SCIREA Journal of Agriculture

http://www.scirea.org/journal/Agriculture

April 26, 2017

Volume 2, Issue 2, April 2017

Correlation analysis of Irrigation water quality parameters from Lake Bosomtwe in the Ashanti Region of Ghana

Adams Sadick[1*], Prince Charles Asante[1], Emmanuel Dugan[2], Jerry Asaana[3]

[1]Analytical Services, Soil Research Institute, Kumasi, Ghana

[2]Soil and Water Conservation, Soil Research Institute, Kumasi, Ghana

[3]Civil Engineering, Bolgatanga Polytechnic, Bolgatanga

*Corresponding author：Adams Sadick

Analytical Services, CSIR-Soil Research Institute, Kumasi, Ghana

Cell phone: +233268198126

Abstract

This paper assessed the suitability of water in Lake Bosomtwe at Ashanti Region of Ghana for irrigation purposes. A total of ten composite samples were taken from different parts of the lake and analyzed for Irrigation water quality parameters like sodium adsorption ratio, soluble sodium percentage, residual sodium carbonate and Kelly's ratio and were calculated from Na^+, Ca^{2+}, Mg^{2+}, K^+, HCO_3^- and CO_3^{2-}. Also, correlation analysis was done to determine the association between the parameters measured. The results showed that the parameters sodium adsorption ratio(SAR), soluble sodium percentage(SSP), residual sodium carbonate(RSC) and Kelly's ratio(KR) had mean values of 18.47, 94%, 20.36 meq/l and 15.33 respectively and were not within the acceptable standards for irrigation. Sodium adsorption ratio strongly correlated positively with SSP (r = +0.753) and KR(r = +0.717) but negatively with RSC (r = -0.803), Ca^{2+} (r = -0.725), Mg^{2+}, HCO_3^- (r= -0.830) and CO_3^{2-} (r= -0.849). It also moderately correlated positively with Na^+(r = +0.318) and K^+ (r = +0.496). Based on the above results the Lake water was not suitable for irrigation and further assessment of the bacteriological quality parameters is recommended.

Keywords: Irrigation water quality, correlation, chemical parameters, Lake Bosomtwe

Introduction

The presence of good quality water is an important feature for preventing water related diseases and improving quality of life (Oluduro et al., 2007). Water is necessary for the development of every nation and access to quality water cannot be prevented in human development (Amfo-Otu et al., 2011). Providing safe, clean, accessible and affordable water is considered to be a fundamental human right (Amfo-Otu et al., 2011).

Lakes have long been at the centre of human attention and growth of human communities but increase in irresponsible use of water resources has affected river and lake water qualities (Sanchez and Manuel, 2007).This may be due to increase in population and pollution caused by toxic wastewater, surface runoffs from domestic and agricultural sources discharged into water bodies which have increased pollution load and further limited healthy water resources (Simeonov et al., 2003). Knowledge and understand of surface water quality for various purposes such as drinking, recreation and irrigation are essential for water resources management. Knowledge of point sources of pollution and pollutant in the catchment area are requirement for appropriate use of water resources (Simeonov et al., 2003).

Lake and surface reservoirs are nature’s most critical freshwater resources and have a number of uses. They are used for domestic, irrigation purposes and provide ecosystems for aquatic life especially fish which is a source of essential protein and for significant element of the world’s biological diversity. They serve as tourism and recreation purposes and are culturally and aesthetically important for people all over the world. They are essential for flood control (An et al., 2002).

An important chemical parameter for assessing the degree of suitability of water for irrigation is sodium content, which is expressed as the sodium adsorption ratio (SAR) measures the potential dangers posed by excessive sodium in irrigation water (Alagbe, 2006). When residual sodium carbonate (RSC) is positive, calcium is lost from the soil solution and increases SAR in the soil solution, thereby increasing the sodium hazard. Apart from the SAR and RSC, other factors have such as soluble sodium percentage (SSP), electrical conductance (EC), Magnesium adsorption ratio (MAR), Kelly's ratio (KR), total hardness (TH), permeability index (PI) and residual sodium bicarbonate (RSBC) have been used to assess the suitability of water for irrigation (Raihan and Alam, 2008: Richards, 1954).

