8.4 - pHc)] \qquad (2)$$

where 8.4 is the approximate of a nonsodic of saline soil in equilibrium with $CaCO_3$ and is substituted for the pH of water. pHc is defined by:

$$pHc = (pK_2 + pK_c) + p\,(Ca^{2+} + Mg^{2+}) + pAlk \qquad (3)$$

where p refers to the negative logarithm, K_2 is the second dissociation equilibrium constant for calcite, concentrations of Ca^{2+}, Mg^{2+}, CO_3^{2-} and HCO_3^{-} in meq/l. The pHc is estimated using the procedures described by standard table given by reference[3]. Values of pHc above 8.4 indicate tendency to dissolve lime from soil through which the water moves; values below 8.4 indicate tendency to precipitate lime from waters applied [3].

The adj SAR procedure explanted above is no longer recommended. The suggestion, if used, the value obtained by that method should be further adjusted by newer adj RNa to evaluate more correctly the effects of HCO_3 on calcium precipitation. An alternative procedure, takes a new look at the older SAR equation and adjusts the calcium concentration of the irrigation water to the expected equilibrium value following an irrigation, and includes the effects of carbon dioxide (CO_2), of bicarbonate (HCO_3) and of salinity (ECw) upon the calcium originally present in the applied water but now a part of the soil-water. The procedure assumes a soil source of calcium - from soil lime ($CaCO_3$) or other soil minerals such as silicates - and no precipitation of magnesium. The adj RNa (adjusted Sodium Adsorption Ratio) is an improvement on the older Sodium Adsorption Ratio (SAR). It can be used to predict more correctly potential infiltration problems due to relatively high sodium (or low calcium) in irrigation water supplies and can be substituted for SAR in standard table by reference [3] The equation for calculation of adj RNa of the surface soil is very similar to the older SAR equation and is [3,13]:

$$\text{adj RNa} = \frac{Na}{\sqrt{\frac{Cax+Mg}{2}}} \qquad (4)$$

where Na, Mg are sodium and magnesium in the irrigation water in (meq/l), Ca_x is a modified calcium value (meq/l) expected to remain in near surface soil water following irrigation with water of given HCO_3^-/Ca^{2+} ratio and EC available from the standard Tables [3].

3- Soluble Sodium Percentage:

The sodium in irrigation waters is also expressed as percent sodium or soluble sodium percentage SSP and can be determined using the following equation :

$$SSP = \frac{Na}{Ca+Mg+Na+K} * 100 \qquad (5)$$

where all ionic concentrations are expressed in meq/l. Irrigation water with SSP greater than 60% may result in Na accumulation and possibly a deterioration of soil structure, infiltration, aeration and reducing soil permeability [17]. The ratio of the exchangeable Na+ to total exchangeable cations (Exchangeable Sodium Percentage, ESP) is a good indicator for soil structure deterioration. High value of ESP means high sodium ion concentration in the water , and high sodium concentration means dispersing soils by replacing the calcium and partly of the magnesium ions from soil exchange complex. The desired value for ESP is 5 or less than 5, while values between 6 and 9 mean increasing problems with soil infiltration and permeability, especially in clay soil. ESP value for irrigation water can be calculated from the following empirical relationship[6]:

$$ESP = \frac{100(-0.0126+0.01475*SAR)}{1+(-0.0126+0.01475*SAR)} \qquad (6)$$

ESP values above 15 mean severe problems for soils. as increased in soil pH, nutrient imbalances, sodium toxicity and dissolution of organic matter [13,22].

4- pH Affect:

The normal pH range for irrigation water is from 6.5 to 8.4, irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion, where low pH may cause accelerated irrigation system corrosion where they occur. High pH above 8.5 are often caused by high carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) concentrations[3,21].

