IRRIGATION WATER QUALITY ASSESSMENT OF SHALLOW QUATERNARY ALLUVIAL AQUIFER SYSTEMS IN OGBIA, BAYELSA STATE, NIGERIA

Udom G. J[1], Nwankwoala H. O[1] and Daniel T. E[2]

[1]Department of Geology, University of Port Harcourt, Nigeria
[2]Bayelsa State Ministry of Water Resources, Yenagoa, Nigeria

ABSTRACT: *Study of groundwater quality has been undertaken in Ogbia, Bayelsa State, Nigeria to assess the suitability of groundwater for irrigation. Knowledge of the effect of irrigation water on soil properties is very important in the area in order to maintain good soil productivity. This study therefore is aimed at determining whether the groundwater in the study area can be used for agricultural purposes. The research was based on the result obtained from the calculated Sodium Adsorption Ratio (SAR). The SAR is the most useful parameter used in the determination of the suitability of the groundwater of any area for agricultural purposes. The calculated SAR for groundwater ranges from 3I.06 to 65.23mg/l, indicating that the groundwater samples, showed low salinity and very high sodium water for irrigation purposes for most soils and crops with danger of development of exchange sodium and salinity. This shows that the groundwater samples are not suitable for irrigation. High SAR values (>I0) could cause sodium to replace adsorbed calcium or magnesium, thereby damaging the soil structure.*

KEYWORDS: Irrigation Water, Sodium Absorption Ratio, Coastal aquifer, groundwater, Salinity

INTRODUCTION

Water plays an important role in promoting agricultural production and standard of human health (Raju *et al*., 2013). The quality and the suitability of groundwater for human consumption and for domestic purposes are determined by its physical, chemical and bacteriological properties. The development and management of groundwater plays a vital role in agricultural production, for poverty reduction, environmental sustenance and sustainable economic development.

Rapid industrialization, urbanization and population growth as well fragile ecology has put tremendous pressure on the water regime. This has resulted in the degradation of both surface and groundwater quality. Both geogenic and anthropogenic reasons are responsible for groundwater quality degradation. The present study was carried out to assess the quality for irrigation purposes in the area.

This demand has led to the use of groundwater not only for its wide spread occurrence and availability but also for its constituent good quality which makes it ideal supply of drinking water. Groundwater has long been considered as one of the purest forms of water available in nature and meets the overall demand for rural and semi-rural people. This was considered as the major source of water for human activities especially in the rural area.

Groundwater is one of the important sources of water supply in Ogbia Local Government Area. This is because most of the available surface water in the area is generally polluted with solid and other wastes generated from oil activities. Most of the groundwater quality in Bayelsa State, Nigeria is of poor quality. The problems and management of poor quality water are different in coastal regions (Sathiyamurthi and Saravanan, 2013). Due to tidal effects and ingress of seawater, majority of the soils of coastal areas of Bayelsa State become saline. Such a salinity problem becomes more hazardous, particularly in the post-rainy season and hampers the pace of production and economic prosperity tremendously and poses serious management problems due to non-availability of good quality water for leaching and irrigation purposes.

In majority of Bayelsa State, particularly Ogbia area, poor quality groundwater is the only source of irrigation. Knowledge of the effect of irrigation water on soil properties is very important in the area in order to maintain good soil productivity.

Water is very essential for the lives of human beings in any society. According to World Health Organization (WHO, 2004), most diseases in human beings are caused by poor quality of water. The groundwater in the study area has been observed to be of poor quality. It therefore becomes imperative to understudy the groundwater quality condition of the area in order to obtain information on the groundwater quality status, especially its use for irrigation purposes.

The study Area

The study area is located within the lower section of the upper flood plain deposits of the sub-aerial Niger Delta (Allen, I965). It lies between latitudes 4^0 33'N and 5^0 00'N and longitudes 6^0 I5'E and 6^0 29'E (Fig. 1). The area is bounded on the north by Yenagoa, the capital of Bayelsa State and Mbiama town in Rivers State, and on the south by Brass and Nembe local government areas of Bayelsa State. It is also bounded on the west by southern Ijaw and Ahoada-west local government areas of Bayelsa State and Rivers State respectively. The area can be accessed on the north by the Mbiama-Yenagoa road and on the south by the Nembe and Brass Rivers. Most part of the area is motorable, hence there is a network of roads that links the different parts of the area and its environs.

