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Assessment of irrigation water quality of Tono Dam in Navrongo, Ghana

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Abstract

Water used for irrigation remains unnoticed when the quality level is changing. Irrigation water is a major source of water for plant growth when rainfall is insufficient. Some important physio-chemical parameters of Tono irrigation dam of Upper East Region were evaluated for the criteria of irrigation water quality. Thirty four (34) water samples were collected in the dry season from eight (8) command areas of the Tono irrigation area. The study revealed that though there was significant difference between the reservoir and some of the command areas in terms of the physio-chemical parameters, temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium carbonate (RSC) and Kelly's ratio of water sampled from eight command areas were found within the permissible limits and therefore suitable for irrigation purposes. Iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) ions which might cause toxicity of the irrigation water were low and had no effect on the quality of irrigation water and the productivity of the crop cultivated.

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Introduction

The quality of irrigation water available to farmers and other irrigators has considerable impact on what plant can be successfully grown, the productivity of these plants, water infiltration and other soil physical conditions. Water quality concerns have often been neglected to the background because good water quality supplies have been plentiful and readily available (Shamsad and Islam, 2005; Islam *et al.,* 1999). Notwithstanding, considerable changes and disparities have been observed in many countries. Intensive use of nearly all good quality supplies means that new irrigation projects, and old projects seeking new or supplemental supplies, must rely on lower quality and less desirable sources (Cuena, 1989).

It is common knowledge that irrigation water quality can have effects on the management of soils, crops and food produce. Characteristics of irrigation water that defines its quality vary with the source of the water. The chemical constituents of irrigation water can affect plant growth directly through deficiency or toxicity, or indirectly by changing plant available nutrients (Ayers and Westcot, 1985; Rowe *et al.,* 1995). Irrigation water can also vary to a great extent in quality depending upon the type and quantity of dissolved salts. In irrigated agriculture, the hazard of salt water is a constant threat to crop productivity and profit margin of farmers. Poor-quality irrigation water becomes more concern as the climate varies from humid to arid conditions. Salts are originated from dissolution or weathering of rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals (Hopkins *et al.,* 2007). These substances are carried with the water to wherever it is used (UCCC, 1974; Tanji, 1990).

Most important criteria that are frequently used in characterizing irrigation water quality include sodium adsorption ratio(SAR), electrical conductivity(EC), residual sodium carbonate(RSC), soluble sodium percentage(SSP), and Kelly's ratio(Golekar *et al.,* 2013). Salt hazards in irrigation water which is measured by the total dissolved solids(TDS) or electrical conductivity(EC) are important to predict salinity and permeability challenges that can affect plant productivity from irrigated farms(Hopkins *et al.,* 2007; Nishanthiny *et al.,* 2010).

To determine the quality of irrigation water, we need to define the characteristics that are important for plant growth, and their permissible levels of concentrations. Having the water tested by a highly regarded laboratory is the first step in this process. A knowledgeable interpretation of the results can help to correct water quality problems and/or choose fertilizers and irrigation techniques to avoid crop damage. To avoid problems when using these poor quality water supplies, there must also be sound planning to ensure that the quality of water available is put to the best use.

In Ghana, there are few irrigation projects to support farming activities for improved food production to ensure food security. There are many areas with great potentials to benefit from dams to enhance agricultural activities in the country. This has not been the case currently, and those that exist, not much studies have been conducted on the water quality and it implication on soil fertility and agricultural production. Tono dam is the largest reservoir in the Upper East Region of Ghana that provides water for irrigation of various crops. Not much study has been done on the dam's water quality. To ensure its continuous use it is important to periodically assess the quality of water it provides.
Therefore, this study was conducted to assess the water quality levels of Tono irrigation water based on some selected water quality parameters.

Materials and methods

Location and climate

The project lies in the guinea savannah ecological zone of Ghana and is located in the Upper East Region and lying between latitude 10 ° 45ˈN and longitude 1° W. It has a potential area of about 3840ha with a developed area of about 3450ha. The project area comprises eight (8) command areas, namely Bonia, Gaani, Korania, Wuru, Yigania, Yigwania, and Chuchuliga zone A and B. The total annual rainfall in the area is around 950mm which normally begins in May, reach a peak in August then drop sharply in October. Thereafter, there is a long dry period from November to the end of April during which period only negligible amounts of rain are received.

