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

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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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mestic use. In most, cases individuals and governments emphasize more of water quantity rather than laying emphasis on its quality. [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, Afinere, 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 on-site 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 (coliiforms) 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
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 km² and it is among one of the leading states in oil production in Nigeria [20]. The study area, lies approximately between Latitude 4°30’N–5°50’N and Longitude 5°05’E–6°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°C to 34°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;

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 Sedi-ments | Late Pleistocene-Holocene |
| Benin Formation          | Oligocene-Pleistocene |
| Agbada Formation         | Ogwashi-Asaba Formation |
| Akata Formation          | Ameki Formation  |

Figure 1. Physiographic Map of Delta State
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 \cite{18,27,4}. The study have alot of rivers and streams such as Ughelli River, Agbarho River, Okpare River, Forocardos River Ughewhe stream Egbo stream, Olomoro stream, Ekpan river, Ekuredeitsek, Jedo river, Eja-etan river, Ubeji creek, Ifie-kporo river and many other that drain into River Niger and Atlantic ocean. \cite{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

\cite{46}, reported that water typically penetrate the subsurface through percolation from surface water bodies, precipitation and infiltrating. \cite{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 \cite{6,20,11,47}. Similarly, studies revealed that the closeness to the sea makes saltwater contamination of the aquifer a permanent threat \cite{28}. 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. \cite{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. \cite{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 \cite{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
## Table 1. Brief information on water resources in Delta State

| Water Type          | Location                                                                 | Hydrochemical Findings                                                                 | Microbial Findings                                      | References |
|---------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------|------------|
| GW                  | Sapele metropolis, Ajobodo, Ogorode, Okirighwre and Ugberikoko          | Fe, Cr, and pH were above WHO Set limit                                                | Nil                                                      | [50]       |
| SW, GW and Harvested Rain water | Ughelli                                                                  | Temperature was below set standard high Ec                                             | Nil                                                      | [51]       |
| GW                  | Aghbahra, Otovwodo, Evwreni, Afiessere, Orhuwhorum, Utorogu, Akperbe, Erumuhohworien, And Ovhori, | Alkal bicarbonate water type is the dominant ionic specie with HCO₃⁻ as the predominant ion. Contaminant in Water resources Was traced to human activities such as septic tanks, pit latrine and drainage systems. | There was presence of E. coli and other pathogens in GW sample studied. | [15]       |
| SW and GW           | Sapele                                                                  | Chloride ion is dominant Physicochemical parameters were below the set limit           | Nil                                                      | [52]       |
| GW                  | Boji Boji Agbor, Alihami, Boji Boji Owa, Agbor Obi, Owa Alero            | Ec, pH TDS, Temp and COD were Relatively low.                                          | Nil                                                      | [55]       |
| GW                  | Jedd, Olugbo-odo, Obodo, Ikoto, Oselle and Lodu Imenyi                   | Groundwater showed effect of corrosion. Slightly affected by Salinization              | Nil                                                      | [27]       |
| GW                  | Isiokolo, Apkerpe, Evwreni, Ovhori, Ughelli, Ofoko 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 - 535 cfu/ml and total coliform (10 - 70 MPN/100 ml) | [56]       |
| SW                  | Agbor, Owa                                                              | Groundwater was considered unsuitable for drinking and other purpose                   | Nil                                                      | [57]       |
| GW                  | Obiaruku, Okuzu                                                         | Groundwater was considered unsuitable for drinking and other purpose                   | Nil                                                      | [58]       |
| GW                  | Warri                                                                   | Major factors that influence water Rock-weathering Human activities High TDS, Pb, Cl, Ni and Cl Slight seawater intrusion | Fecal Coliform Above set limit                           | [59]       |
| SW                  | Kokori-Erhoike                                                          | High TS, Ec, Ca, Mg, PO₄³⁻                                                           | Nil                                                      | [60]       |
| GW                  | Warri                                                                   | Groundwater was considered Acidity                                                    | Nil                                                      | [19]       |
| GW                  | Ozoro                                                                   | High concentration of Cu                                                               | Nil                                                      | [61]       |
| GW & SW             | Ubeji, Ejeha, 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, SO₄²⁻, Na⁺ and PO₄³⁻                                | Nil                                                      | [63]       |
| GW                  | Ekrebe Unuode, Okotie, street, Okan, Akpovi Avenue, Aghraho, Oboru Akpoguma and Ekehrhervwe | Hydrochemical facies: MgCl₂, 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 | Coliform bacteria and Enterococcus faecalis            | [20]       |
| GW                  | Delta state                                                             | Chloride water type (sea water Intrusion), low pH                                      | Vibri sp., Escherichia coli, Salmonella sp., Shigella sp | [66]       |
| GW & SW             | Opuraja Community                                                        | acidic pH                                                                               | Coliforms were above permissible limit                   | [67]       |
| GW                  | Amba, Okorodudu, Low Beach, Quar ters, Court road all in Burutu          |                                                                                         | Coliforms were above permissible limit                   | [68]       |