The Benin Formation (overlain by quaternary deposits in some places) is the water bearing zone of the area. The sand and sandstones of the Benin Formation are coarse to fine, commonly granular in texture and can be partly unconsolidated. The sands may represent upper deltaic plain deposit and/or braided stream point bars and channel fills. The Shales are few and thin and may represent back swamp deposits (Etu-Efeotor, 1981). It is overlain by quaternary deposits (40 - I50m thick) and generally consists of rapidly alternating sequence of sands and silty clays with the latter become increasingly more prominent seawards (Akpokodje, I990). The clayey intercalations within the Benin Formation have given rise to multi- aquifer system in the area (Etu-Efeotor, I98I; Etu-Efeotor and Odigi, I983; Etu-Efeotor and Akpokodje, I990). The first aquifer is commonly unconfined while the rest are confined. The average depths for boreholes in the study area are between 50 and 60 meters (Ala *et al.*, 2001).

Deep boreholes in the study area tap water from the confined aquifer from depths up to about 200m. The study area has been noted to have poor groundwater quality due to objectionable high concentration of certain groundwater parameters and encroachment of saltwater or brackish water into the freshwater aquifers (Nwankwoala & Udom, 2011; Nwankwoala, 2013).

The static water level in the area ranges from 0 - 1m during the rainy season and 1 - 3m during the dry season. The main source of recharge is through direct precipitation where annual rainfall is as high as 3000mm (Amajor, 1986, I989, 1991). The water infiltrates through the highly permeable sands of the Benin Formation to recharge the aquifers. Groundwater in the area occurs principally under water table conditions (Nwankwoala & Udom, 2011).

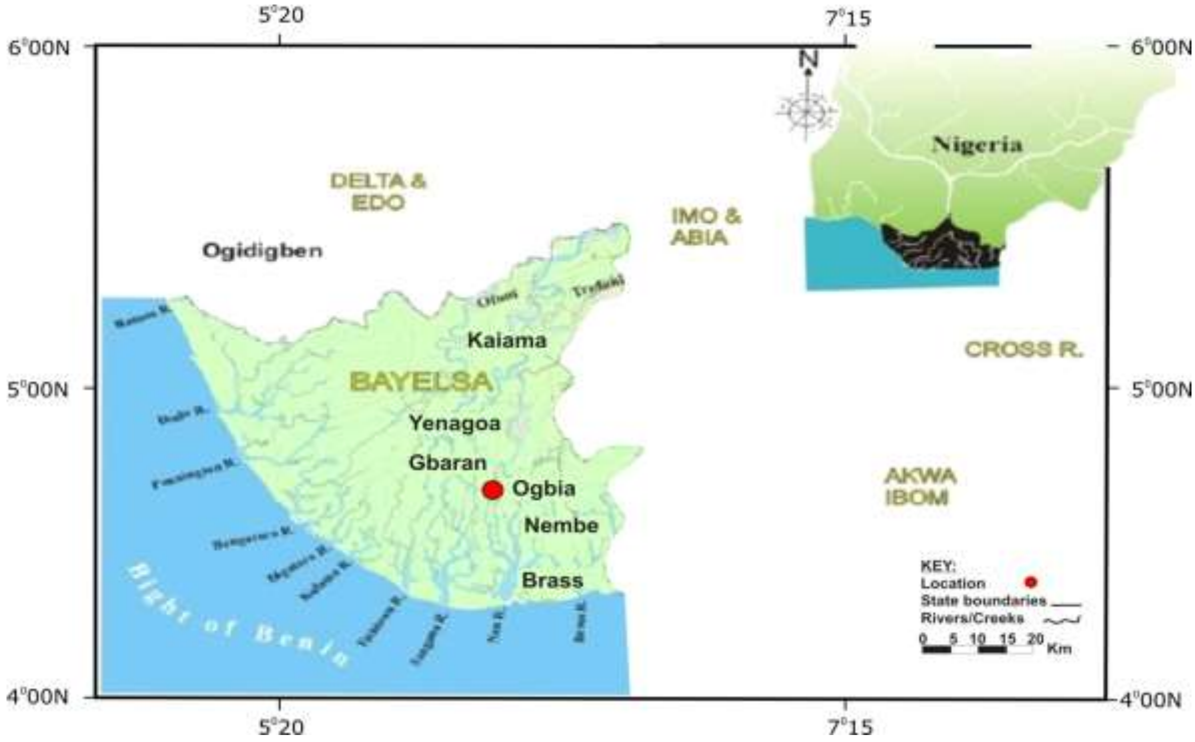

Fig. 1: Map of Bayelsa State Showing the Study Area (Ogbia)