5- Residual Sodium Carbonate:

RSC represents the amount of sodium carbonate and sodium bicarbonate in water when total carbonate and bicarbonate levels exceed total amount of calcium and magnesium. It is usually expressed as meq/l of sodium carbonate. Residual carbonate levels less than 1.25 meq/l are considered safe. Waters with RSC of 1.25-2.50 meq/l are within the marginal range. These waters should be used with good irrigation management techniques and soil salinity monitored by laboratory analysis. RSC values of 2.50 meq/l or greater are considered too high making the water unsuitable for irrigation use. RSC is determined by [16,17,18]:

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \qquad (7)$$

All ion concentrations are expressed in meq/l.

6- Chloride Hazard:

Chloride is a common ion in irrigation water. Although chloride is essential to plant in very low amount, it can cause toxicity to sensitive crops at high concentration (Table 1). If the chloride contamination in the leaves exceeds the tolerance of the crop, injury symptoms are developed such as leaf burn or drying of leaf tissue. These symptoms occur when leaves accumulate from 0.3 to 1.0 percent chloride. It is not absorbed by the soil but moves readily with the soil water [3,7,21].

7- Magnesium Hazard

Although calcium and magnesium ions are essential for plant growth but they may be associated with soil aggregation and friability. High concentration of calcium and magnesium in irrigation water can increase soil pH, resulting in reducing availability of phosphorus. Water contains calcium and magnesium concentration higher than 10 meq/l (200mg/l) cannot be used in agriculture[10,13,22]. Magnesium ion concentration also plays an important role in productivity of soil. It has been noted that if magnesium hazard is less than 50, the water is safe and suitable for irrigation. It can be calculated by this formula:

$$MH = \frac{Mg}{Mg+Ca} * 100 \qquad (8)$$

where Ca and Mg ions are expressed in meq/l[9,10,11].

8- Sulfate

Sulfate (SO_4) is relatively common in water and has no major effect on the soil other than contributing to the total salt content. Irrigation water high in sulfate ions reduces phosphorus availability to plants. SO_4 less than 400 mg/l is desired range but higher than 400mg/l will acidify the soil[(5)].

9- Nitrate

Waters high in N can cause quality problems in crops such as barley and sugar beets and excessive vegetative growth in some vegetables. However, these problems can usually be overcome by good fertilizer and irrigation management. Regardless of the crop, nitrate should be credited toward the fertilizer rate especially when the concentration of NO_3 exceeds 45 mg/l [(21)].

RESULTS AND DISCUSSION

Statistical analysis (mean, maximum, minimum values and standard deviation) of parameters of monthly values for physical and chemical characterization of the five station samples are calculated using Microsoft Excel Program 2007, they are listed in Table 2.

It was observed from table 2 that electrical conductivity of water for all stations ranged from (455.5 to 1704) µS/cm. Maximum EC was observed in station DIW in the range of (675 to 1704) µS/cm with a mean value of (1071.357µS/cm=1.71dS/m) and minimum was found in station DI2 varied from (455.5 to 790) µS/cm with a mean value of (582.94 µS/cm=.583dS/m), while TDS for all stations ranged from (224.5 to 2164) mg/l. Maximum was found in station DI5 with a mean value (769.7mg/l) and minimum in station DI2 (mean=308.9) as shown in figure 2, these indicating slight to moderate degree of restriction on the use water that can be used moderate amount of leaching. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control[(7)]. However, water samples of stations DIW and DI5 fall in the high salinity hazard class (C3) may have detrimentally effects on sensitive crops and adverse effects on many plants requires selection of salt-tolerant plants, careful irrigation, good drainage and leaching, while water samples of other stations fall in the medium salinity hazard class (C2) can be used in most cases without special practices for salinity control, where sensitive plants may show stress; moderate leaching prevents salt accumulation in soil [(10)] (figure 3). Irrigation water with conductivity in the range of (750-2250 µS/cm) is permissible for irrigation and widely used. It is clear that most water used for irrigation is of good to excellent quality and is unlikely to present serious salinity constraints. Salinity control, however, becomes more difficult as water quality becomes poorer. As water salinity increases, greater care must be taken to leach salts out of the root zone before their accumulation reaches a concentration which might affect yields [3].