The quality of freshwater is mainly affected by natural processes such weathering and soil erosion as well as anthropogenic activities. The anthropogenic activity represents a constant polluting source whereas surface runoff is a seasonal phenomenon, mainly affected by climatic conditions (Singh et al., 2004). Water quality monitoring has a high priority for the determination of current conditions and long term trends for effective management. Therefore it is important to frequently monitor water quality used for various purposes. Lake Bosomtwe lie in an area where farming activities is the main occupation but rain fed agriculture is predominant in the catchment area. It is however not clear in literature if the water quality is suitable for irrigation purposes. Therefore this study aims at using correlation analysis in assessing irrigation water quality parameters of water from Lake Bosomtwe.

Materials and methods

Lake Bosomtwe is situated 35 km southeast of Kumasi in the Ashanti Region of Ghana. Kumasi is about 150km from the coast, and has an elevation of 310m above mean sea level (Michael 1992). Other nearby towns includes Konongo (elevation 233m), 30km to the northeast of the lake, and Bekwai (elevation 230m), and 20km to the southwest. Lake Bosomtwe lies in an isolated closed basin entirely surrounded by the Pra River basin, which has an area of 22500km^2 and has climate, vegetation, and bedrock similar to the lake basin (Figure. 1).

Figure 1. Map of Ghana showing the locationof Lake Bosomtwe and Pra River basin (Asamoah et al., 2015)

Lake Bosomtwe is found in a roughly circular closed basin which was formed by a large meteor impact. The crater, which occurs in Precambrian bedrock of schist and intruding granites is about 11 km in diameter and has an area of 106 km^2, of which 52 km^2 are covered by the lake. The deepest part of the lake has an elevation of 21 m above mean sea-level, and the highest point on the rim has an elevation of 460m. The basin is surrounded by steep slopes which rise from the lake edge at 99m, to 460m over a distance of about 1.5km (Michael 1992). The lowest point on the rim of the crater has an elevation of 210m, which is the elevation at which the lake will overflow (Michael, 1992). Just to the south of the basin lies the Obosum Range, this has a peak of 710m. The plain lying to the west, north and east of the basin has a typical elevation of 240m. The lake's watershed is surrounded by forest and cultivated land. During the fieldwork it was realized that the lake is surrounded by 21 small villages with an aggregate population of about 1000 people. As the lake water is barely potable, little is ever drawn from the lake. Instead, villagers make use of boreholes for domestic activity. It was also realized that no stream or lake water is used for irrigation or industrial purposes as a result of the high concentration of sodium ions as indicated by the villagers. (Figure 2). The lake is the habitat for mainly tilapia fish and a few cat and mud fishes.

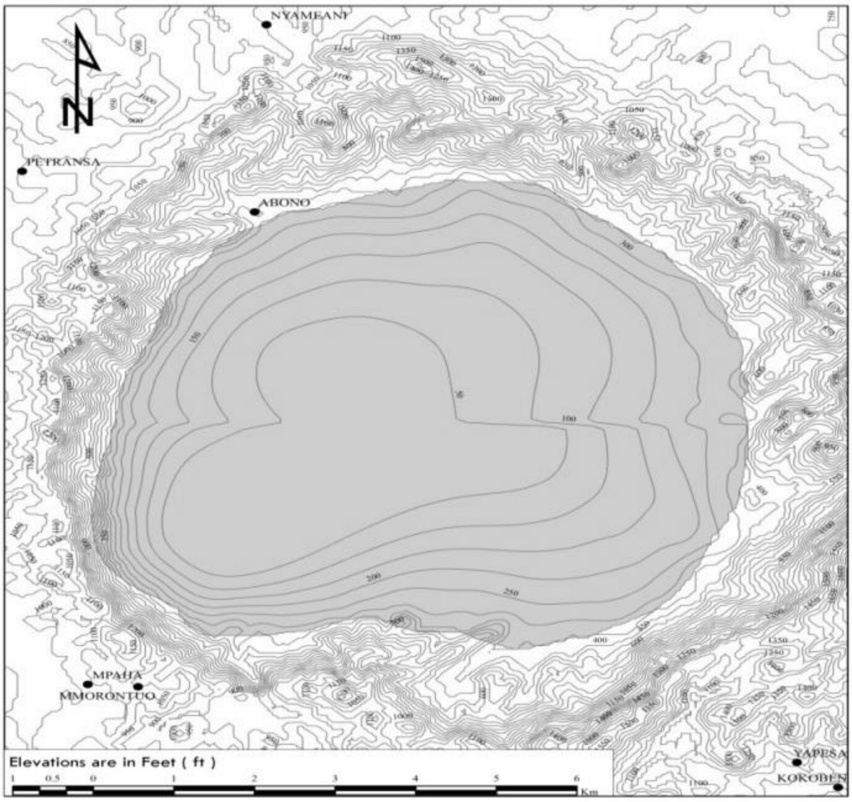

Figure 2: Map of Lake Bosomtwe showing watershed boundary

(Asamoah et al., 2015)

The climate is characterized by a dry season between December and February, highest rainfall in June, and a cooler and drier period in August with smaller rainfall in October.