Methods of Study

Thirty (30) groundwater samples were collected from functional boreholes selected randomly within the study area. The depths of the boreholes were between 45m-95m deep while their screen depth ranges from 35m-75m respectively. These thirty (30) groundwater samples were collected within fifteen (I5) communities. In each community, two groundwater samples were collected. This is to ensure that every part of the study area was covered. Fig.2 shows the sampling locations within the study area. A total of thirty (30) functional boreholes were sampled. Prior to the all sample collection in the field, the sample containers were rinsed with the groundwater to be collected before sampling. The sample was then collected with the I.5 litres plastic bottles after allowing the borehole to run for about five (5) minutes.

The sample was collected close to the well head and the bottle filled to the brim. After each sample collection, the bottle lid was immediately replaced to minimize oxygen contamination and the escape of dissolved gases. The sample collected was transported to the laboratory for analysis within twelve (I2) hours.

Samples meant for anion determination were acidified and the choice of acid depended on the anion. For example, sample meant for Iron determination was primed with 0.5M solution of nitric acid to keep the Iron in solution and all groundwater samples were properly labeled. The co-ordinates of all the sampling locations were recorded using Geographic Positioning System

(GPS) garmin channel 78 model (Table 1). The temperatures of the samples were also recorded in the field using thermometer. The analytical data quality was ensured through careful standardization, procedural blank measurement and duplicate sample.

Table 1: Sampled Locations and their Co-ordinates.

s/n	Locations/Communities	Latitude	Longitude
I	Otuasega	04 54’32.5”	006 23’03.3”
2	Otuasega	04 55’04.5”	006 24’I3.8”
3	Oruma	04 55’03.0”	006 24’56.3”
4	Oruma	04 55 ’02.5”	006 24’49.8”
5	Imiringi	04 52’3I.0”	006 22’4I.2”
6	Imiringi	04 5I’I2.9”	006 22’33.2”
7	Elebele	04 5I’08.9”	006 20’52.6”
8	Elebele	04 5I’36.5”	006 20’47.5”
9	Emeyal	04 50’28.8”	006 2I’09.6”
I0	Emeyal	04 50’08.7”	006 2I’0I.0”
I I	Otuoke	04 48’I4.3”	006 I9’38.I”
I2	Otuoke	04 47’24.2”	006 I8’55.8”
I3	Otuokpoti	04 49’57.7”	006 I6’3I.0”
I4	Otuokpoti	04 50’23.7”	006 I6’25.9”
I5	Onuebum	04 48’24.4	006 I5’42.8”
I6	Onuebum	04 48’33.9”	006 I5’38.2”
I7	Kolo	04 48’38.I”	006 22’36.2”
I8	Kolo	04 47’5I.6”	006 22’35.0”
I9	Otakeme	04 44’27.3”	006 22’09.7”
20	Otakeme	04 42’55.3”	006 2I’4I.2”
2I	Otabagi	04 42’3I.8”	006 2I’53.I”
22	Otabagi	04 42’39.2”	006 22’00.7”
23	Ogbia Town	04 4I’I6.4”	006 I9’2I.3”
24	Ogbia Town	04 4I’I3.4”	006 I8’52.6”
25	Oloibiri	04 40’23.0”	006 I8’56.3”
26	Oloibiri	04 40’I5.5”	006 I8’49.8”
27	Opume	04 39’37.9”	006 2I’29.4”
28	Opume	04 39’36.5”	006 2I’II.8”
29	Akipilai	04 37’49.2”	006 20’2I.4”
30	Akipilai	04 37’50.6”	006 20’I3.8”

