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Journal of Environmental & Earth Sciences
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REVIEW

A Comprehensive Review of Water Quality Monitoring and Assessment in Delta State, Southern Part of Nigeria

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ARTICLE INFO

Article history
Received: 17 February 2021
Accepted: 6 April 2021
Published Online: 28 April 2021

Keywords:
Geogenic
Anthropogenic
Hydrogeochemical
Cause of pollution
Coliform
Nigeria

ABSTRACT

This research presents a review on water resources in Delta state, southern part of Nigeria, with emphasis on hydrogeochemical and microbial assessment. It evaluates factors responsible for water contamination, and their resulting health challenges within the study area. To achieve the objective of this study, related articles were downloaded from Google, published article on influence of hydrogeochemical and microbial activities on water resources. These articles were thoroughly studied. Findings from this study, suggested that groundwater was more studied than surface water. We also observed that groundwater within the riverine communities is much more prone to pollution when compared to groundwater in an upland area. Results from various authors suggested that, larger percentage of groundwater showed presence of coliform. Further findings suggested that geochemical processes such as rock water interaction, seawater intrusion and precipitation influences groundwater quality within the study area especially within Sombreiro-Warri Deltaic Plain Deposit.

1. Introduction

Water resource is a vital natural resource, utilized by millions of people across the globe for drinking, irrigation, industrial, and other use. [1] were of the view that nearly 1.1 billion people are deprived access to potable water globally, and that human life is lost every year from water- related diseases. [2] reported that for water to be of good quality, it must be colourless, odourless, tasteless and free from faecal pollution. The quality of water depends on the physicochemical and biological attribute of the water, which in turns depends on the geology of the area and also impacts of anthropogenic activities [3]. Water may be available in large quantity but if it is contaminated is considered unfit for use. It is better for water resource to be small in quantity and free from contaminations. It would have been easier to mitigate water resource pollution if the state and federal government were to be in charge of water supply for domestic use, unlike in time past (before independence) in Nigeria, were the government was in charge of water supply and it was free for inhabitant of the study area. However, in today's world water supply is strictly left in the hands of individuals this has led to individual sitting personnel borehole in their premises for domestic water use. While people living around the riverine community/ creeks solely rely on surface water (stream and river) for do-

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DOI: https://doi.org/10.30564/jees.v3i1.2900

mestic use. In most, cases individuals and governments emphasize more of water quantity rather than laying emphasis on its quality [4,5]. [6] stated that most part of the study area is richly blessed water resources, but the major concern is that the water resource of the area is highly prone to pollution/ contamination from various sources. [7] reported that globally most of the health related problems is linked to water borne disease as shown in Table 2. [8] further reported that wastewater from petroleum flow stations are continually being discharged indiscriminately into surface water resulting to impairment of water quality, especially in oil producing communities within the study area. [9,10,12,13,14,15] were of the view that pollution of water bodies was attributed to indiscriminate use fertilizers, rural-urban migration, exploration of crude oil, mismanagement of natural water resources and construction activities especially by construction companies. According to [16] there are other sources of water pollution aside oil spill, the occurrence of these oil spills and other anthropogenic activities has led to serious pollution of water resources within the study area. Some of the towns and village affected by oil spillage in study area include the following: Jesse, Opukebe, Jone Creek, Afisere, Uzere, Kwale, Ogulahga, Ozoro, Ekerejegbe, Olomoro, Ekakpare and Otorogu. [17] reported that oil exploration and exploitation in the Niger Delta especially within the creek have also undoubtedly, contributed decline in water quality. [18] further reported that groundwater pollution is on the increase across major town and cities where human activities have continuously prevailed. [18] were of the view that most sewage system construction by individuals usually lack environmental regulatory control and thus quality is compromised, thereby leading to collapse of most septic tanks which in-turn finds its way into surface and groundwater. They further reported that human wastes contain sodium (Na^+) and chloride (Cl^-) and they are often disposed in onsite septic systems and that consequently, elevated concentrations of Na^+ and Cl^- in groundwater. [19], assessed groundwater quality in residential areas close to dumpsites in Warri and environs. Their findings showed that the first aquifer in Warri from which most wells and boreholes are tapping water from, acidic water with low pH value which renders water unfit for drinking in the area except if it is treated. [20] studied groundwater in selected area across Delta state. It was the first paper to such report such holistic finding. Their results showed that the study area has low pH and low salinity. High iron content was discovered in water and there was occurrence of faecel in water. [21] reported that most of the water samples within Okwagbe in Delta state were acidic groundwater being the most acidic. [22] reported that Niger Delta is not essentially rich in nitrate. Moreover excess of nitrate in water may lead to water pollution as shown in Table 2. Previous studies have shown a significant decline of water resources in the study area [18,23,24,25,26,27,28]. Microorganisms are mostly found in surface water. In rare scenario they are found in groundwater when groundwater is directly polluted by surface water. [29], acknowledge that faecal contaminant such as *E. coli(s)* are considered to be high threat to water bodies more especially in un-planned urban were water supply is left in the hand of individuals. [30,31] were of the view that bacteriologically polluted water is considered to be highly dangerous to health because it can lead to possible outbreaks of typhoid, cholera epidemics. Different microorganisms can be found in water. [32] stated that in a practice sense it impossible to constantly check, differentiate the various kinds of disease-causing microorganism present in water. In most cases, microorganisms (colioforms) can be used to assess water for microbial contamination. [33,34] were of the opinion that coliform bacteria may not be pathogenic, but might predict the possibility, but not the certainty, of the presence of pathogenic microbes that can cause hazardous diseases. [35] further pointed out that pathogens are mostly spread by untreated or poorly treated sewage in water-borne infections. A lot of disease in this generation are related to contaminants ingested in into water bodies. According to [31] poor physicochemical quality of water may have adverse health effects causing avoidable economic and human losses. In the same vein, a detailed knowledge of geochemistry is considered paramount in evaluating the hydrochemistry of water and plan the monitoring of water quality [36,37]. [38] acknowledge that surface water on a global scale serves as recipient of great quantities of waste discharged through agriculture, industrial, domestic and petroleum related activities. This has led to pure and hygienic water scarcity, disruption of socioeconomic activities and poor aesthetic quality of most of the water bodies Although several scholar that evaluated water resources of the study area compared sampled results to water quality guidelines by [39]; [40] and it acceptability of public drinking water supplies. However, the study of [20] access groundwater quality in Delta state, Nigeria. Although the study is of upmost importance, as it extensively discusses groundwater quality in the aforementioned area, but the study was undertaken more than 12 years ago. It is of upmost importance to carry out this study and establish the current status of groundwater in Delta state. The present study reports the major results of research focused on effect of microbial, anthropogenic and geogenic activities on water resource quality in Delta state. Within the scope of the authors exhaustive search, there are no detailed reviews on the effect of anthropogenic/geogenic activities on water resources of Delta State context. Hence, this study was initiated to review the quality of water resources within the study area with emphasis on hydrogeochemistry and microbial studies. Furthermore, diverse recommendations are preferred in the paper which is considered necessary for future

 DOI: https://doi.org/10.30564/jees.v3i1.2900

monitoring of water resources of the study area. Literature on generalized on studies on surface and groundwater of the Delta state, Nigeria (the Niger Delta Basin) is shown in Table 1 and also found elsewhere.