Sodium concentrations in the samples of all stations varied from (17.5 to 96.2mg/l). Maximum was in the station DIW in the range (30.5 to 96.2mg/l) with a mean value of (46.25mg/l=2.01meq/l) and minimum was found in station DI2 varied from (17.5 to 32 mg/l) with a mean value of (22.3mg/l=0.97meq/l), did not exceed the lower limit, indicating none restriction on use .

SAR in all stations ranged from 0.539 to 1.607. Maximum was in the station DIW in the range (0.738 to 1.607) with a mean value of (0.985) and minimum was found in station DI2 varied from (0.539 to 0.81) with a mean value of (0.666), while adj SAR and adj RNa values range from 0.178 to 0.999 (mean = 0.582) and from 0.34 to 0.622 (mean = 0.4755) respectively (Table 3). The comparison between SAR, adj SAR and adj RNa values and their standard values reflects water is suitable for irrigation. The potential soil infiltration and permeability problems created from applications of irrigation cannot be adequately assessed on the basis of the SAR alone; therefore, the best measure of a water likely effect on soil permeability is the waters SAR considered together with its EC(figure 4). In this respect, the US salinity diagram (Figure 3) which is based on the integrated effect of EC (salinity hazard) and SAR (alkalinity hazard), has been used to assess the water suitability for irrigation [9, 22]. When the analytical data of EC and SAR plotted on the US salinity diagram, it is illustrated that water samples of DIW and DI5 fall in the class of C3-S1 indicating high salinity with low sodium water, which can be used for irrigation on almost all types of soil, with only a minimum risk of exchangeable sodium. This type of water can be suitable for plants having good salt tolerance but restricts its suitability for irrigation, especially in soils with restricted drainage [6], while water samples of other stations fall in the class of C2-S1 indicating medium salinity with low sodium water, which can be suitable to salt tolerant plants with probability developed permeability problem of soil when Lime is not existing.

The values for the SSP of the collected water samples ranged from 11.244 to 17.375 with a mean 14.999 as minimum value in station DI5 and from 15.070 to 24.519 with a mean 20.027 as maximum value in station DI4, indicating good irrigation water quality. The water samples in all stations has an ESP value of less than 5 (Table 3), which is a desired value for irrigation.

Table 2 shows that the pH of all stations varies from 6.9 to 8.2 , which indicates that pH is within normal range (Table 1).

Table 3 clearly shows that all samples have RSC less than zero and are good for irrigation purposes.

Cl^- in all stations ranged from (20 to 260 mg/l). Maximum was in the station DI5 in the range (33.2 mg/l to 260 mg/l= 7.33 meq/l) with a mean value of (103.809 mg/l= 2.93 meq/l), indicating slight to moderate degree of restriction on the use with injury to sensitive plants and minimum was found in station DI3 varied from (22.5 to 44 mg/l) with a mean value of (31.53 mg/l= 0.889 meq/l), is safe for all plants.

The concentration of calcium and magnesium in the studied water samples were not exceeding 200mg/l (Table 2), indicating that it is not expected to cause any problem for irrigation purpose. In the analyzed water samples, MH is found between 30.843 in station DI2 and 49.119 in station DI5 (Table 3), the mean is nearly 40.343, indicating that it is suitable for irrigation.

As shown on Table 2, all values of SO_4 are less than 400mg/l, indicating no problem in irrigation. The NO_3 values in the present study varied from 2.5 to 16.5 which are less than 45 mg/l and are good and suitable for irrigation purposes.

CONCLUSIONS

The analysis revealed that most of the constituents in the water samples are within the prescribed limits. The US salinity diagram illustrates that water samples of DIW and DI5 fall in the class of C3-S1 indicating high salinity with low sodium water, which can be used for irrigation on almost all types of soil, with only a minimum risk of exchangeable sodium, while water samples of other stations fall in the class of C2-S1 indicating medium salinity with low sodium water, which can be suitable to salt tolerant plants with probability develop permeability problem of soil when Lime is not existing. Therefore, the sustainable use of Diyala river water in agriculture can be beneficial to the environment, but it requires the control of soil salinity at the field level. Overall, Diyala river water can be classified with few exceptions as suitable for irrigation use.

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Table (1): Water quality classes for agricultural irrigation[3, 6].