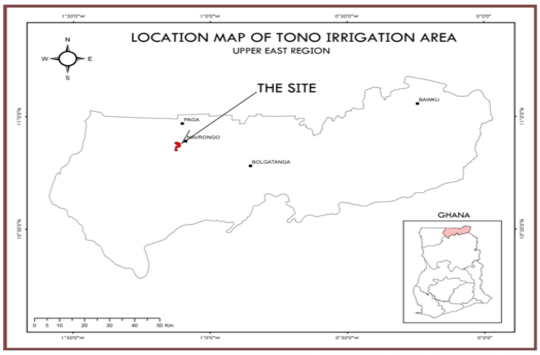

Fig. 1. Map of Upper East Region showing the location of Tono irrigation area.

Mean monthly temperatures remain high throughout the year only falling around 26° C in August and September at Navrongo. March and April are the hottest months recording nearly 32°C. Absolute minimum temperatures of around 16° c are usually recorded in December or January with absolute maximum temperature of about 35°C recorded in March and April.

Relative humidity percent for the study area is high during rainy season in particular, from July to September, and low in the dry harmattan period from January to February. Detailed data indicate low diurnal and monthly humidity readings between noon and 1500 hours and high diurnal humidity readings between midnight and 0600 hours. Usually, humidity during the noon to 1500 hours period may be 20 to 30 percent lower than at 0900 hours.

Water sampling and analysis

A total of thirty (34) water samples were collected from the dam, main canal, and laterals of all the command areas. This was done during cropping period of the peak dry season. Each sample was a composite of 10 sub-samples. The bottles used for sampling (voltic bottles) were cleaned with hydrochloric acid (HCl) and rinsed repeatedly with deionized water as suggested by De (1989). The bottles were kept air tight and labeled properly for identification. Stoppering of the bottles was done quickly to avoid aeration during sampling.

Electrical conductivity (EC), pH and temperature of the samples were measured on the spot using portable EC-meter, pH-meter and thermometer, respectively. Total dissolved solids (TDS) were estimated by the method described by Todd (1980).

The samples collected from the study area were carefully transported to CSIR-Soil Research Institute's laboratory, Ghana and kept in a refrigerator for analysis. Na^+ and K^+ were determined by flame photometry (Jackson, 1967); Ca^{2+}, Mg^{2+}, Cu^{2+}, Zn, Mn and Fe by Atomic Absorption Spectrophotometer (AAS) (Jackson, 1967; Page *et al.,* 1982); Cl^- , HCO_3^- , CO_3^{2-} ,SO_4^{2-} , NO_3^- and PO_4^-, titration method (Jackson, 1967); the Sodium Adsorption Ratio (SAR), the Soluble Sodium Percentage(SSP), the Residual Sodium Carbonate(RSC) and Kelly's ratio were determined by the methods described by Richards (1954), Todd (1980), Eaton (1950) and Kelly (1953) respectively. The results from the main canal and command areas were compared with that of the dam (reservoir).

Results and discussion

Table 1 shows the suitability of water quality for irrigation purposes. Tables (2-4) also represent the physio-chemical results of the analysis of water samples at the study area.

The average temperature of the irrigation water samples at the time of sampling at the study area was 25 °C ranging from 24 to 25 °C. The average EC value was 125.8 µs/cm also ranging from 124.1 to 129.1 µs/cm. This according to Wilcox (1955) falls within the irrigation water classification stand 'excellent to good'. In terms of the 'degree of restriction on use' the irrigation water of the study area is suitable for irrigation purpose as it falls under category 'none' (UCCC, 1974). The primary effect of high EC water on crop productivity is the inability of the plant to compete with the ions in the soil solution of water. The higher the EC, the less water is available to the plants, even though the soil may appear wet, leading to low productivity.

Table 1. Guidelines for Interpretations of Water Quality for Irrigation (UCCC, 1974).

Potential Irrigation Problem			Units	Degree of Restriction on Use		
				None	Slight moderate	to Severe
Salinity (affect crop water availability						
	EC_w		ds/m	<0.7	0.7-3.0	> 3.0
	Or					
	TDS		mg/l	< 450	450-2000	> 2000
Infiltration (affect infiltration of water into the soil. Evaluate using EC_w and SAR together)						
SAR	= 0-3	And EC_w	=	0.7	0.7-0.2	<0.2
	= 3-6		=	>1.2	1.2-0.3	<0.3
	= 6-12		=	>1.9	1.9-0.5	<0.5
	= 12-20		=	>2.9	2.9-1.3	<1.3
	= 20-40		=	>5.0	5.0-2.9	<1.9
Specific Ion Toxicity						
	Sodium		meq/*l*	<3.0	3.0-9.0	>9.0
	Chloride		meq/*l*	<4.0	4.0-10.0	>10.0
	Boron		meq/*l*	<0.7	0.7-3.0	>3.0
Miscellaneous effect						
	Nitrogen(NO_3-N)		meq/*l*	<5	5-30	>30
	Bicarbonate(HCO_3^-)		meq/*l*	0-120	120-180	180-600
	Carbonate(CO_3^-)		meq/*l*			
	pH			Normal range 6.5-8.4		

Table 2. Irrigation water quality parameters.