Because the area of the watershed is small compared to that of the lake, 80% of the water that enters the lake annually is from rainfall on its surface which makes the water balance of the basin extremely sensitive to small changes in annual rainfall. The average monthly temperature ranges from 23.2^{o}C in August to 26.8^{o}C in February, and average monthly humidity range from 84.7% in August to 75.3% in January (Michael, 1992).

The data used for the correlation analysis was obtained from the research previously done by Asamoah et al, 2015. These data were used to estimate the Sodium Adsorption Ratio (SAR), the Soluble Sodium Percentage (SSP), the Residual Sodium Carbonate (RSC) and Kelly's ratio using the relationships described by Richards (1954), Todd (1980), Eaton (1950) and Kelly (1953) respectively.

According to Richards (1954), sodium adsorption ratio (SAR) is expressed as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + mg^{2+}}{2}}}$$

Todd defined soluble sodium percentage (SSP) as:

$$SSP = \frac{Na^{+} + K^{+}}{Ca^{2+} + mg^{2+} + Na^{+} + K^{+}} \times 100$$

Eaton expressed residual sodium carbonate as:

$$RSC = \left[HCO_3^{-} + CO_3^{2-}\right] - \left[Ca^{2+} + mg^{2+}\right]$$

Kelly also described Kelly's ratio as:

$$KR = \frac{Na^{+}}{Ca^{2+} + mg^{2+}}$$

Statistical Analysis

Data collected were subjected to statistical analysis SPSS version 20. Pearson correlation coefficient was calculated to test the degree of relationship between irrigation water quality parameters. This was computed using the relation:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right] * \left[n\sum y^2 - \left(\sum y\right)^2\right]}}$$

According to Pallant 2011, a correlation coefficient can be described as: small correlation - $0.10 \leq r \leq 0.29$, medium correlation - $0.30 \leq r \leq 0.49$ and large correlation - $0.50 \leq r \leq 1.0$. The positive and the negative point to the direction of the relationship, where the positive indicates an increase in one variable associated with an increase in the other, whilst the negative correlation means an increase in one variable related to a decrease in the other. The coefficient of determination which explains the changes in one variable as explained by the changes in the other variable (r^2) was calculated.

Results & Discussion

The basic criteria for evaluating the irrigation water quality are calculations of SAR (Sodium Absorption Ratio), which is the measure of sodicity of the water, SSP (sodium soluble percentage), RSC (Residual sodium carbonate), KR (Kelly ratio), cations and anions which were obtained from the research previously done by Asamoah et al., 2015).

Correlation Analysis

From the Pearson correlation coefficient SAR showed positive correlation with SSP (r= +0.753), KR (r= +0.717), Na^+ (r= +0.318) and K^+ (r= +0.496) as in table 3. This implies that changes in SSP, KR, Na^+ and K^+ are associated with SAR. The degree of the association for SSP and KR with SAR is stronger and positive, implying that an increase in SAR is associated with an increase in SSP and KR. This may be so because they are all determined by using almost the same cations with some variations in the factors and are pointing to the same fact from different perspectives. The correlation for Na^+ and K^+ were also positive but medium. This is expected for Na^+ since an increase in SAR indicate high availability of Na^+ in the irrigation water and hence in soils. The sodium hazard or SAR is expressed in terms of classification of irrigation water as low (S1: <10), medium (S2: 10 to 18), high (S3: 18 to 26) and very high (S4: > 26) as shown in figure 3. A high SAR value implies a hazard of sodium (alkali) replacing Ca^{2+} and Mg^{2+} in the soil through a cation exchange process that damages soil structure, mainly permeability, and which ultimately affects the fertility status of the soil and reduces crop yield (Gupta, 2005).