Salinity Hazard							
Irrigation water classification					Degree of restriction on use		
Parameter	Excellent	Good	Permissible	Unsuitable	None	Slight to Moderate	Severe
EC (dS/m)	< 0.25	0.25-0.75	0.75-2.25	2.25-5.0	< 0.7	0.7-3.0	> 3.0
TDS (mg/L)	< 200	200-500	500-1500	1500-3000	< 450	450-2000	> 2000
Effect on plants	No detrimental effects	Sensitive plants show salt stress	Salt tolerant plants only	Very salt tolerant plants only	-		

Soil water Infiltration (Evaluate using EC and SAR together)							
EC(dS/m)	SAR	Degree of restriction	Remarks	Degree of restriction on use			
< 0.25	<10	Low	Satisfactory for all crops	EC (dS/m) & SAR	None	Slight to Moderate	Severe
0.25-0.75	10-18	Medium	Satisfactory, some salt sensitive crops will be affected	SAR 0-3 &EC	> 0.7	0.7-0.2	< 0.2
0.75-2.25	18-26	High	Satisfactory for most crops, salinity condition will be develop unless leaching and drainage are adequate	If SAR 3-6 & EC	> 0.2	0.2-0.3	< 0.3
				If SAR6-12 &EC	> 1.9	1.9-0.5	< 0.5
2.25-5	>26	Very high	Suitable for most salt tolerant plants, leaching and drainage are imperative	If SAR 12-20 &EC	> 2.9	2.9-1.3	< 1.3
				If SAR 20-40 & EC	> 5.0	5.0-2.9	< 2.9

Specific Ion Toxicity							
Degree of restriction on use					Degree of restriction on use		
-	Low	Medium	High	Very high	None	Slight to Moderate	Severe
Na(mg/l)	-	-	-	-	< 100	> 100	> 100
Na^+ (SAR)	< 10.0	10-18	18-26	> 26.0	< 3.0	3-9	> 9.0
Na^+ (SSP)	< 20.0	20-40	40-80	> 80	-	-	-

Irrigation Water Classification							
-	Safe	Sensitive plants	Moderately to tolerant plants	Unsuitable or tolerant plants	No Problem	Increasing problem	Sever problem
Cl^- (meq/L)	< 2	2-4	4-10	> 10	< 4	4-10	> 10

Miscellaneous Effects						
Irrigation water classification				Degree of restriction on use		
-	Safe	Permissible	Unsuitable	None	Slight to Moderate	Severe
RSC (meq/L)	< 1.25	1.25-2.5	> 2.5	-	-	-
HCO3 (meq/L)	-	-	-	< 1.5	1.5-8.5	> 8.5

Guidelines for interpretation of irrigation water quality of other parameters	
Water parameters	Normal ranking in irrigation water
Calcium Ca^{2+} (meq/l)	0-20
Magnesium Mg^{2+}(meq/l)	0-5
Carbonate CO_3^{2-}(meq/l)	0-1
Bicarbonate HCO_3^- (meq/l)	0-10
Sulfate SO_4^{2-} (meq/l)	0-20
Potassium K^+ mg/l	0-2
Acid/Basic pH 1-14	6.0-8.5

Table (2): Summary Statistics of the Analytical Data.