S. site	Lateral	Temp(◦C)	EC(µs/cm)	pH	TDS(mg/l)	SAR	SSP (%)	RSC(meq/l)	KR
Dam	1	25	124.1	7.3	79.4	0.38	28.11	0.28	0.28
Dam	2	25	124.1	7.3	79.4	0.38	28.11	0.28	0.28
Dam	3	24	124.1	7.3	79.4	0.38	28.11	0.28	0.28
Dam	4	25	124.1	7.3	79.4	0.38	28.11	0.28	0.28
Main canal	1	25	124.4	7.2	79.6	0.35	26.22	0.20	0.25
Main canal	2	25	124.4	7.2	79.6	0.35	26.22	0.20	0.25
Main canal	3	25	124.4	7.2	79.6	0.35	26.22	0.20	0.25
Main canal	4	24	124.4	7.2	79.6	0.35	26.22	0.20	0.25
Gaani	1	25	128.5	7.7	82.2	0.43	28.88	0.18	0.30
Gaani	2	25	129.1	7.5	82.6	0.42	28.13	0.15	0.29
Gaani	3	25	126.1	7.6	80.7	0.46	32.60	0.32	0.36
Gaani	4	25	126.0	7.6	80.6	0.50	32.68	0.27	0.37
Korania	1	25	126.3	7.4	80.8	0.36	25.86	0.13	0.25
Korania	2	25	126.2	7.3	80.8	0.36	25.67	0.14	0.25
Korania	3	24	126.4	7.5	80.9	0.35	25.51	0.14	0.24
Korania	4	25	126.7	7.5	81.1	0.35	26.38	0.19	0.25
Bonia	1	25	126.1	7.3	80.7	0.48	33.76	0.39	0.38
Bonia	2	25	126.4	7.2	80.9	0.41	31.06	0.36	0.32
Bonia	3	24	127.5	7.0	81.6	0.41	30.61	0.38	0.31
Bonia	4	25	126.0	7.1	80.6	0.42	31.44	0.39	0.33

Chuchuliga	1	24	125.9	7.4	80.9	0.45	30.93	0.31	0.34
Chuchuliga	2	25	125.3	7.4	80.6	0.44	30.30	0.29	0.32
Chuchuliga	3	25	125.8	7.3	80.8	0.45	30.69	0.30	0.33
Chuchuliga	4	25	125.4	7.5	81.0	0.44	30.15	0.28	0.32
Wuru	1	25	126.3	7.2	80.8	0.42	28.09	0.13	0.29
Wuru	2	25	127.3	7.2	81.5	0.41	27.64	0.10	0.29
Wuru	3	24	126.2	7.2	80.8	0.41	29.16	0.10	0.32
Wuru	4	25	126.0	7.3	80.6	0.40	27.15	0.07	0.28
Yigania	1	25	125.9	7.2	80.6	0.46	31.55	0.32	0.34
Yigania	2	25	126.1	7.3	80.7	0.46	31.56	0.31	0.35
Yigania	3	25	126.1	7.3	80.7	0.47	32.67	0.33	0.37
Yigania	4	25	125.9	7.3	80.6	0.46	31.56	0.27	0.35
Yigwania	1	24	125.1	7.4	80.1	0.37	26.68	0.20	0.26
Yigwania	2	25	125.1	7.2	80.1	0.36	26.85	0.21	0.26
Yigwania	3	25	125.0	7.4	80.0	0.42	28.95	0.23	0.30
Yigwania	4	25	125.3	7.4	80.2	0.40	28.32	0.23	0.29
Mean		24.81	25.8	7.3	80.54	0.41	28.95	0.24	0.30
Range		24-25	24.1-29.1	7.0-7.7	79.4-82.6	0.35-0.50	25.51-33.76	0.07-0.39	0.24-0.38
SD		0.401	1.161	0.148	0.755	0.044	2.366	0.086	0.041
%CV		1.7	0.5	1.0	0.5	4.8	3.6	12.9	6.7