The values of SAR of the water samples from the study area ranged from 17.59 to 19.70 with an average value of 18.47 as in Table 1. According to Richards, 1954, for salinity classification (Figure 3), all the irrigation water samples fell under high sodium hazard (S3) and low salinity hazard (C1). Salinity classification was done using the diagram in figure 3, as given by US salinity laboratory. The diagram classifies 16 classes with reference to SAR as an index of sodium hazard and EC as an index of salinity hazard. The average Soluble Sodium Percentage (SSP) value was found to be 94%. Base on the classification after Todd, (1980) for SSP, all the 10 water samples fell under 'poor' class. It is clear in table 1 that the highest Residual Sodium Carbonate (RSC) value of the irrigation water analyzed was 20.60 meq/l with a mean of 20.36meq/l. According to Raihan and Alam (2008), a positive RSC value means that the level of dissolved Ca^{2+} and Mg^{2+} ions is less than that of CO_3^{2-} and

HCO_3^-. This is true for this study where the Ca^{2+} and Mg^{2+} is less than CO_3^{2-} and HCO_3^- as in table 1. RSC is not satisfactory in this study because according to Gupta 2005, a good water quality for irrigation should have RSC value less than 5meq/l, but in this case all RSC values were more than the 5 meq/l.

Also SAR showed negative correlation with Ca^{2+} (r = -0.725), Mg^{2+} (r = -0.430), HCO_3^- (r = -0.830) and CO_3^{2-} (r = -0.849) which implies that high values of SAR is associated with decrease in the above chemical parameters and vice versa. The negative association is expected because it is denominator in the formula for calculating the SAR. This means higher concentrations of Ca^{2+} and Mg^{2+} are related to decrease in SAR value for the irrigation water. The values of HCO_3^- and CO_3^{2-} varied from 10.25 to10.79meq/l and 10.00 and 10.50meq/l with average values of 10.74meq/l and 10.34meq/l. In terms of degree of restriction on use of HCO_3^- and CO_3^{2-} they fall under category of 'none'. Irrigation water rich in HCO_3^- tends to precipitate insoluble Ca^{2+} and Mg^{2+} in the soil which ultimately leaves higher proportion of Na^+ to be available in solution and increase the SAR value (Singh et al., 2004).

According to Ayers and Westcot 1985, although ordinary HCO_3^- is not toxic it can cause zinc deficiency in rice and this is severe when zinc exceeds 2meq/l in water used for flooding growing paddy rice. Kelly, 1953 also suggested that KR for irrigation water should not exceed 1.0 but all the results obtained exceeded 1.0 showing that the water is not suitable for irrigation.

At the same level of salinity and SAR, adsorption of Na^+ by soils and clay mineral is greater at higher Mg : Ca ratio. This is because the bonding energy of Mg^{2+} is less than that of Ca^{2+}, allowing more Na^+ adsorption and it happens when the ratio exceeds 4.0 (Michael, 1992). Ayers and Westcot, 1985, also reported that soil containing high level of exchangeable Mg^{2+} causes an infiltration problem. In all the water samples analyzed, the ratios of Mg^{2+} and Ca^{2+} were greater than 1.0 as shown in Table 1. It therefore indicates that there is no healthy proportion between Ca^{2+} and Mg^{2+} and this can leads to a bad permeability and tilth problems of the irrigated soil (Ayers and Westcot, 1985). Also the ratio of Na^+ to Ca^{2+} showed low suitability as irrigation water. The presence of high Na^+ in irrigation water promotes soil dispersion and structure breakdown when Na^+ to Ca^{2+} ratio exceeds 3.1 (Michael, 1992). This also results in severe water infiltration problems, mainly due to insufficient Ca^{2+} to suppress the dispersing effect of Na^+ (Ayers and Westcot, 1985). Excessive Na^+ also creates problems in crop water uptake, poor seedling emergence, lack of aeration, plant and root disease (Ayers and Westcot 1985).

Table 1: Values of irrigation water quality parameters by Asamoah et al., 2015

Location	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	CO_3^{2-}	SAR	SSP	RSC	KR	Ca:Mg
	meq/l							%	meq/l		
1	0.15	0.52	10.87	1.08	10.65	10.33	18.74	95	20.31	16.22	3.5
2	0.17	0.62	11.08	1.09	10.78	10.51	17.59	94	20.50	14.03	3.7
3	0.15	0.58	10.82	1.10	10.70	10.43	18.03	94	20.40	14.82	3.9
4	0.14	0.58	11.26	1.12	10.25	10.00	19.70	95	19.53	15.64	4.1
5	0.14	0.54	10.87	1.11	10.44	10.19	18.74	95	19.95	15.99	3.9
6	0.15	0.56	10.87	1.09	10.79	10.42	18.12	94	20.50	15.31	3.7
7	0.15	0.54	11.00	1.08	10.79	10.50	18.64	95	20.60	15.94	3.6
8	0.15	0.59	11.22	1.10	10.64	10.33	18.39	94	20.23	15.16	3.9
9	0.15	0.58	11.17	1.08	10.66	10.33	18.31	94	20.26	15.30	3.8
10	0.14	0.58	11.04	1.10	10.69	10.33	18.40	94	20.30	15.33	4.1
Mean	0.15	0.57	11.04	1.10	10.74	10.34	18.47	94	20.36	15.33	3.8