2. Study Area

2.1 Location, Climate and Vegetation

The study area lies in the western part of the Niger Delta region. It spans over 15,000 km^2 and it is among one of the leading states in oil production in Nigeria [20]. The study area, lies approximately between Latitude 4^{0}30`N–5$^0$50`N and Longitude 5^{0}05`E– 6$^0$41`E, with high average annual precipitation of about 1900 mm and elevation of 280 m as shown in Figure 1.With mean annual temperatures range from about 22^{0}C to 34^{0}C, and rainfall is between 1,501 mm to 1850 mm; mean evapotranspiration is 1117 mm [41,42]. According to [20] the study area is < than 6 m above Sea Level (SL) in the lowlands that adjoin the sea, to heights > than 280 m above SL in the plateau that defines the northern fringe of the state see (Figure 1). The vegetation of study area varies from salt water swamp within the coastal area adjoining the sea to rain forest towards the northern portions of the state [20]. [6] were of the view that the geomorphology of the study area is sub-divided into marine environment namely: continental, transitional and marine environments. [43,44] sub-divided geomorphological unit of the study area into five categories:

i. Abandoned and active coastal beaches;

ii. Dry flat land and plain;

iii. Back-swamps deltaic plan, freshwater swamps, alluvium and meander belt;

iv. Salt water mangrove swamps;

v. Dry deltaic plan with abundant swamp zones;

vi. Sombreiro Warri plain;

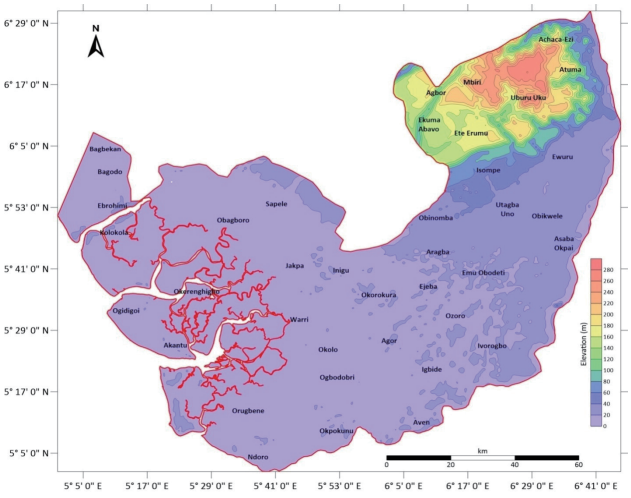

Figure 1. Physiographic Map of Delta State

2.2 Geology/Hydrogeology of the Study Area

The study area lies within the Niger Delta Basin with different formations as shown in Table 1.

i. The Akata Formation overlies the Agbada Formation it composed of continuous shale and about 10% sandstone [6]. There has been reported the shale of Akata Formation is believed to be over pressured and under compacted. It ranges from Eocene to Recent and was deposited under marine conditions.

ii. The Agbada Formation conformably overlies the Akata Formation in the subsurface. It consists of parallel alternating sequence of shale and sandstone with age ranging from Eocene in the northern part to Pliocene/ Pleistocene in the southern part, and Recent in the delta surface. Its lateral equivalents at the surface are the Ogwashi-Asaba Formation and Ameki Formation of Eocene- Oligocene age. The Ogwashi-Asaba Formation constitutes the main rock outcrops in the Asaba Capital Territory.

iii. The continental Miocene-Recent, the Benin Formation is of Miocene to Recent in age and conformably overlies the Agbada Formation. The formation comprises largely of sand with less shale/clay. They are also poorly-sorted, sub-angular to well-rounded, and bear lignite streaks and wood fragments. The Benin Formation occurs just west and northwest of Asaba town [42] and this extends into Agbor town. The west and south of Abraka alongside Sapele, Warri and Ughelli the Benin Formation is masked by the younger Holocene deposits of the Sombreiro-Warri Deltaic Plain, the Mangrove Swamp and Freshwater Swamp wetlands. These aforementioned deposit have not assigned formally to geological names based on the fact that universally they are considered to be recent expressions of the continuation of the Benin Formation are only identified by the physiographic terrains in which they occur. The aerial distribution of these delta top deposits coincides somewhat with the associated physiographic subdivisions shown in Figure 1.

Table 1. Geological sequence of Delta State (modified after [45])

Formation		Age
Deltaic Plain Sediments		Late Pleistocene-Holocene
Benin Formation		Oligocene-Pleistocene
Agbada Formation	Ogwashi-Asaba Formation	Oligocene-miocene
Akata Formation	Ameki Formation	Eocene

DOI: https://doi.org/10.30564/jees.v3i1.2900

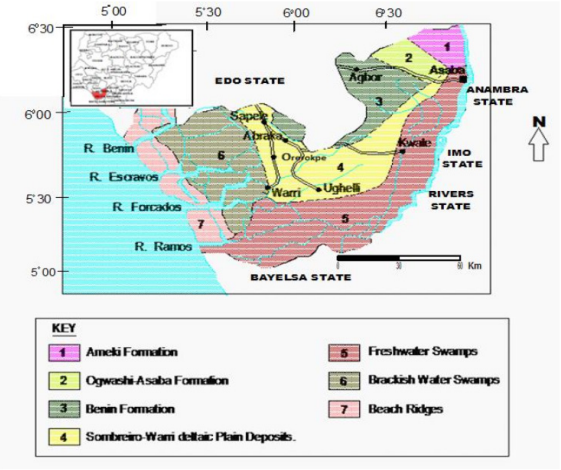

Figure 2. Geological Map of Delta State (modified from [42])

3. Overview of Water Resources Potential of Delta State

3.1 Surface Water Resources

The study area is highly blessed with surface water especially along the south-eastern area, and along the creek and coastal regions. Several authors have reported that one of the major challenges of surface water in the study area is seawater intrusion [18,27,4]. The study have alot of rivers and streams such as Ughelli River, Agbarho River, Okpare River, Forcardos River Ughewhe stream Egbo stream, Olomoro stream, Ekpan river, Ekuredeitsek, Jeddo river, Eja-etan river, Ubeji creek, Ifie-kporo river and many other that drain into River Niger and Atlantic ocean. [6] were of the same view that intense rainfall has resulted in surface runoff, especially along the NE region of the study area. These runoffs often drain into the River Niger, while some gathers in pools, evaporate or infiltrates into the ground, as direct recharge. The River Niger and Asaba Plateau, with its undulating slopes dominate the Asaba landscape (see Figure 1).