Many of the toxic solid materials may be found in the water samples which may cause harm to the plants (Matthess, 1982); hence it is important to consider TDS as one of the parameters. As EC and TDS values of irrigation water are interrelated, both values are indicative of saline water in the absence of non-ionic dissolved constituent (Michael, 1992). The TDS values ranged from 79.4 to 82.6mg/*l*. This indicates that the values are suitable for irrigation purpose. The only area which showed slightly increase in TDS was 'Gaani' which has TDS value of 82.6mg/l at one of the laterals (UCCC, 1974).

Although plant growth is primarily limited by the salinity level of the irrigation water, the application of water with sodium imbalance can further reduce yield under certain soil texture condition (Matthess, 1982). Irrigation water with high sodium (Na^+) can bring about a displacement of exchangeable cations Ca^{2+} and mg^{2+} from the clay minerals of the soil, followed by the replacement of the cations by sodium. A situation called Sodium Adsorption Ratio (SAR), causes swelling and dispersion of soil clay, surface crusting, pore plugging, obstructs infiltration and may increase runoff (Matthess, 1982). The values of SAR of the water samples from the study area ranged from 0.35 to 0.50 with an average value of 0.42 (Table 2). According to Richards (1954), for salinity classification (Figure 2), all the irrigation water samples fell under low sodium hazard (S_1) and low salinity hazard (C_1). Salinity classification was done using the diagram in figure 2. This was given by US salinity laboratory (Richards, 1954). The diagram classifies 16 classes with reference to SAR as an index of sodium hazard and EC as an index of salinity hazard.

The normal pH range for irrigation water according to UCCC (1974) is 6.5-8.5. High pH above 8.5 is often caused by high bicarbonate and carbonate concentrations. This often cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. This alkaline water could intensify the impact of high SAR water. The pH values of the irrigation water ranged from 7.0 to 7.7 with an average value of 7.3 which according to DOE (1997) and UCCC (1974) is within the permissible limit for irrigated agriculture.

The Soluble Sodium Percentage (SSP) values were found to vary from 25.51 to 33.76% with an average value of 28.95 %, depending upon locations. Base on the classification after Todd (1960) for SSP, all the 34 irrigation water samples fell under 'Good' class. The areas which showed slight increase in SSP were Gaani, Bonia and Yigania.

The table below also shows that the highest Residual Sodium Carbonate (RSC) value of the irrigation water was 0.39 which was sampled from Bonia location. The average value of RSC of the water sample was 0.24. Based on Eaton (1950), all the 34 samples fell under 'Excellent' class.

The Kelly's ratio of collected irrigation water samples from the study area ranged from 0.24 to 0.38 with an average value of 0.30, which showed all values were under acceptable range and suitable for irrigation purposes (Kelly, 1953).

Table 3. Cations (meq/*l*).