**Where:** GW= Groundwater, SW=Surface water
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 | Excess Na causes hypertension, congenital diseases, kidney disorders and nervous disorders in human body [69] |
|            | • Leachages from septic tanks in densely populated area | |
|            | • Animal waste | |
| Cl         | • CI in water originates from industrial effluents, sewage and urban runoff that contain saline intrusion | Excess Cl in water such as hypertension, chances of stroke, ventricular hypertrophy, osteoporosis, renal stones, and asthma ([70]; [71]) |
|            | • 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 | |
| K          | • Fertilizer application | Presence of K in water may lead to kidney disease, heart disease, coronary artery disease, hypertension, diabetes, and adrenal insufficiency |
|            | • Landfill leachates | |
|            | • Animal waste and leakage from septic tanks | |
| HCO₃⁻      | • Sewage waste and landfill leachate | |
| Nickel     | • Smelting | Possible carcinogen |
|            | • Refining and petroleum industries | |
|            | • Chemical and catalyst production | |
|            | • Septic tank over flow and leakages | |
|            | • Organic and chemical fertilizers | |
| NO₃⁻       | • Application of fertilizer | |
|            | • Wide application of H₂SO₄ in electroplating | |
| SO₄²⁻      | • Anthropogenic sulfur emissions from fossil fuel combustion may also contribute to the overall SO₄ concentrations in groundwater | |
| Mg         | • The concentration of Mg in river and sea water can be increased by rainwater falling on rocks | |
|            | • Occur as result of soluble and abundance in most rock types | High concentration of Mg in water may lead to the damage of gastrointestinal tract, nervous system and the kidneys. |
| Ca         | • The amount of dissolved lead in surface water and groundwater depends on pH and the concentration of dissolved salts | High concentration of Ca in water may lead to hypercalcaemia, metabolic alkalosis and renal insufficiency) and hypercalcaemia. |
|            | • And the types of mineral surfaces present | The presence of Pb in water may lead to tiredness, sleeplessness, irritability, headaches, joint pain and gastrointestinal. |
|            | • 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 |
| Pb         | • It may be due to industrial activities, refuse dumps and metal scraps along the river courses which are also source of groundwater | Excess Pb in water may cause damage to kidney and liver in human |
|            | • It may be due to industrial activities, refuse dumps and metal scrap | |
|            | • Along the river courses which are also source of groundwater | |
| Fe         | • 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 |
|            | • 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 |
|            | • Water drained from agricultural fields, municipal waste water, rainfall | |
|            | • Low pH- Acid rain as a result of gas flaring | |
|            | • pH above 8.5 is regarded as hard water. | The higher Ec may cause a gastrointestinal irritation in human beings. 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 |

Table 2. Source of various ions in water resources, and attendant health implications
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 NaHCO3 type does not exist within Warri. His results implies that salinization 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 SO4, Cl, Cu, Fe, Pb, NO3, 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 [29] 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
the view that the sedimentation pattern as well as stratification determines both the quality and quantity of water in the region. \cite{45} reported that ground water in Oterokpe, 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. \cite{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 \cite{74} the source of most of the hydrochemical 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 \cite{31,36,67}. According to \cite{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 \cite{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. \cite{75} report that groundwater studied at Akpiroroh, Erhidi, Abavo, Ogume, 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. \cite{39} 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. \cite{20} suggested that shallow aquifer is more vulnerable to contamination of all kind. \cite{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 \cite{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 \cite{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 \cite{67,82,85,86,14} showed striking similarity that groundwater resource in Burutu Warri, Amavi kingdom and Ughelli respectively showed all forms of coliform that were far above \cite{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 \cite{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 is more 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
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.

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