3.2 Groundwater Resources

[46], reported that water typically penetrate the subsurface through percolation from surface water bodies, precipitation and infiltrating. [6] reported that over 90 % of the potable water needs of the state are obtained from shallow aquifers by the use of shallow tube and hand dug wells. Previous studies revealed aquifer as easily prone to chemical and microbial contamination based on the fact that they occur few meters below the earth surface [6,20,11,47]. Similarly, studies revealed that the closeness to the sea makes saltwater contamination of the aquifer a permanent threat [48]. Groundwater occurs in all the geological formations was described in the older terrace deposits, the Ogwashi-Asaba Formation and the deeper Ameki Formation. The first aquifer comprises of the terrace deposits and the underlying upper horizons of the Ogwashi-Asaba Formation. The second and deeper aquifer comprises of the sand horizons of the Ogwashi-Asaba Formation. [49], reported that elsewhere in Delta state (Abraka, Ughelli, Warri and Sapele), water table conditions prevail in the area and that the depth to water varies within Abraka inland from about 4 to 26 m, south east part of Delta state. [6] acknowledge that the Ameki Formation is considered too deep in this area which makes it not economically viable aquifer. This has led to the fact that no successful boreholes has been drilled it Ameki Formation to its deep range. Findings from [42] further revealed that majority of boreholes in Asaba obtain water from the shallow old terrace alluvium.

4. Methodology and Data Gathering

In the current study, information related to this study was the source for using google search engine. Published articles on water resources and bacteriological assessment of water quality in Delta state, Nigeria between last few decades were downloaded and reviewed. These relevant papers were thoroughly studied and findings from the paper were carefully presented in tabular form with details of publication particulars, study location, period, approach, methodology as shown in Table.1. Assessment of water resources quality is based on the following:

i. Hydrogeochemical assessment
ii. Microbial assessment

5. Results and Discussions

Table 1 below presents brief information on hydrochemical and microbial status of water resources of Delta State.

5.1 Hydrogeochemical Assessment

The extensive human activities in the study area, have led to a series of water resource pollution. Various human activities have altered the hydrochemistry of water as captured in various publications and commentaries. Water resource pollution is considered as a major threat to human life and aquatic organism. Having established the fact in the introductory part of the paper that the water resources of the study area is moderately to highly polluted in some areas to the extent of not being potable due to area-specific anthropogenic influences. It was considered imperative to review the extent of pollution and, if possible, quantify

 DOI: https://doi.org/10.30564/jees.v3i1.2900

Table 1. Brief information on water resources in Delta State

Water Type	Location	Key findings		References
		Hydrochemical	Microbial	
GW	Sapele metropolis, Ajogodo, Ogorode, Okirighwre and Ugberikoko	Fe, Cr, and pH were above WHO Set limit	Nil	[50]
SW, GW and Harvested Rain water	Ughelli		Nil	[51]
GW	Sapele	Temperature was below set standard high Ec	Nil	[52]
SW and GW	Agbahra, Otovwodo, Evwreni, Afiesere, Orhuwhorum, Utorogu, Akperhe, Eruemuhohworien, And Ovhori,	Alkali bicarbonate water type is the dominant ionic specie with HCO_3 as the predominant ion. Contaminant in Water resources Was traced to human activities such as septic tanks, pit latrine	There was presence of *E.col* in GW sample studied.	[15]
GW	Sapele	Chloride ion is dominant Physicochemical parameters were below the set limit	Nil	[52]
SW	Warri	Anthropogenic influenced Sample water Pb, Cd and Cu were above Set limit	Nil	[54]
GW	Orerokpe	Rock-Water interaction is the major factor that influences GW	Nil	[47]
GW	Boji Boji Agbor, Alihami, Boji Boji Owa, Agbor Obi, Owa Alero	Ec, pH TDS, Temp and COD were Relatively low.	Nil	[55]
GW	Jeddo, Olugbo-odo, Obodo, Ikoto, Osele and Lodu Imenyi	Groundwater showed effect of corrosion. Slightly affected by Salinization	Nil	[27]
GW	Isiokolo, Apkerphe, Evwreni, Ovhori, Ughelli, Oferokpe and Agbraha	Precipitation has influence on groundwater quality, Groundwater showed slight presence of sea water intrusion.	Nil	[26]
GW	Agbor-nta, Owa Oyibu,	Major factors that influences GW Water-soil interaction Pollution related to biochemical Dominant Cl ion as a result of Base exchange reaction	Aerobic bacteria counts 5 - 535cfu/ml and total coliform (10 - 70MPN/100ml	[56]
SW	Agbor, Owa,			[57]
GW	Obiaruku, Okuzu	Groundwater was considered unsuitable for drinking and other purpose		[58]
GW	Warri	Major factors that influence water Rock-weathering Human activities High TDS, Pb, Ci, Ni and Cl Slight seawater intrusion	Fecal Colioform Above set limit	[59]
SW	Kokori-Erhoike	High TS, Ec, Ca, Mg,PO^{3-}	Nil	[60]
GW	Warri	Groundwater was considered Acidity		[19]
GW	Ozoro	High concentration of Cu	Nil	[61]
GW & SW	Ubeji, Ejeba, Jakpa, Airport Junction, Udu Road,Okumagba Avenue, Esisi road and Warri River	Geogenic and anthropogenic activities played a major role in water quality	Nil	[62]
GW	Boji Boji Agbor, Alihami, Boji Boji Owa, Agbor Obi, Owa Alero	Slightly high concentrations of Ca, SO_4^{2-}, Na^+ and PO^{3-}	Nil	[63]
GW	Ekrebe Unuode, Okotie, street, Okan, Akpovi Avenue, Agbraho, Oboru Akpoguma and Ekrerhervwe	Hydrochemical facies: $MgCl_2$ and NaCl facies Major factor influencing GW is precipitation Parameters were below set Standard	Coliform Faecal coliform	[28]
GW	Agbor	Pb and pH were above set limit	No significance Coliform	[64]
GW	Burutu	Analyzed parameters were Slightly above set limit. The is Presence of seawater intrusion		[65]
GW	Delta state	Chloride water type (sea water Intrusion), low pH	Coliform bacteria and *Enterococcus faecalis*	[20]
GW & SW	Opuraja Community	acidic pH	*Vibrio* sp., *Escherichia coli*, *Salmonella* sp., *Shigella* sp	[66]
GW	Amba, Okorodudu, Low Beach, Quarters, Court road all in Burutu		Coliforms were above permissible limit	[67]
GW	Udu		Coliforms were above permissible limit	[68]

Where: GW= Groundwater, SW=Surface water

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Table 2. Source of various ions in water resources, and attendant health implications