S. site	Lateral	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Zn^{2+}	Cu^{2+}	Mn^{2+}	Fe^{2+}
Dam	1	0.61	0.31	0.34	0.10	0.12	0.11	0.02	0.02
Dam	2	0.61	0.31	0.34	0.10	0.11	0.11	0.01	0.02
Dam	3	0.61	0.31	0.34	0.10	0.12	0.11	0.02	0.02
Dam	4	0.61	0.31	0.34	0.10	0.11	0.11	0.01	0.02
Main canal	1	0.61	0.25	0.35	0.10	0.12	0.11	0.01	0.02
Main canal	2	0.61	0.25	0.35	0.10	0.11	0.11	0.01	0.02
Main canal	3	0.61	0.25	0.35	0.10	0.12	0.11	0.01	0.02
Main canal	4	0.61	0.25	0.35	0.10	0.12	0.11	0.01	0.02
Gaani	1	0.56	0.42	0.30	0.10	0.12	0.12	0.02	0.02
Gaani	2	0.62	0.40	0.30	0.11	0.11	0.11	0.01	0.02
Gaani	3	0.46	0.39	0.30	0.11	0.11	0.11	0.01	0.02
Gaani	4	0.51	0.38	0.30	0.11	0.10	0.11	0.02	0.02
Korania	1	0.60	0.43	0.26	0.11	0.11	0.12	0.01	0.02
Korania	2	0.60	0.42	0.26	0.10	0.11	0.12	0.01	0.02
Korania	3	0.61	0.43	0.25	0.11	0.12	0.12	0.01	0.02
Korania	4	0.60	0.41	0.25	0.11	0.11	0.12	0.02	0.02
Bonia	1	0.45	0.34	0.30	0.11	0.10	0.11	0.02	0.02
Bonia	2	0.45	0.35	0.26	0.11	0.11	0.11	0.01	0.02
Bonia	3	0.45	0.37	0.26	0.11	0.11	0.11	0.01	0.02
Bonia	4	0.45	0.36	0.27	0.11	0.11	0.11	0.01	0.02
Chuchuliga	1	0.46	0.43	0.30	0.10	0.10	0.12	0.02	0.02
Chuchuliga	2	0.46	0.44	0.30	0.10	0.10	0.12	0.02	0.02
Chuchuliga	3	0.47	0.43	0.30	0.10	0.11	0.12	0.02	0.02
Chuchuliga	4	0.47	0.43	0.30	0.10	0.11	0.12	0.02	0.02
Wuru	1	0.61	0.42	0.30	0.10	0.11	0.12	0.02	0.02
Wuru	2	0.63	0.43	0.30	0.10	0.11	0.11	0.01	0.02
Wuru	3	0.63	0.43	0.30	0.10	0.11	0.11	0.02	0.02
Wuru	4	0.62	0.45	0.30	0.10	0.11	0.11	0.01	0.02
Yigania	1	0.58	0.28	0.30	0.10	0.10	0.12	0.02	0.02
Yigania	2	0.56	0.31	0.30	0.10	0.12	0.11	0.01	0.02
Yigania	3	0.57	0.29	0.31	0.11	0.11	0.11	0.01	0.02
Yigania	4	0.59	0.31	0.31	0.11	0.11	0.12	0.01	0.02
Yigwania	1	0.65	0.34	0.26	0.11	0.11	0.12	0.02	0.02
Yigwania	2	0.64	0.33	0.25	0.11	0.11	0.11	0.01	0.02
Yigwania	3	0.63	0.34	0.29	0.11	0.11	0.12	0.02	0.02
Yigwania	4	0.63	0.34	0.28	0.11	0.11	0.11	0.02	0.02
Mean		0.57	0.36	0.30	0.10	0.11	0.11	0.014	0.02
Range		0.45-0.65	0.25-0.45	0.25-0.35	0.10-0.11	0.10-0.12	0.11-0.12	0.010-0.120	0.02-0.02
SD		0.069	0.066	0.031	0.005	0.006	0.005	0.005	0.0
%CV		4.3	3.1	3.1	2.8	5.0	2.8	28.3	0.0

Chloride (Cl^{-}) and Sulphate (SO_4^{2-}) contents of the 34 irrigation water samples of the study area varied from 0.010 to 0.122 meq/*l* with an average value of 0.052meq/*l* and 0.04meq/*l* respectively. The water sample of lateral at Gaani showed the highest value of Cl^{-}. Higher Cl^{-} value of concentration at Gaani might be due to the impact of settlement and anthropogenic effect (Islam *et al.,* 1999). It is evident that the values of Cl^- and SO_4^{2-} of the study area were within the recommended limit (BWPCB, 1976; WHO, 1984; Ayers and Westcot, 1985) and suitable for irrigation (Marschner, 1989; UCCC, 1974).

Table 4. Anions (meq/*l*).