Characteristics	stations	Min	Max	Mean	Standard deviation
pH	DIW	7.1	7.9	7.53	0.258
	DI2	7.1	7.5	7.36	0.12
	DI3	6.9	7.6	7.37	0.197
	DI4	7	7.45	7.27	0.136
	DI5	7.3	8.2	7.68	0.272
SO_4(mg/l)	DIW	110	217.5	164.15	43.532
	DI2	94	221.5	151.667	47.577
	DI3	99.5	205	141.689	39.76
	DI4	11.5	218	147.938	37.976
	DI5	154.5	260	191.578	35.216
NO_3(mg/l)	DIW	4.6	16.5	8.61	3.985
	DI2	2.5	8.75	6.184	2.055
	DI3	3	9.5	5.887	2.214
	DI4	3.15	9	5.1	1.639
	DI5	3	11	4.735	2.355
TDS(mg/l)	DIW	295	853	482.55	171.427
	DI2	224.5	400	308.864	66.249
	DI3	229.5	420	327.864	67.754
	DI4	257.5	785	386.65	152.441
	DI5	355	2164	769.682	482.338
Mg(mg/l)	DIW	19.2	58.5	30.35	11.511
	DI2	14.5	34.6	20.596	5.76
	DI3	15.8	33.5	22.223	4.735
	DI4	16.55	27.3	23.095	3.882
	DI5	20.3	122	52.6	29.481
Ca(mg/l)	DIW	52	176.5	83.54	37.202
	DI2	38.9	63.55	52.227	8.364
	DI3	37.55	68	53.986	9.513
	DI4	48	71.4	58.41	8.519
	DI5	55.03	208	124.194	46.841
Cl(mg/l)	DIW	30	172.5	57.22	42.79
	DI2	22.5	44	31.527	7.149
	DI3	20	47.8	31.591	8.365
	DI4	27	52.5	35.44	7.717
	DI5	33.2	260	103.809	69.796
EC(µs/cm)	DIW	675	1704	1071.357	352.521
	DI2	455.5	790	582.938	130.223
	DI3	467.5	791.5	622.25	137.662
	DI4	474	841	658.125	137.096
	DI5	1075	1610	1249.75	173.422
Na(mg/l)	DIW	30.5	96.2	46.25	24.958
	DI2	17.5	32	22.286	5.589
	DI3	19.5	42	26.571	7.95
	DI4	22.25	44	28.2	7.907
	DI5	30.5	45	38.643	5.146
Characteristics	stations	Min	Max	Mean	Standard deviation
K(mg/l)	DIW	1.8	3.4	2.742	0.664
	DI2	0.85	3.3	1.7	0.812
	DI3	0.9	3.6	1.864	0.91
	DI4	1.3	2.8	1.95	0.662
	DI5	1.9	3.4	2.493	0.61
HCO_3(meq/l)	DIW	0.075	0.63	0.268	0.217
	DI2	0.03	0.34	0.18	0.115
	DI3	0.04	0.36	0.21	0.136
	DI4	0.005	0.251	0.141	0.121
	DI5	0.29	0.83	0.532	0.208
CO_3(meq/l)	DIW	0.075	0.63	0.268	0.217
	DI2	0	0.096	0.053	0.04
	DI3	0	0.087	0.029	0.032
	DI4	0	0.093	0.025	0.039
	DI5	0.29	0.83	0.532	0.208

Table (3): Calculated Irrigation Quality Characteristics.