Major ions	Possible sources of the various Ions	Health Implications
Na	• Leachate from landfill and garbage dumps located in the SE part of the area • leakages from septic tanks in densely populated area • Animal waste	Excess Na causes hypertension, congenial diseases, kidney disorders and nervous disorders in human body [69]
Cl	• Cl in water originates from industrial effluents, sewage and urban runoff that contain saline intrusion • Sewage discharges and leakages in the densely populated area • Leakage from septic tanks • Leachate from landfill and garbage dumps • Waste from animals generated along river side	Excess Cl in water such as hypertension, chances of stroke, ventricular hypertrophy, osteoporosis, renal stones, and asthma ([70]; [71])
K	• Fertilizer application • Landfill leachates • Animal waste and leakage from septic tanks	Presence of K in water may lead to kidney disease, heart disease, coronary artery disease, hypertension, diabetes, and adrenal insufficiency
HCO_3	• Sewage waste and landfill leachate	
Nickel	• Smelting • Refining and petroleum industries • Chemical and catalyst production	Possible carcinogen
NO_3	• Septic tank over flow and leakages • organic and chemical fertilizers	High concentration of NO_3 in water may lead to gastric cancer, goiter, birth malformation and hypertension
SO_4	• Application of fertilizer • Wide application of H_2SO_4 in electroplating • Anthropogenic sulfur emissions from fossil fuel combustion may also contribute to the overall SO_4 concentrations in groundwater	High SO4 such as dehydration, catharsis, gastrointestinal irritation and diarrhea.
Mg	• Discharge and emissions from industries that use or manufacture magnesium. • The concentration of Mg in river and sea water can be increased by rainwater falling on rocks	High concentration of Mg in water may lead to the damage of gastrointestinal tract, nervous system and the kidneys.
Ca	• Occur as result of soluble and abundance in most rock types	High concentration of Ca in water may lead to hypercalcaemia, metabolic alkalosis and renal insufficiency) and hypercalcaemia.
Pb	• The amount of dissolved lead in surface water and groundwater depends on pH and the concentration of dissolved salts • And the types of mineral surfaces present	The presence of Pb in water may lead to tiredness, sleeplessness, irritability, headaches, joint pain and gastrointestinal.
Fe	• Possibly due to industrial activities, refuse dumps and metal scraps along the river courses, which are also sources of groundwater	Excess Fe in water when taken by human may lead to genetic disorder, depression, rapid and shallow respiration, coma, convulsions, respiratory failure, and cardiac arrest
Zn	• It may be due to industrial activities, refuse dumps and metal scraps • along the river courses which are also source of groundwater	High concentration of zinc in water can lead to nausea, stomach cramps and vomiting.
Cu	• It may be due to industrial activities, refuse dumps and metal scraps • along the river courses which are also source of groundwater	Excess Cu in water may lead to nausea, vomiting, stomach cramps or diarrhea, it can further cause damage to kidney and liver in human
Mn	• Manganese often occurs naturally together, through the weathering of rocks and minerals, may also be present in underground water due pollution sources	Excessive intake of manganese in water may lead to neurological disorder
Cr	• The major sources of Cr in water is releases from electroplating processes and the disposal of chromium containing wastes	High intake of chromium may lead to carcinogenic disease
Ec	• Water drained from agricultural fields, municipal waste water, rainfall	The higher Ec may cause a gastrointestinal irritation in human beings.
pH	• Low pH- Acid rain as a result of gas flaring • pH above 8.5 is regarded as hard water.	i. Hard water does not pose a health risk, but can cause aesthetic problems Though pH has no direct effect on human health, all biogeochemical reactions are sensitive to variation of pH. ii. Hard water does not pose a health risk, but can cause aesthetic problems

 DOI: https://doi.org/10.30564/jees.v3i1.2900

it. Most of the activities are in one way or the other connected to modern day development, unlike in decades ago were the quality of water resource was considered fit for various purpose. [28] were of the view that major cations were below maximum permissible limits within the Sombreiro-Warri plains, Warri Delta state. They further stated that the depth to water level within the Sombreiro-Warri plains varies from 1.2 to 6.45 m. [62] pointed out that within the Sombreiro-Warri Deltaic plain sands Cl concentration in groundwater fall below saltwater intrusion bench mark of 130 mg/l, according to [72]. Although, [26] pointed out that chloride is also a reliable tool for judgment on saltwater intrusion because it is the most stable macro element in seawater and the most sensitive to saltwater intrusion. Klassen, et al., (2014) were of the opinion that when chloride content greater than 130-484.0 mg/l in groundwater is 90-95% indication of saltwater intrusion. Studies have shown that there is presence of high chloride concentration is an indication of salt water contamination in Niger Delta Region [26,27,73,74]. They went further to point out that it implies the absence of marine influence on groundwater within Warri, Delta state, although their findings contradict report from [59] which was of the view that the Nacl water type in the Warri area suggests possible salinization of groundwater within the Sombreiro-Warri Deltaic plain sands. [59] went further to prove fact that $NaHCO_3$ type does not exist within Warri. His results implies that salinitization in the study area is caused mainly by recent sea water intrusion. Findings from [59]; [16] suggested that the groundwater within the Sombreiro-Warri Deltaic plain sands is considered fresh water type based on total dissolved solid assessment. [59] further reported that three groups of groundwater types exist within the Sombreiro-Warri Deltaic plain sands in Warri, Delta state namely: calcium bicarbonate water type, calcium chloride water type and sodium chloride water type. He further acknowledges that the calcium bicarbonate water type reflects groundwater zone that is characterized with low electrical conductivity (Ec) and TDS. While the sodium chloride water type reflects groundwater of the discharge zone area that is generally characterized with high Ec and TDS. The calcium chloride water type is the transition zone between the two water types. From his findings it was observed that the Nacl water type is water type close to the sea shore, while the calcium carbonate water type is confined within the hinter lands. [59] was of the opinion that salt water intrusion plays a major role in groundwater geochemistry of groundwater around the sea shore. From total dissolved solid and Chadba's plot suggested that water fell within the four categories, namely soft, moderately hard, hard and very hard [59,27,75] evaluated hand dug wells from different locations in Agbarho in Delta state, findings from the study suggested that SO_4, Cl, Cu, Fe, Pb, NO_3, Cr, Zn, Na, Mn and K were below WHO permissible limit. Hence, result from the study revealed that groundwater is fit for domestic use and that anthropogenic activities within the area have no strong influence on groundwater within Agbarho community in Delta state. [24] were of the same view with [75] that Pb concentration in groundwater within the part of Warri metropolis was found to be below WHO permissible limit. Studies from [28] on heavy metals such as Pb, Cd and Cr in groundwater within Agbarho, Delta and were compared to MPLs set by SON result from their study suggested that aforementioned heavy metals were below the set limit. Further findings from [28] which suggested that Pb, Cr and Cd were below detection limit in groundwater in Sombreiro-Warri Deltaic Plain Deposit of Agbarho, Delta state. Although studies from other scholars suggested that Pb, Cr and Cd concentration was detected in water in Warri, Delta state [76,77]. [24] reported that pH of groundwater within these towns; Ekpan, Mosogar, Agbor and Adeje site all located in Delta state were considered to be acidic based on pH values obtained from groundwater samples. From the pH values one could suggest low pH (acidic water) may possibly trigger corrosion in groundwater. In the same vein, [26]; [18] were of the view that 96.3 % groundwater within some selected towns and village such: Akpkerhe, Ovhori, Evwreni, Agbarha, Isiokolo, Orerokpe and Ughelli fell within the acidic water based on pH value obtained from their study, the effect of low pH in groundwater could be seen in Table 2. The acidity of groundwater within this area could be attributed to precipitates acid rain in the region acid rain [78, 12]. The occurrence of acid rain in the Niger Delta region of Nigeria has been studied by various authors in the past [78,79,80,12]. Aside anthropogenic activities that influence water quality. The controlling effect of geology on groundwater occurrence in Niger Delta is no longer in doubt, as its influences the geochemistry of groundwater [26]. [26] reported that Gibbs plot from studied groundwater in around community and towns in Delta state aforementioned suggested that precipitation is major process that influence groundwater. This is in line with reports by several author as mentioned above. [27] suggested that groundwater within the Sombreiro-Warri plains was considered fresh water based on TDS values obtained from groundwater. Although result from their study showed variation in TDS, the sources of material in TDS may come from nature, i.e. geological condition and seawater, and from human activities, i.e. domestic and industrial waste and also agriculture [48]. [81] reported that variation in TDS values may also occur due to geogenic activities of a particular region. [82] were of