Table 2: Correlation coefficients among selected water Quality parameters

Variates		Ca	Mg	Na	K	HCO_3^-	CO_3^-
Ca		1					
Mg		.473	1				
		.167					
Na		.008	.549	1			
		.983	.100				
K		-.515	.239	.235	1		
		.127	.507	.513			
HCO_3^-		.608	.086	-.365	-.784**	1	
		.062	.812	.300	.007		
CO_3^{2-}		.700*	.124	-.384	-.743*	.971**	1

		.024	.732	.273	.014	.000	

Table 3: Correlation coefficients among selected water quality parameters (continuation)

Variates		SAR	SSP	RSC	KR
		-.725	-.393	.598	-.702
Ca		.018	.261	.068	.024
		-.430	-.707	.001	-.910
Mg		.215	.022	.998	.000
		.318	-.107	-.437	-.197
Na		.370	.768	.207	.585
		.496	.159	-.796	-.015
K		.145	.661	.006	.966
		-.830	-.536	.991	-.375**
HCO_3^-		.003	.110	.000	.285
		-.849*	-.465	.983	-.437*
CO_3^{2-}		.002	.176	.000	.206
			.753	-.803	.717
SAR		1	.012	.005	.020
SSP		.753	1		
		.012			
RSC		-.803	-.441	1	
		.005	.202		
KR		.717*	.774**	-.312	1
		.020	.009	.380	

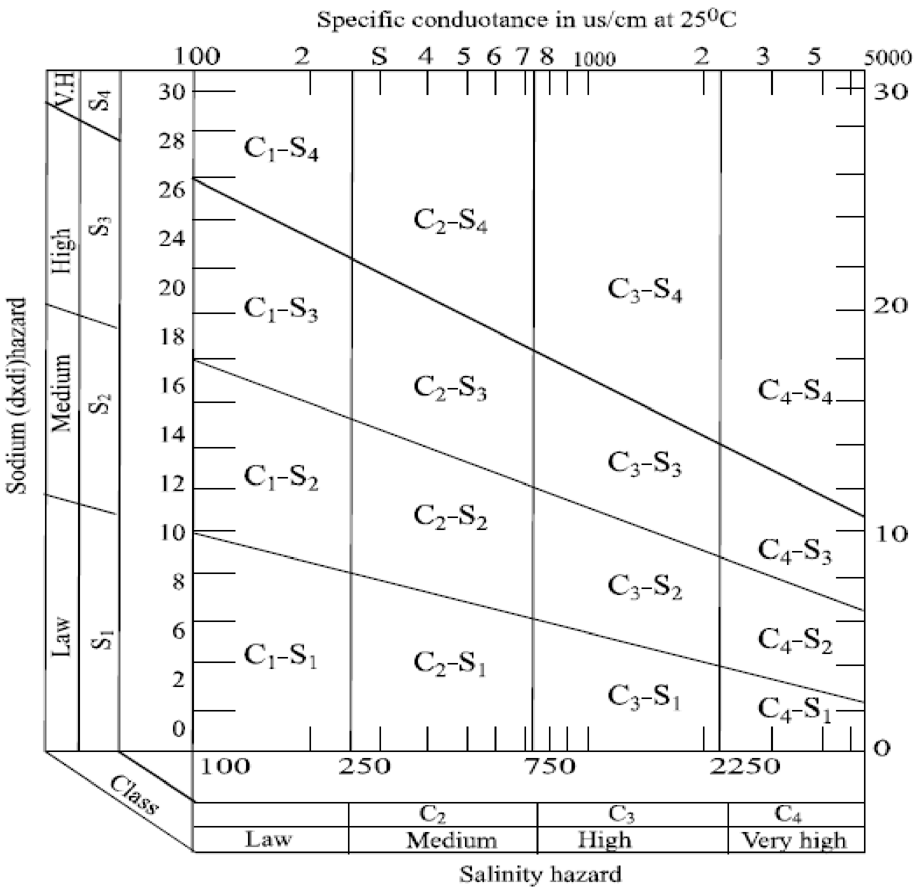

Fig. 3 Salinity classification of irrigation water samples (Richards, 1954).