Characteristics	stations	Min	Max	Mean	Standard deviation
SAR	DIW	0.738	1.607	0.985	0.468
	DI2	0.539	0.81	0.666	0.112
	DI3	0.618	1.041	0.768	0.155
	DI4	0.594	1.122	0.788	0.177
	DI5	0.674	0.841	0.768	0.0644
Adj SAR	DIW	0.478	1.144	0.922	0.244
	DI2	0.374	0.875	0.519	0.174
	DI3	0.379	0.847	0.593	0.199
	DI4	0.178	0.999	0.582	0.301
	DI5	0.723	1.343	1.065	0.220
Adj RNa	DIW	0.491	0.616	0.564	0.047
	DI2	0.374	0.875	0.543	0.174
	DI3	0.293	0.624	0.479	0.117
	DI4	0.340	0.622	0.476	0.116
	DI5	0.428	0.751	0.612	0.117
SSP	DIW	16.879	23.411	19.706	7.789
	DI2	15.636	23.672	18.345	2.548
	DI3	16.477	22.613	19.978	2.084
	DI4	15.070	24.519	20.027	3.127
	DI5	11.244	17.375	14.999	2.261
ESP(SAR)	DIW	-0.172	1.098	0.190717	0.454
	DI2	-0.467	-0.065	-0.278	0.166
	DI3	-0.35	0.275	-0.139	0.221
	DI4	-0.385	0.393	-0.099	0.261
	DI5	-0.267	-0.0195	-0.127	0.095
Characteristics	**stations**	**Min**	**Max**	**Mean**	**Standard deviation**
ESP(adj SAR)	DIW	-0.558	0.426	0.005	0.360
	DI2	-0.713	0.031	-0.497	0.258
	DI3	-0.706	-0.011	-0.433	0.297
	DI4	-1.008	0.213	-0.46017	0.456
	DI5	-0.194	0.716	0.237	0.322
ESP(adj RNa)	DIW	-0.539	-0.353	-0.446	0.069
	DI2	-0.881	-0.536	-0.711	0.163
	DI3	-0.954	-0.341	-0.685	0.226
	DI4	-0.764	-0.344	-0.562	0.172
	DI5	-0.633	-0.153	-0.399	0.174
pHc	DIW	8.0	8.9	8.4	0.308
	DI2	8.2	8.9	8.6	0.264
	DI3	8.4	9.0	8.6	0.273
	DI4	8.4	9.2	8.7	0.34
	DI5	7.7	8.2	8.0	0.176
RSC	DIW	-7.998	-0.995	-4.955	2.336
	DI2	-5.885	-3.081	-4.404	0.967
	DI3	-6.12	-3.464	-4.766	0.872
	DI4	-5.765	-4.274	-5.064	0.488
	DI5	-20.083	-6.391	-10.944	5.346
Mg^{2+}Hazards	DIW	33.923	45.511	37.849	3.543
	DI2	30.843	47.483	38.997	4.504
	DI3	36.011	46.305	40.343	3.815
	DI4	36.113	44.456	39.354	2.723
	DI5	31.273	49.119	39.735	5.133

Fig.(1): Study area map(13).

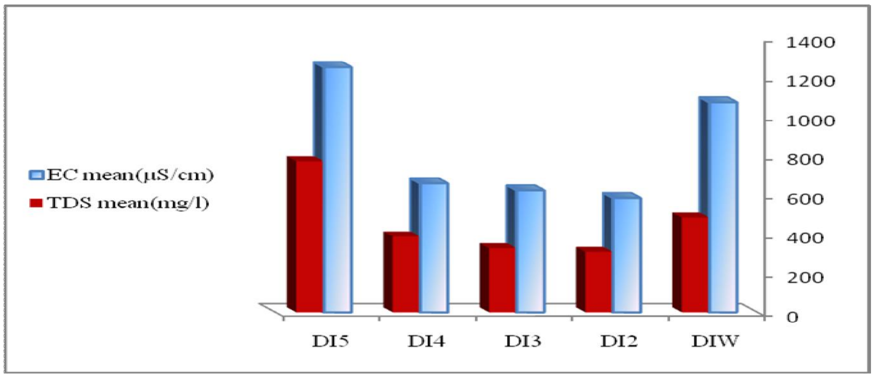

Fig.(2): Measurement values of EC and TDS.

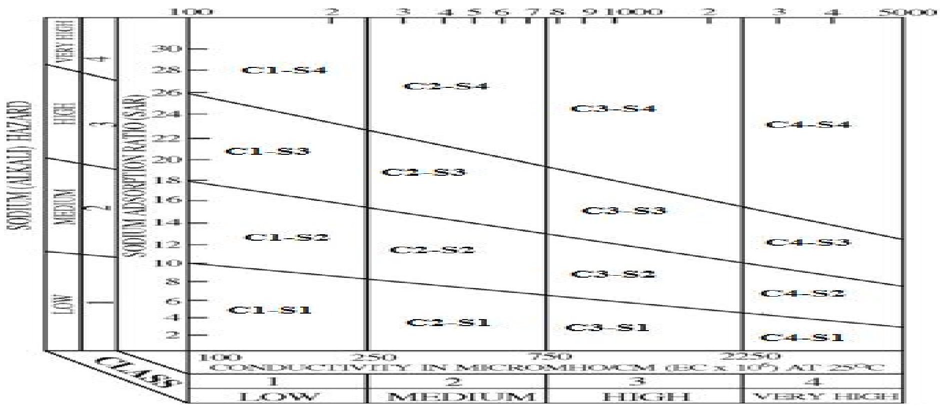

Fig.(3): Rating of water samples in relation to salinity and sodium hazard(6).