DOI: https://doi.org/10.30564/jees.v3i1.2900

the view that the sedimentation pattern as well as stratification determines both the quality and quantity of water in the region. [47] reported that ground water in Orerokpe, Delta state was considered soft and its chemical composition is being influenced mainly by geogenic factors which is accelerated by the mildly acidic nature of recharging rainfall. [83] further suggested that whenever water is contaminated it adverse effect is shown on human health, domestic and industrial development, survival of lives which serve as a source of food for humans. Thus their impacts could be severe depending on the constituents of such wastes. According to [74] the source of most of the hydrogeochemical parameters in the water in the area is dissolution from the rocks as the water percolates underground. However, percolation and geochemical processes within the groundwater system also account for some of the high concentrations in physicochemical parameters.

5.2 Influence of Microbial Organism on Water Resources

Microbial studies in water resources are scanty in literature within the study area. Unsanitary water has particularly devastating effects on young children and adults in most developing world, including Nigeria. Several scholars reported that wells situated in highly populated area are in most cases cited close to domestic refuse dumps, pit latrines and stagnant waters and drainages [31,56,67]. According to [18], the total coliform bacteria and faecal coliform have the highest mean values in river are greater than open well and not in rainwater in the region. They further reported that presence of open wells and river water resources in the creek/riverine communities especially makes water vulnerable to microbial/pathogenic organisms, and makes these water sources of low quality for domestic uses. However [66] reported that several infectious diseases are transmitted via water through the fecal-oral route. Although, several authors consider *E faecalis* to be a good indicator of faecal pollution because of their greater resistance than coliforms to environmental pressure. The presence of these faecal coliforms in some of the water resources suggests that these coliform bacteria in water indicate that the water has been contaminated with fecal material of man or other animals. [75] report that groundwater studied at Akpiroroh, Erhidi, Abavo, Oguname, Ahirim show no trace of coliform, while that of Oseri, Uvwiamughe, Idirima, Urhoboghara and Ogubane were contaminated with coliform bacteria, and those of Ogubane showed the highest coliform count, this may be attributed to the fact that there might of presence of pit latrine and also practice open defecation. [59] reported that groundwater within Sombreiro-Warri Deltaic plain, Warri Delta states showed fecal coliform that are higher in concentration, above the stipulated WHO permissible limit. [20] suggested that shallow aquifer is more vulnerable to contamination of all kind. [68] reported that groundwater samples analyzed at Udu community in Delta state showed the presence of bacterial counts which were probably obtained from environmental sources, and were far above [39,40] allowable limits. They further attributed the occurrence of high coliform populations in all the water samples is an indication of poor sanitary conditions in the community. The [84] guideline stipulated a coliform count of zero (0) per 100 ml. Total Coliform organisms per 100 ml are an indication of some degree of contamination. Findings from [67,82,85,86,14] showed striking similarity that groundwater resource in Burutu Warri, Amai kingdom and Ughelli respectively showed all forms of coliform that were far above [39] standard. This may be attributed to the facts that well are cited close to septic tanks, open defecation and pit latrine are practically been practiced by people of the area.

6. Concluding Remarks and Recommendations

6.1 Concluding Remarks

On a general note water of good quality is needed for healthy life, but with a steady increase in water pollution. It is necessary to know the quality of water used by human being has become a serious issue in past years [87]. As water of good quality for human continues to receive the attention of government agencies, academics and health services, institutions and non-government organization. Report by WHO clearly stated the world is currently facing water crisis. The assessment of water quality is highly needed, however, is very costly and the government agencies would rather live in denial, take the goodness of the quality of water being consumed by the citizens as fore-granted even if the contrary is true. However findings from the study, revealed that groundwater is more studied compared to surface water. Most of the researches carried out on water resources quality assessment were carried out across the study area exception of north-east part of the study area. As mentioned by several scholars, acid-rain is one of the major problems that affect groundwater pH especially along the oil producing area of the state. Findings from the study showed that groundwater chemistry is influenced dominantly by rock weathering and precipitation processes. The differences in concentrations of the various ions in the groundwater may be linked to the amounts of ions in the rock matrix, reaction characteristics and transport history. From findings, it was observed that large

 DOI: https://doi.org/10.30564/jees.v3i1.2900

percentage of groundwater samples have fecal coliform. Lastly, findings from this reviewed literature showed that decline in water quality is considered dangerous to human and animal.

6.2 Recommendation

The government should set up relevant bodies that will enforce strict measures to ensure good water quality available for the people of Delta state especially the people living around the creeks and rural communities and there should be sensitization on effect of oil spillage on water resources. This could help to mitigate the current irregularities in the quality of commercially accessible water. It is further recommended that:

• It will be better off if water storage tanks are non-metallic to avoid corrosion.

• The inhabitants of the study area should be educated on the danger of their act in respect to the way sewage is disposed and related diseases that accompany the act is therefore advocated

• It is necessary for water to be thoroughly treated before usage.

• Water exploration should leave in hand of state and federal government especially within rural communities.

• Microbial treatment should be carried out on water resources before consumption

• Wells should be located far from domestic refuse waste, pit latrine, stagnant water and drainages

• Reasonable amount of money should be allocated by state and federal government for improvement of public water.

Finally, in other to improve quality for water resources for domestic and other use, it is recommended that government and private partnership are highly needed such that water management plants be set up in most urban and suburban locations to ensure the availability of pipe-borne water.

Acknowledgment

The authors sincerely acknowledge the effort of Ike Joy of the Department of Energy and Petroleum Studies Novena University Oguma, Delta state Nigeria for pain sticking in editing the manuscript. I, Dr. Moses Oghenenyoreme Eyankware is grateful to Professor A.O.I. Selemo for his encouragements and mentorship.

References

[1] Arif, S., Khan, U., Turab, A., Hussain, I., Habib, A., Mansoor, T., Mallick, D., Suhag, Z., Bhatti, Z., Ahmed I. Evaluation of Solar Disinfection of water intervention delivered through Lady Health Workers in reduction of diarrheal episodes in under five children. International Journal Pedestrian Child Care, 2016. 1:1.