S. site	Lateral	HCO_3^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cl^-
Dam	1	1.21	0.04	0.02	0.007	0.011
Dam	2	1.21	0.04	0.02	0.007	0.011
Dam	3	1.21	0.04	0.02	0.007	0.011
Dam	4	1.21	0.04	0.02	0.007	0.011
Main canal	1	1.2	0.04	0.02	0.008	0.011
Main canal	2	1.2	0.04	0.02	0.008	0.011
Main canal	3	1.2	0.04	0.02	0.008	0.011
Main canal	4	1.2	0.04	0.02	0.008	0.011
Gaani	1	1.16	0.04	0.04	0.011	0.092
Gaani	2	1.17	0.04	0.04	0.013	0.122
Gaani	3	1.16	0.04	0.04	0.013	0.11
Gaani	4	1.16	0.04	0.04	0.01	0.011
Korania	1	1.16	0.04	0.05	0.011	0.092
Korania	2	1.17	0.04	0.04	0.01	0.11
Korania	3	1.18	0.04	0.04	0.01	0.1
Korania	4	1.2	0.04	0.04	0.01	0.011
Bonia	1	1.18	0.04	0.05	0.016	0.011
Bonia	2	1.17	0.04	0.04	0.014	0.121
Bonia	3	1.2	0.04	0.04	0.013	0.09
Bonia	4	1.2	0.04	0.04	0.014	0.011
Chuchuliga	1	1.2	0.04	0.05	0.011	0.03
Chuchuliga	2	1.21	0.04	0.04	0.01	0.02
Chuchuliga	3	1.2	0.04	0.05	0.014	0.1
Chuchuliga	4	1.2	0.04	0.04	0.01	0.011
Wuru	1	1.17	0.04	0.05	0.024	0.092
Wuru	2	1.16	0.04	0.05	0.019	0.062
Wuru	3	1.17	0.04	0.05	0.014	0.11
Wuru	4	1.15	0.04	0.04	0.01	0.01
Yigania	1	1.18	0.04	0.05	0.014	0.091
Yigania	2	1.19	0.04	0.04	0.013	0.121
Yigania	3	1.19	0.04	0.04	0.013	0.11
Yigania	4	1.18	0.04	0.04	0.022	0.011
Yigwania	1	1.18	0.04	0.05	0.019	0.092
Yigwania	2	1.19	0.04	0.05	0.013	0.011
Yigwania	3	1.20	0.04	0.05	0.016	0.011
Yigwania	4	1.20	0.04	0.04	0.010	0.011
Mean		1.19	0.04	0.04	0.012	0.052
Range		1.15-1.21	0.04-0.04	0.02-0.05	0.007-0.024	0.010-0.122
SD		0.018	0.0	0.011	0.004	0.046
%CV		0.8	0.0	8.6	24.5	62.6

Agricultural activities which could introduce nutrients in the dam and its canals would eventually lead to eutrophication of the dam. Nitrate and phosphate concentrations ranged from 0.02 to 0.05meq/*l* and 0.007 to 0.024meq/*l*. These are low and acceptable according to Marschner, (1989) and UCCC, (1974).Toxicity of the water may be determined from the Fe, Cu, Zn and Mn levels; these are low and have no effect on the quality of irrigation water and the productivity of the crop cultivated.

The results also show that the range of bicarbonate (HCO_3^-) of irrigation water samples of the study area was between 1.15 and 1.21 meq/*l* with an average value of 1.19 meq/*l*. The water in the irrigation dam was suitable for irrigation which is in the agreement with the findings of Ayers and Westcot (1985). The values of water samples of the study area fell into 'none to slight' of degree of restrictions on use (UCCC, 1974).

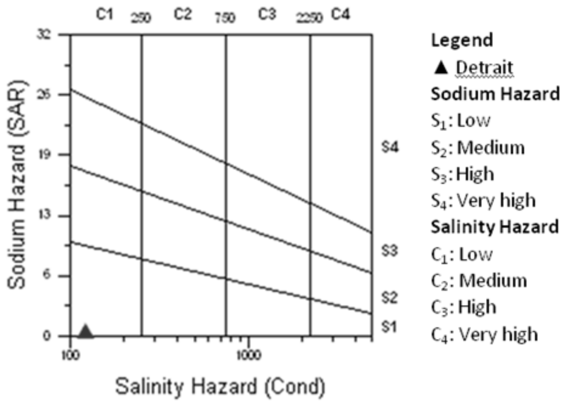

Fig. 2. Salinity classification of irrigation water samples (Richards, 1954).

Conclusion

Different physio-chemical properties of irrigation water of Tono irrigation dam were compared with the international water quality standards set for irrigation. Electrical conductivity (EC), pH, total dissolved solids (TDS), iron (Fe), and chloride (Cl^-) fall in the class of 'excellent to good' and category 'none' in terms of the degree of restriction on use. Tono irrigation dam had no salinity problem and on the basis of SAR, SSP and RSC values, no permeability problem was found to exist in the area. The values of the toxic heavy metals: copper (Cu), zinc (Zn) and manganese (Mn) were also found in the permissible limit.

On the basis of agricultural activities which could introduce nutrients into the reservoir, canals and laterals which would eventually lead to eutrophication, nitrate and phosphate values are low and acceptable. Efficient and effective dam management mechanisms should be continued to prevent possible eutrophication. Management should pay attention to frequent water quality monitoring to enhance farmers' confidence in the quality of water for irrigation in their farms. Plant water requirement for higher productivity should be studied to complement management strategies.

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