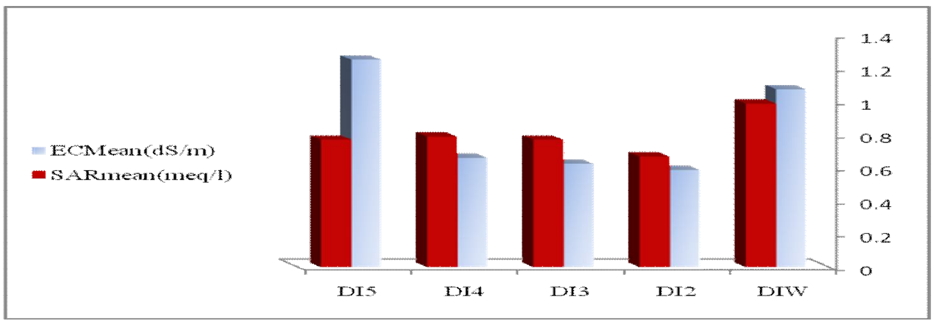

Fig.(4): Measurement values of EC and SAR.

تقيم نوعية مياه نهر ديالى لأغراض الري

م.م. ناهده حميد حمزه
قسم الهندسة المدنية–جامعة ديالى

الخلاصة

تضمنت الدراسة تقييم صلاحية مياه نهر ديالى لأغراض الري، حيث تم أختيار اربع محطات على طول نهر ديالى وهي محطة الرصد لنهر ديالى في جلولاء (DI2)، محطة الرصد في السعدية (DI3)، محطة الرصد في المقدادية (DI4) ومحطة الرصد في بعقوبه (DI5)، بالأضافة الى محطة الرصد على نهر الوند في خانقين (DIW). تم جمع عينات المياه وتحليل العناصر $pH, EC, TDS, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, HCO_3^{-}, CO_3^{2-}, SO_4^{2-}, Cl^{-}$ و NO_3^{-} شهرياً لهذه المحطات للفترة من كانون الثاني الى تشرين الثاني ٢٠١٠. ولتصنيف نوعية المياه وتقييم صلاحيتها لأغراض الري تم حساب قيم نسبة أمتزاز الصوديوم (SAR)، نسبة الصوديوم القابل للذوبان (SSP) وكاربونات الصوديوم المتبقيه (RSC) بأتباع المعادلات القياسية ووجدت القيم (٠,٩٨٥)، (٢٠,٠٢٧) و(–٤,٤٠٤) على التوالي. ووفقاً لقيم التوصيل الكهربائي ونسبة امتزاز الصوديوم ومقارنتها بمخطط تصنيف الملوحة الامريكية ، أوضحت آن عينات المياه للمحطات DIw,DI5 هي ضمن الصنف (C3-S1) (ماء عالي الملوحة–قليل الصوديوم) والذي ممكن أن يكون صالح للري في جميع انواع الاتربة تقريباً مع خطر قليل لتكوين تركيزات خطرة من الصوديوم القابل للتبادل، بينما عينات المياه لبقية المحطات هي ضمن الصنف (C2-S1) (ماء متوسط الملوحة–قليل الصوديوم)، الماء ملائم للنباتات جيدة التحمل للأملاح مع احتمال تطور مشكلة النفاذية للترب الناعمة النسجة عند عدم وجود اللايم. قيم كاربونات الصوديوم المتبقية سالبة لجميع قيم العينات وهذا يشير الى عدم اكتمال ترسيب الصوديوم والمغنيسيوم. أما بالنسبة لبقية العناصر الأخرى فأنها ضمن الحدود المسموح به، أخيراً فإن نوعية مياه نهر ديالى ممكن أن يصنف بانها مناسبة للري عدا بعض الاستثناءات القليلة.

الكلمات الدالة: نهر ديالى، الري، نسبة امتزاز الصوديوم، نسبة الصوديوم القابل للذوبان، كاربونات الصوديوم المتبقية.