[2] Abdel-Satar, A. M., Ali, M. H., Goher, M.E. . Indices of water quality and metal pollution of Nile River Egypt. Egypt Journal Aquatic Research, 2017. 43:21-29.

[3] Eyankware, M. O., Nnajieze, V. S., Aleke, C. G. Geochemical assessment of water quality for irrigation purpose, in abandoned limestone quarry pit at Nkalagu area, Southern Benue Trough Nigeria. Environmental Earth Science, 2018. https://doi.org/10.1007/s12665-018-7232-x.

[4] Eyankware, M.O., Nnabo, P. N., Ogwah, C. Impact of past mining activities on water resources around active and abandoned mines and quarries in Ebonyi State, South-Eastern Nigeria -A mini review. Hydro Science & Marine Engineering,2020a
DOI: https://doi.org/10.30564/hsme.v2i2.2412.

[5] Ulakpa, R .O.E., Eyankware, M. O. Contamination assessment of water resources around waste dumpsites in Abakaliki, Nigeria; A Mini Review. Journal Clean WAS, 2021. 5(1): 13-16. https://doi.org/10.26480/jcleanwas.01.2021.13.16.

[6] Orji, E.A., Egboka, B.C.E. The Hydrogeology of Delta State, Nigeria. The Pacific Journal of Science and Technology, 2015. (16)2; 257-268.

[7] Onifade, A., Ilori, R. Microbiological analysis of sachet water vended in Ondo State Nigeria. Environmental Research Journal, 2008. 2:107-110.

[8] Sarkodie PA, Agyapong D, Larbi GO, Owusu-Ansah E (2014) A comparative study of the quality of wastewater from Tema Oil Refinery (TOR) against EPA standards and its effect on the environment. Civil and Environmental Research, 2014. 6: 85-92.

[9] Oribhabor, B. J. Impact of human activities on biodiversity in Nigeria aquatic ecosystems. Sci. Intern, 2015. 4, 12-20.

[10] Ugochukwu PA, and Chidozie IPD. Water quality assessment and resource potentials: the case of Aba–Urban and its Environs, Niger Delta Basin. Water Resources,2018. 45(2):250-267.

[11] Eyankware, M. O., Ufomata, D. O., Effam, C. S., Akakuru, O. C. Physicochemical and bacteriological assessment of groundwater quality in Ughelli and its environs. International Journal of Innovational and Scientific Research. 2015. 14(2): 236-243.

[12] Eyankware, M. O., Selemo, A. O. I., Omo-Irabor. O. O. Hydrogeochemical assessment of ground and surface water of Eruemukohwarien community and its environs for domestic and irrigation purpose, West-

  DOI: https://doi.org/10.30564/jees.v3i1.2900

ern Niger Delta Region, Nigeria. Journal of Science and Technology, 2016. 3(10), 91-108.

[13] Eyankware, M. O., Akudinobi, B. E. B., Akakuru, O. C. Quality Assessment and hydrochemical charactertics of groundwater in Ughelli and its adjoining Area for irrigation purpose, Niger Delta Region, Nigeria. Indian Journal of Science, 2017. 3(10), 120-134.

[14] Efe, S. I., Mogborukor, J. O. A. Acid Rain in Niger Delta Region: Implication on water resources quality and crisis. An International Journal of Science and Technology Bahir Dar, Ethiopia, 2012.1(1):17-46.

[15] Stewart, R. Environmental science in the 21st Century- An online textbook. Retrieved on the 1st of March 2013 from G: 2013.groundwatercontamination.html.

[16] Efe, S. I. Quality of rainwater harvesting for rural communities of Delta State, Nigeria. Environmentalist, 2006. 26;175-181.

[17] Ogbuagu DH, Okoli CG, Gilbert CL, Madu S. Determination of the contamination of groundwater sources in Okirika Mainland with Polynuclear aromatic compounds (PAHs). British Journal of Environment & Climate Change, 2011. 1: 90-102.

[18] Ohwoghere, A. O., Adaikpoh, E. O. Assessment of shallow aquifers contamination by failure of on site sewage disposal system in Ughelli, Western Niger Delta, Nigeria. Journal of Environment and Earth Science, 2013. 5(9), 208-216.

[19] Akudo, E. O., Ozulu, G. U., Osogbue, L.C. Quality assessment of groundwater in selected waste dumpsite areas in Warri, Nigeria. Environmental Research Journal, 2010.4(4):281-285.

[20] Olobaniyi, S. B., Ogban, F.E., Ejechi, B.O., Ugbe, F.C. Quality of groundwater In Delta State, Nigeria. Journal of Environment and Hydrology, 2007a. 15(1);1-10.

[21] Olorunfemi D, Efechuku U, Esuana J. Toxicological evaluation of drinking water sources in some rural communities in southern nigeria after mycofiltration treatment. Polish Journal of Environmental Studies, 2015. 24(3); 1205-1212.

[22] Adesuyi, A.A., Nnodu, V.C., Njoku, K.L., Jolaoso, A. Nitrate and Phosphate Pollution in Surface Water of Nwaja Creek, Port Harcourt, Niger Delta, Nigeria. International Journal of Geology, Agriculture and Environmental Sciences, 2015. 3, 14-20.

[23] Esi , E. O., Marere, S. O., Peretomode, M., Asiagbe, E. T., Ohwona, C. Evaluation of physiochemical parameters in hand-dug wells water in Burutu, Delta State, Nigeria. American Journal of Environmental Protection, 2013.

DOI: 10.11648/j.ajep.20130206.13.

[24] Emagbetere, JU, Oroka, VO, Ugbune U, Edjere A. Assessment of the Level of Groundwater Contamination and Its Implications in Oil Pipeline Areas of Delta State, Nigeria. Journal of Environment and Earth Science, 2014.

[25] Efe, S. I. Spatial variation in acid and some heavy metal composition of rainwater harvesting in the oil producing region of Nigeria. Natural Hazard , 2010. 5: 307-319,

DOI: 10.1007/s11069-010-9526-2.

[26] Eyankware, M. O., Omo-Irabor, O. O. An integrated approach to groundwater quality assessment in determining factors that influence the geochemistry and origin of sandstone aquifers, Southern Niger Delta Region of Nigeria. Malaysian Journal of Geoscience, 2019.3 (2), 23-32.

[27] Eyankware, M. O., Aleke, C.G., Selemo, A.O.I., Nnabo, P.N. Hydrogeochemical studies and suitability assessment of groundwater quality for irrigation at Warri and environs., Niger delta basin, Nigeria. Groundwater for Sustainable Development. 2020b.

DOI: https://doi.org/10.1016/j.gsd.2019.100293.

[28] Efobo, O., Ugbe, F. C., Akpoborie, I. A. Groundwater conditions and hydrogeochemistry of the Sombreiro-Warri Deltaic plain deposit (Shallow Benin Formation) in the vicinity of Agbarho, Nigeria. Journal of Scientific Research. 2020. http://dx.doi.org/10.3329/jsr.v12i4.45187.