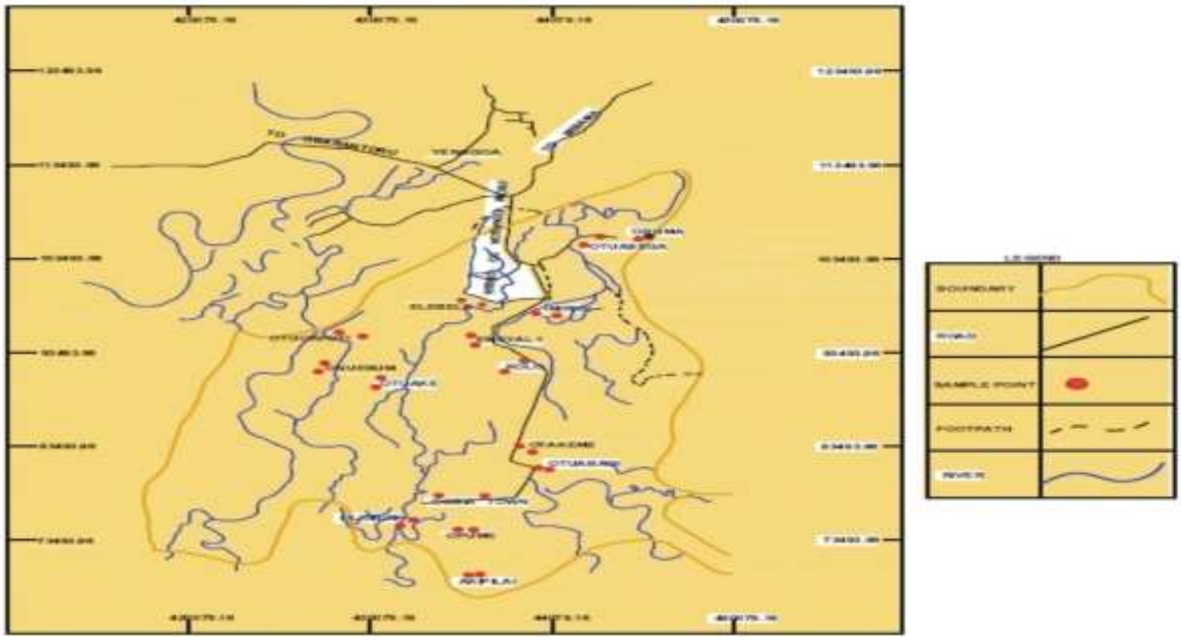

Fig.2: Sampling Locations of the Study Area

Determination of Sodium Absorption Ratio (SAR)

Water used for irrigation can be rated based on salinity hazard and sodium/alkali hazard, according to the method formulated by U.S Salinity Laboratory (1954). This method utilizes SAR and conductivity as a basis for rating irrigation water. To determine whether the groundwater in the study area can be used for agricultural purposes will be based on the result obtained from the calculated sodium adsorption ratio (SAR). This is the most useful parameter that is use to determine the suitability of the groundwater of any area for agricultural purposes.

Sodium is introduced into the aquifer in the area from rainwater and dissolution from rocks. Due to its effects on soil and plants, sodium is considered one of the major factors governing irrigation water (U.S.A. Salinity Laboratory, I954; Offodile, 2002). Suitability of water for irrigation is based on the sodium absorption ratio (SAR). SAR is calculated from the ionic concentrations of Na, Ca and Mg (constituent values are expressed in meq/l, Richard, I954).

$$SAR = Na/\sqrt{(Ca + Mg)/2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Ca^{2+}, Na^{2+} and Mg^{2+} have been used to calculate sodium adsorption ratio (SAR) for the water samples. The ratio is used to assess the suitability of the water for irrigation. The calculated SAR values were obtained from the analyzed water samples and results shown in Table 2.