Conclusions

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. Based on the values for SAR, SSP, RSC and KR of the water samples from Lake Bosomtwe analysed, it is obvious that the quality are not within the permissible limits for irrigation water and therefore not suitable for irrigation purpose. If farmers are using the water for irrigation purposes, they should know that their yield, soil properties will be affected. It is important to conduct an assessment among farmers living at the fringes of the Lake if they have been using the Lake water for irrigation. These will be important to advise them appropriately. The effect of the water on their crop productivity and soil quality can also be examined in future studies. SAR showed negative correlation with Ca^{2+}, Mg^{2+}, HCO_3^- and CO_3^- implying that a decrease in these values increases the SAR. Therefore to make the water suitable for irrigation these parameters need to be corrected. Analysis of these parameters will help in putting proper water resources management system in place for the utilisation of the water in Lake Bosomtwe.

Acknowledgments

Authors express their deepest appreciation to the management of Lake Bosomtwe and the errand boys for providing us the necessary support during water sampling.

References

[1] Alagbe, S. A. (2006). Preliminary evaluation of hydrochemistry of the Kalambaina formation, Sokoto Basin, Nigeria, Environmental Geology. 51, 39-45.

[2] Amfo-Otu, R. Wiafe, E. D., Kocke, B. B. (2011). Assessment of water quality in Ahor Lake-Ghana. African Journal of Environmental Science and Technology Volume 5(12) pp. 1093-1099).

[3] An, Y. J., Kampbell. D. H., Sewell. G.W. (2002). Water quality at five marines in Lake Taxomas related to methyltert- butylether (MTBE). Environmental Pollution, 118: 331-336.

[4] Asamoah, E., Nketia, K. A., Sadick, A., Gyambibi, K. A., Forkuo, E. K., Ayer, J. and Adjei, E. O. (2015). Water Quality Assessment of Lake Bosomtwe for Irrigation Purpose. International Journal of Agricultural and Crop Sciences. Vol 8(3), 366-372

[5] Ayres, R. S., Westcot D.W., (1985). Water Quality for Agriculture. Irrigation and Drainage Paper No. 29. Food and Agriculture Organization of the United Nations. Rome. p. 1-117.

[6] Eaton, F. M. (1950). Significance of carbonate in irrigation waters. Soil Science 95, 123-133

[7] Gupta, P.K. (2005). Methods in Environmental Analysis: Water, Soil and Air. Agrobios, Jodhpur, India, pp. 1-127.

[8] Kelly, W. P. (1953). Use of Saline Irrigation Water. Soil Science, 95: 355-391.

[9] Michael, A. M. (1992). Irrigation Theory and Practices. Vikash Publishing House Pvt. Ltd., New Delhi, India. pp. 686- 740.

[10] Oluduro. A. O, Adewoye. B. I. (2007). Efficiency of moringa Oleifera Sead extract on the micro flora of surface and ground water J. plant Sci. 6: 453-438.

[11] Pallant, J. 2011. SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS fourth Edition. Allen & Unwin, Australia.

[12] Raihan, F. and Alam, J.B. (2008). Assessment of groundwater quality in Sunamganj of Bangladesh. Iranian Journal of Environmental Health Science & Engineering. 5, 155-166.

[13] Richards, L. A. (1954). Diagnosis and Improvement of Saline and Alkali Soils, U. S. Department of Agriculture Handbook, Vol. 60, Washington D. C., USA. p.160.

[14] Sanchez. E., Manuel. F. (2007). Use of the water quality index and dissolved oxygen deficit as simple Indicators of watersheds pollution. Ecological Indicators, 7: 315–328.

[15] Simeonov, V., Stratis, J.A., Samara, C., Zachariadis G., Voutsa, D., Anthemidis, A., Sofoniou, M.,Kouimtzis, T. h. (2003). Assessment of the surface water quality in Northern Greece. Water Res, 37: 4119–4124.

[16] Singh. K.P., A. Malik. D. Mohan and S. Sinha. (2004). Multivariate Statistical Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality of Gomti River (India) - a Case Study. Water Research, 38 (18): 3980-3992.

[17] Todd, D. K. (1980). Ground Water Hydrology. 2nd ed., John Wiley and Sons Inc. New York, USA. pp. 10 138. 14.