[29] Daud ,M., Nafees, M., Ali, S., Rizwan, M., Bajwa, R.A., Shakoor, M. B., Arshad, M. U., Chatha, S. A. S., Deeba. F., Murad, W. Drinking water quality status and contamination in Pakistan. BioMed Research International, 2017.https://doi.org/10.1155/2017/7908183.

[30] Hutchinson, M.M., Ridgeway. Microbial agent of drinking water supplies. Aquatic Microbiology Shewan and Stainer Eds. Soc. of appl. Bact. Technical Series, 1975. No 9.

[31] Okuofu, A. C., Echafona, N.O., Ayeni, O.G. Bacteriological and physicochemical examination of well waters in Ahmadu Bello University (main campus), Zaria, Nigeria. Journal of the Nigerian Association of Hydrogeologists (NAH), 1990. 2(1), 111-115.

[32] New Hampshire Department of Environmental Services. Interpreting the presence of coliform bacteria in drinking water. Environmental fact sheet. New Hampshire, Department of Environmental Services, New Hampshire, 2010.

[33] Emmanuel E, Pierre MG, Perrodin Y. Groundwater contamination by microbiological and chemical substances released from hospital wastewater and health risk assessment for drinking water consumers. Envi-

ronment International, 2009. 35:718-726.

[34] Odonkor ST, Ampofo J., A. Escherichia coli as an indicator of bacteriological quality of water: an overview. Microbiology Research, 2013. 4(e2): 5-11.

[35] Vunain, E., Masoamphambe, E.F., Mpeketula, P.M.G., Monjerezi, M., Etale, A. Evaluation of coagulating efficiency and water borne pathogens reduction capacity of Moringa oleifera seed powder for treatment of domestic wastewater from Zomba Malawi. Journal of Environmental Chemical Engineering, 2017.103118.

[36] Cocker MD. Geochemistry and hydrochemistry of the Oconee River Basin. In: Hatcher KJ (ed) Proceedings of 1995 Georgia water resources conference held on the 11–12 April 1995, University of Georgia. 1995. Pp 67-70.

[37] Pazand K., Gbanbari, Y., Aghavali, Hezarkhani A. Groundwater geochemistry in the middle Meshkinshahr basin of Ardabil province in Iran. Environmental Earth Science, 2011.

DOI:10.1007/s12665-011-1131-8.

[38] Mimosa M. Water Quality Assessment and Determination of Pollution Sources along the Axios/Vardar River, South Eastern Europe, Desalination, 2007. 213: 159-173.

[39] Word Health Organization WHO. Guidelines for drinking water quality, 2nd edition, Geneva, 3, 1-250. www. globalsecurity.org download. 2008 .

[40] Standards Organization of Nigeria (SON). Nigerian industrial standard: Nigerian standard for drinking water quality, Abuja.2007.

[41] Federal Ministry of Environment .FME. Guidelines and standards for water quality in Nigerian Publication, 2001. 1-114). Abuja: FME.

[42] Akpoborie, I. A., Nfor, B., Etobro, A. A. I., Odagwe, S. Aspects of the geology and groundwater conditions of Asaba, Nigeria. Archives of Applied Science Research, 2011. 3(2):537- 550.

[43] Nigerian Meteorological Agency. Asaba Meteorological Bulletin. In: National Meteorological Report. 2003.

[44] Allen, J. R. (1965). Late Quaternary Niger Delta and Adjacent Areas Sedimentary Environment and lithofacies, Am. Assoc. Petroleum Geology Bulletin. 49:547- 600.

[45] Short, K.C. and A.J. Stauble. Outline of Geology of Niger Delta. Bull. Am. Assoc. Petr. Geol. 1967. 54(5):761-779.

[46] Amangabara, G. T., Ejenma, E. Groundwater Quality Assessment of Yenagoa and Environs Bayelsa State, Nigeria between 2010 and 2011. Resource Environment, 2012. 2 (2), 20-29.

[47] Aweto K, Akpoborie IA. Geoelectric and hydrogeochemical mapping of Quaternary deposits at Orerokpe in the Western Niger Delta. Journal Applied Science Environmental Management, 2011. 15(2);351-359.

[48] Eyankware, M.O., Igwe, E. O., Ulakpa, R.O.E., Ogwah, C. Achieving sustainable use and management of water resources for irrigation in Nigeria-Review. Journal of Environmental & Earth Sciences, 2020C. 2(2): 47-55.

[49] Akpoborie, I. A., Oghenevwede, E. (2014). Groundwater conditions and hydrogeochemistry of the shallow Benin Formation Aquifer in the Vicinity of Abraka. Nigeria. International Journal of Water resources and Environmental Engineering, 2014. 6(1):19-31.

[50] Aweto, K. E., Ohwoghere, A. O. An integration of geophysical and geochemical data in evaluating groundwater resources in sapele metropolis, western Niger Delta. Nigerian. Journal of Science and Environment, 2013. 12 (1); 49-52.

[51] Ushurhe, O., Origho, T. A comparative assessment of the quality of harvested rainwater, underground water and surface water for domestic purposes in Ughelli, southern Nigeria. Journal of Environmental and Earth Science, 2013, 3(12): 11.

[52] Emagbetere, J. U., Molua, C. O. Levels of temperature and electrical conductivity of ground water in Sapele local government area of Delta State, Nigeria. Elixir Pollution, 2012. (46)8141-8142.

[53] Akpoborie, I. A., Biokoro, U. C., Emoyan, O. O. Groundwater conditions and major-ion hydrogeochemistry of the Benin formation and the Ethiope River at the Sapele Municipality, Nigeria. Journal of Environmental Science Toxicology and Food Technology, 2015. 9(1&2); 08-15.

[54] Ogaga, A.A., Olusegun, A.O., Elijah, I.O. Heavy metal levels in water and sediment of Warri River, Niger Delta, Nigeria. International Journal of Geology, Agriculture and Environmental Science, 2015. 3(1): 20-24.

[55] Oyem, H. H., Oyem, I.M., Ezeweali, D. Temperature, pH, electrical conductivity, total dissolved solids and chemical oxygen demand of groundwater in Boji-Boji Agbor/Owa area and immediate suburbs. Research Journal of Environmental Science, 2014. https://doi.org/10.3923/rjes.2014.444.450.

[56] Olobaniyi, S.B., Ogala , J. E., Nfor, N.B. Hydrogeochemical and bacteriological investigation of groundwater in Agbor area, southern Nigeria. Journal of Mining and Geology, 2007b. 43(1); 79-89.

[57] Akpofure RR, Ikhifa OG , Okokoyo AP. Effects of agricultural activities on the water quality of Orogo-

  DOI: https://doi.org/10.30564/jees.v3i1.2900

do River, Agbor Nigeria. Journal of Applied Sciences Research, 2006. 2(5): 256-259.

[58] Amitaye, A. N. Quality Assessment of Ethiope River course from Obiaruku, Delta State, using physico-chemical parameters as indicators. Journal of Environmental Management and Safety, 2014.5(2); 135-144.

[59] Omanudhowho, I. G. Hydrochemical characteristics and quality assessment of groundwater in Warri, South south Nigeria.Published MS.c Dissertation. 2012.