RESULTS AND DISCUSSION

Table 2: Sodium Adsorption Ratio (SAR) calculated values

Borehole s/n	SAR Values(mg/l	Water class (SAR >26)
Borehole I	32.860	Unsuitable for irrigation
Borehole 2	3I.750	Unsuitable for irrigation
Borehole 3	35.53I	Unsuitable for irrigation
Borehole 4	38.490	Unsuitable for irrigation
Borehole 5	30.I00	Unsuitable for irrigation
Borehole 6	3I.064	Unsuitable for irrigation
Borehole 7	34.606	Unsuitable for irrigation
Borehole 8	55.858	Unsuitable for irrigation
Borehole 9	35.665	Unsuitable for irrigation
Borehole I0	55.3II	Unsuitable for irrigation
Borehole II	44.499	Unsuitable for irrigation
Borehole I2	40.799	Unsuitable for irrigation
Borehole I3	3I.306	Unsuitable for irrigation
Borehole I4	32.359	Unsuitable for irrigation
Borehole I5	34.I99	Unsuitable for irrigation
Borehole I6	34.338	Unsuitable for irrigation
Borehole I7	35.432	Unsuitable for irrigation
Borehole I8	36.728	Unsuitable for irrigation
Borehole I9	55.5I2	Unsuitable for irrigation
Borehole 20	65.232	Unsuitable for irrigation
Borehole 2I	4I.64I	Unsuitable for irrigation
Borehole 22	33.946	Unsuitable for irrigation
Borehole 23	5I.I8I	Unsuitable for irrigation
Borehole 24	49.422	Unsuitable for irrigation
Borehole 25	42.980	Unsuitable for irrigation
Borehole 26	40.7I2	Unsuitable for irrigation
Borehole 27	33.028	Unsuitable for irrigation
Borehole 28	58.776	Unsuitable for irrigation
Borehole 29	32.703	Unsuitable for irrigation
Borehole 30	36.97I	Unsuitable for irrigation
Maximum	65.232	
Minimum	3I.306	
Mean	37.366	
	Standard	SAR>26 very high (Johnson, I975)

Salinity and Sodium Hazards

The groundwater quality requirements for irrigation purpose affect the agricultural productivity. The chemical parameters which decide the suitability for irrigation are electrical conductance, total dissolved solids, relative proportions of Na to Ca and Mg, relative proportions of HCO_3 to Ca and Mg etc. For irrigation point of view, the total concentration of soluble salts in water is responsible for salinity hazard since salt tolerance capacity varies in different plant species. Soils containing chloride and sulphate as dominant ions are known as saline soils.

Sodium has a tendency to reduce the permeability of soil after reacting with it. Alkali soils containing large proportions of sodium and carbonate do not support plant growth. The unsuitability of groundwater of the study area is classified on the basis of SAR. The sodium adsorption ratio (SAR) is recommended as the measure of the suitability or unsuitability of water for irrigation by the U.S Salinity Laboratory, Department of Agriculture.

According to Richards (I954), the concentration of soluble salt for irrigation is classified into four classes based on electrical conductivity and SAR. The various classes of salinity hazard Include, C1 (EC<25µs/cm) Low, medium C2 (EC250-750µs/cm), high C3 (EC 750-2250µs/cm), and very high C4 (EC>2250µs/cm). The sodium hazard classes include, low S1 (SAR<I0), medium S2 (SAR I0-I8), high S3 (SAR I8-26), and very high S4 (SAR>26). Water with high EC leads to formation of saline soil, high Sodium (Na) leads to development of an alkaline soil. The Sodium or alkaline hazard in the use of water for irrigation is determined by absolute and relative concentrations of cations.

If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of clay particles. The calculated SAR (Table 2) for groundwater ranges from 3I.06 to 65.23mg/l. This data indicate that the groundwater samples falls between S4, showing low salinity and very high sodium water for irrigation purposes for most soils and crops with danger of development of exchange sodium and salinity. This shows that the groundwater samples are not suitable for irrigation. Also, according to Johnson (I975), SAR values below I0mg/l are good for irrigation. High SAR values (>I0) could cause sodium to replace adsorbed calcium or magnesium, thereby damaging the soil structure.

When the concentration of sodium is high in irrigation water, sodium ions tend to be adsorbed by clay particles, displacing magnesium and calcium ions. The exchange process of sodium in water for magnesium and calcium in soil reduces permeability and eventually results in soil with poor drainage. Hence, air and water circulation is restricted during wet conditions and such soils are very hard when dry (Collins and Jenkins, 1996; Saleh *et al*, I999).

CONCLUSION

The results showed that I0% of the water samples were in the excellent category, 46.6% were in the good water category while 43.3% of the water samples were in the poor water category. Also from the result of the sodium adsorption ratio (SAR), it indicates that, the groundwater is not suitable for irrigation. This study also revealed that when the concentration of sodium is high in irrigation water, sodium ions tend to be adsorbed by clay particles, displacing magnesium and calcium ions. The exchange process of sodium in water for magnesium and calcium in soil reduces permeability and eventually results in soil with poor drainage. Hence, air and water circulation is restricted during wet conditions and such soils are very hard when dry.

Injudicious exploration of irrigation water and sea water ingress is the major factor that may lead to higher concentrations of Na and Cl in the irrigation water in the area. There is therefore the need for regular monitoring and characterization of irrigation water for improvement in agronomic techniques as well as introduce appropriate steps to also make irrigation waters better in quality in the area.