[60] Arise, R. O., Osioma, E., Akanji, M. A. Assessment of water quality parameters from Swamps around Kokori Erhoike Petroleum Flow Station in Delta State, Nigeria. Der Chemica Sinica, 2013, 4(1):155-161.

[61] Akpomrere, O. R., Uguru, H. Copper concentration and distribution in the groundwater of Delta State Polytechnic, Ozoro, Nigeria. Asian Journal of Geographical Research, 2020.3(3): 1-8.

[62] Overare, B., Avwenagha, E. O., Okpara, E., Osokpor, J., Ogbe, O.B., Overare, A.E., Ogueh, E.D. Hydro-Geochemical attributes of Quaternary Sands in Warri, western Niger Delta, Nigeria. Pacific Journal of Science and Technology, 2016. 17(1):301-310.

[63] Oyem, H. H., Oyem, I.M., Obiwulu, E.N. Barium, Calcium and sodium, cyanide, phosphate and sulphate contents of groundwater in some Ika Communities of Delta State, Nigeria. Journal of Geoscience and Environmental Protection. 2017. https://doi.org/10.4236/gep.2017.58009.

[64] Oboh, I. P., Egun, N. K. Assessment of the water quality of selected boreholes close to a dumpsite in Agbor Metropolis, Delta State, Nigeria. African Scientist, 2017.18(1); 43-51.

[65] Esi , E. O., Marere, S. O., Peretomode, M., Asiagbe, E. T., Ohwona, C. Evaluation of physiochemical parameters in hand-dug wells water in Burutu, Delta State, Nigeria. American Journal of Environmental Protection,2013.

DOI: 10.11648/j.ajep.20130206.13.

[66] Ibiene, A.A., Agbeyi, E. V., Okonko, I. O. Bacteriological assessment of drinking water sources In Opuraja community of Delta State, Nigeria. Nature and Science, 2012.10(1):36-41.

[67] Okiriguo, V.I., Diakparomre, O. Microbiological Assessment of Well Water Obtained in Burutu Town, Delta State, Nigeria. Continental Journal of Biological Sciences, 2019.

DOI: 10.5281/zenodo.3820667.

[68] Olomukoro, J. O., Oviojie, O. E. Physico-Chemical Characteristics and Bacteriological Studies in Hand Dug Wells in Udu Community of Delta State, Nigeria. Journal of Environment and Earth Science, 2014. 4(22); 116-120.

[69] Ramesh, K., Elango, L., 2011. Groundwater quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India. Environmental Monitoring Assessment, 2011.

DOI: 10.1007/s10661-011-2231-3.

[70] Ravindra K, Garg VK. Hydro-chemical survey of groundwater of Hisar city and assessment of defuorination methods used in India. Environment Monitoring Assessment, 2007. 132(1–3):33-43.

[71] Lima TB, Silva ON, Oliveira JTA, Vasconcelos IM, Scalabrin FB, Rocha TL, Castro CFS. Identification of E. dysenteric laxative peptide: a novel strategy in the treatment of chronic constipation and irritable bowel syndrome. Peptides, 20101.31(8):1426-1433.

[72] Klassen, J.K., D.M. Allen, and D. Kirst.. Chemical Indicators of Saltwater Intrusion for the Gulf Island, British Columbia. Unpubl. Research Report. Dept. of Earth Sci., Simon Fraser Univ., Canada. 2014.

[73] Uma, K.O. and Egboka, B.C.E. Hydrogeochemistry, contaminant transport and tectonic effects in the Okposi-Uburu salt area of Imo State, Nigeria Hydrological Science Journal, 1986. 31, pp. 205-221.

[74] Nwankwoala, H.O. , Udom, G.J. Hydrogeochemical Evaluation of groundwater in parts of Eastern Niger Delta, Nigeria, Journal of academic and applied studies,201. 1(2); 33-58.

[75] Asadu, A.N. Assessment of Water Quality of Delta State, Agbarho Area, Nigeria. International Research Journal of Interdisciplinary & Multidisciplinary Studies. 2016. 2(4): 57-65.

[76] Akpoborie, I.A., Ekakite, A. O., Adaikpoh, E.O. The Quality of Groundwater from Dug wells in Parts of the Western Niger Delta. Knowledge Review, 2000. 2: 72-79.

[77] Abimbola, A. F., Odukoya, A. M., Olatunji. A. S. Influence of bedrock on the hydrogeochemical characteristics of groundwater in northern parts of Ibadan Metropolis. Water Resource-journal of Nigerian Association of Hydrogeologists (NAH), 2002.13, 1-6.

[78] Alakpodia, J.I.The environment of the Niger Delta. In B.C. Uweru and J.O. Ubrurhe (Eds), Readings in General Studies, Nigerian People and Culture. (pp190-203) About Research Pub. 2000.

[79] Okecha, S.A. Pollution and conservation of Nigeria's environment. Ekpoma T. Afriqu Inter Ass. W.A.2000.

[80] Oguejiofor, G.C. Gas flaring in Nigeria: converting fuel gas pollutant into revenue – earning fertilizer by low cost retrofit of flare stations. Environmental Education & Information, 2000. 2(2): 91-100.

 DOI: https://doi.org/10.30564/jees.v3i1.2900

[81] MohammedAslam, M. A., Rizvi, S.S. Hydrogeochemical characterization and appraisal of groundwater suitability for domestic and irrigational purposes in a semiarid region, Karnataka state, India. 2020. https://doi.org/10.1007/s13201-020-01320-1.

[82] Nwankwolala, H.O., Ngah, SA. Groundwater resources of the Niger Delta: Quality implications and management considerations. International Journal of water resources and environmental engineering, 2014. 6(5);155-163.

[83] Akpan, D., Ajayi, O. Adverse Effect of Water Contamination or Pollution to Human Health and Safety in the Nigeria Delta – Nigeria: An Environmental Case Study. Journal of Environmental Earth Sciences, 2016. 6 (10), 91-94.

[84] World Health Organization WHO. Guidelines for drinking water quality. Incorporating 1st and 2nd addenda, 1. Recommendations, 3rd edition, Geneva. 1997.

[85] Ezenwaji E E, Ezenweani ID. Spatial analysis of groundwater quality in Warri Urban, Nigeria. Sustainable Water Resources Management, 2019. 5:873-882 https://doi.org/10.1007/s40899-018-0264-2.

[86] Eboh, J O., Ogu, G I., Idara, M U.(2017). Microbiological Quality of borehole and well Water Sources In Amai Kingdom, Ukwuani Local Government Area Of oDelta State, Nigeria. International Journal of Advanced Academic Research | Sciences, Technology & Engineering, 201. 3(7): 17-28.

[87] Olatunji AS, Abimbola AF, Olorunta MO, Odewede AA. Hydrogeochemical evaluation of groundwater resources in shallow coastal aquifers around Ikorodu, Southwestern Nigeria. Water Resource, 2005.16:65-71.

DOI: https://doi.org/10.30564/jees.v3i1.2900