REFERENCES

Akpokodje, E.G. (1987): Engineering geological characteristics and Classification of the Major Superficial Soils of the Niger Delta. *Engineering Geology*, 23: 193 – 211

Allen, J. R. L (I965). Coastal Geomorphology of the eastern Nigerian beach ridges and vegetated tidal flats. *Geology and Mining*, Mijabonw, Vol. 44, pp 2-20.

Amajor, L. C (1989). Geological appraisal of groundwater exploitation in the Eastern Niger Delta, In: C. O Ofoegbu (ed). Groundwater and Mineral Resources of Nigeria: Braunschweig/Weisbaden, Friedr Vieweg and Sihn, 85 - 100 pp.

Amajor, L.C (1986). Geochemical Characteristics of Groundwater in Port Harcourt and its Environs. Proc. Int'l Symp. on Groundwater Resources of Nigeria, Lagos, pp 358 – 375.

Amajor, L.C (1991). Aquifer in the Benin Formation (Miocene – Recent), Eastern Niger Delta, Nigeria: Lithostratigraphy, Hydraulics and Water Quality. *Environmental Geology Water Science*, Vol. 17 (2):85 – 101

Collins, R & Jenkins, A (1996). The impact of agricultural land use on stream chemistry in the middle hills of the Himalayas, Nepal. *Journal of Hydrology*, 185:71 – 86.

Etu-Efeotor, J. O and Odigi, M. I. (1983). Water Supply Problems in the eastern Niger Delta, Bulletin of Nigeria Mining & Geosc Assoc. 20; pp 183-1992.

Etu-Efeotor, J.O & Akpokodje, E.G (1990). Aquifer systems of the Niger Delta. *Journal of Mining and Geology*, Vol. 26 (2): 279-284

Etu-Efeotor, J.O (1981). Preliminary hydrogeochemical investigation of subsurface waters in parts of the Niger Delta. *Journal of Mining and Geology*, Vol. 18 (1): 103 – 328.

Johnson, E.E (1975). Groundwater and Wells. Johnson Division, UOP Inc. St. Paul MN, pp65 -80.

Nigerian Standard for drinking water Quality (NSDWQ) Guidelines, (2007) 2ed; Nigerian Industrial standard; pp14-21

Nwankwoala, H. O (2013). Evaluation of hydrochemical characteristics of groundwater in Port Harcourt, Nigeria. Unpublished Ph.D Thesis, University of Port Harcourt, Nigeria

Nwankwoala, H. O. and Udom, G. J., (2011). Studies on Ion chemistry and Hydrochemical processes of groundwater in Port-Harcourt, Southern Nigeria, *Journal of Sspatial Hydrology, Vol. 11 no. 1 spring; pp35-37.*

Odigi, M.I & Etu – Efeotor, J.O (1983). Water supply problems in the eastern Niger Delta. *Journal of Mining and Geology*, Vol.20, pp183 – 193

Offodile, M.E (2002). Groundwater Study and Development in Nigeria. Mecon Eng. Services Ltd, Jos, Nigeria. Pp239 255

Raju, S.G; Reddy, A.K; and Shivakumar, K.N (2013). Physico-chemical characteristics of groundwater in and around Kadiri Schist Belt, Anantapur District, Andhra Pradesh, India. *International Journal of Earth Sciences and Engineering*, 6(1): 119 – 127

Richards, L. A., (1954): Diagnosis and Improvement of Saline and Alkali Soils, *Agric. Handbook 60*, U.S. Department of Agric., Washington D,C. 160p.

Saleh, A; Al-Ruwaih, F & Shehata, M (1999). Hydrogeochemical processes operating in the main aquifers of Kuwait. *Journal of Arid Environments*, 42:195 - 209

Sathiyamurthi, S and Saravanan, S (2013). Multivariate analysis and quality assessment of irrigation water of coastal areas of Chidambaram Taluk. *International Journal of Earth Sciences and Engineering*, 6(1): 178 – 184.

US Salinity Laboratory Staff (1954). Diagnosis and Improvement of Saline and Alkali Soils. U.S Department of Agriculture Handbook 60.

World Health Organization (2004). Guide-lines for Drinking Water Quality: Incorporating 1st and 2nd Addenda, Vol. 1. Recommendations. – 3rd ed. Geneva.