

THE EFFECTS OF ON-SITE SANITATION FACILITIES ON GROUNDWATER POLLUTION IN JAMBUTU, YOLA, NIGERIA

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ABSTRACT

Open defecation is becoming a growing problem in Jambutu; as such the study was aimed at investigating the effects of on-site sanitation system (OSS) facilities on groundwater pollution in Jambutu, perennially flooded area. This was achieved through investigating pH, TDS, TSS, EC, DO, Cl⁻, NO₃⁻, NO₂⁻, NH₃, K, P, Cu, Pb, Ni, Cr⁶⁺, Co, TCC, FCC, and E.coli of boreholes water in the study area in both dry and rainy seasons and compared with standard guidelines for drinking water quality. Correlation analysis of mean distance (23.482 m) of water source from OSS with the results from the investigation of the selected water quality parameters revealed positive correlations with TC (0.0290, 0.1103), FC (0.1412, 0.3575) E.coli (0.1817, 0.5731) for dry and rainy seasons respectively and negative correlations with pH (-0.6348) in rainy season, TDS (-0.4378, -0.4768), TSS (-0.2158, -0.4291) and NH₃ (-0.7811, -0.5353) for dry and rainy seasons respectively, Cl⁻ (-0.7665), Cu (-0.3407), NO₃⁻ (-0.0417) and K (-0.2133) for dry season. The positive correlations of some water quality parameters with mean distance could be attributed to leachates from OSS as a result of perennial flash floods in the area. Further research should be carried out in the area to determine safe borehole depth, design of OSS structures for flood prone areas like Jambutu and design of centralised conventional sewerage system as a new sanitation method to ensure safe portable water.

Keywords: Onsite Sanitation System (OSS); Groundwater pollution; quality parameters; Perennial floods.

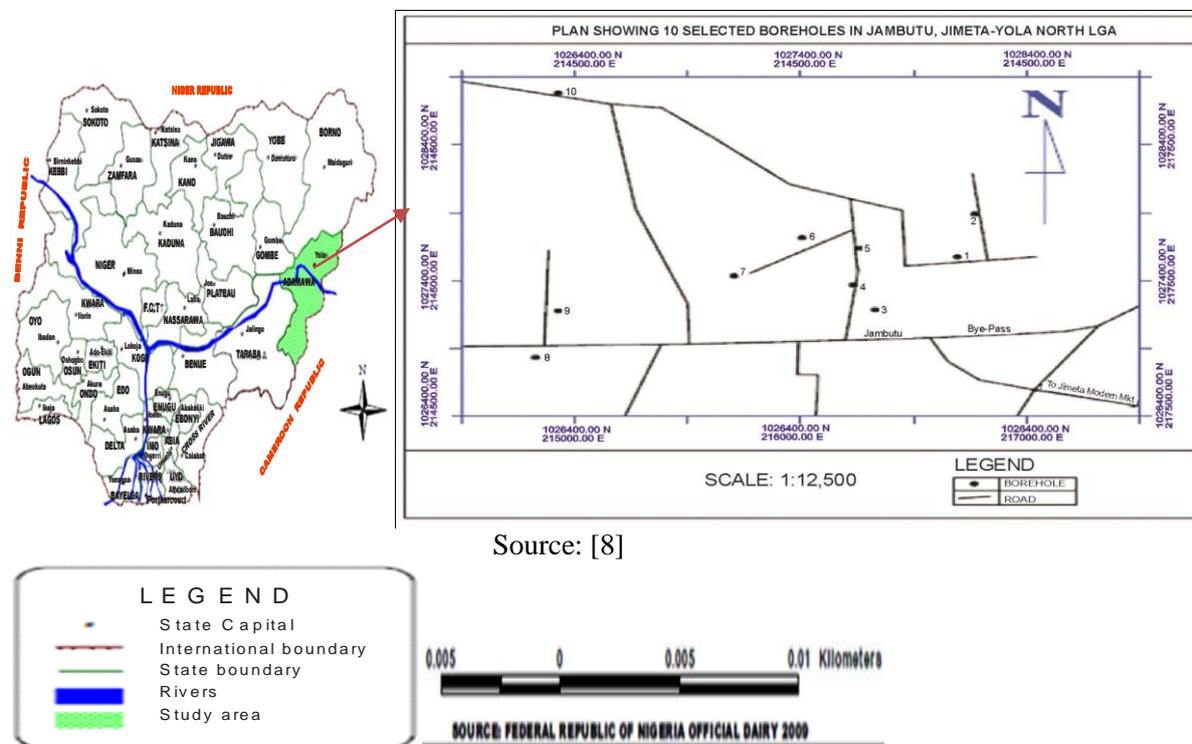
1 INTRODUCTION

Groundwater quality is deteriorating due to geogenic as well as anthropogenic factors. Among the anthropogenic factors is the impact of on-site sanitation (OSS) on groundwater quality which is of great concern. The groundwater pollution from on-site sanitation (OSS) facilities such as geological settings has been dealt with widely in different parts of the world but the hydrogeological factors, such as depth to water table, nature of the soil matrix, and lateral separation between the OSS facility and groundwater source are some of the key parameters affecting groundwater pollution [1]. Groundwater pollution is the introduction or presence of organic, inorganic, biological, radiological or physical foreign substances in water that tend to degrade its quality. Evidences from literature indicate that most of the previous studies on groundwater quality in Nigeria were centred on effects of leachate from waste dumpsites with little or no reference to other on-site sanitary conditions especially the impact of OSS facilities [2] who reported that absence of wastewater management and clean water supply creates major health issues which escalate the poverty level by causing disease, death and environmental deterioration, especially in developing countries such as Nigeria. It has been estimated that about 80% of all the diseases in the developing countries is related to unsafe water supply and inadequate sanitation [3]. According [4], there is a significant lack of proper wastewater treatment in Nigeria like most developing countries. Untreated wastewater or effluent is one of the most common types of pollution found around urban rivers and in groundwater sources in many African cities [5]. On-site sanitation system is a wastewater management system that treats wastewater of individual houses, apartment blocks or small

communities close to their origin. Typically, OSS is a combination of many technologies within a given geographical boundary, namely, onsite facilities, low cost collection facilities and dispersed location of treatment, Memorandum of Understanding Centre of Excellence MoU DCoE in DWWM [6]. The hydrogeological formation (such as depth to water table, nature of the soil matrix, and lateral separation between the OSS facility and groundwater source of an area) is a major factor that determines the pollution of its groundwater resource. The lateral distance is an obvious criterion which can be checked with relative ease. According to the recommended standard, the lateral distance between OSS facility and any drinking water source is estimated to be a minimum of 30 m [7]. The absence of centralised and clean water supply system and conventional centralised wastewater management infrastructure in Jambutu have led people to depend on groundwater to meet their water needs and OSS facilities for wastewater management. It is also prone to perennial flooding due to its location within the lower sub-basin of the upper Benue valley and has inadequate drainage [8]. Consequently, this study is aimed to determine the relationship between the pollutants in groundwater sampled boreholes with lateral distances between the boreholes and the OSS facilities.

2 THE STUDY AREA

The study area is Jambutu, in Yola North Local Government Area, Adamawa State, Nigeria. The parameters of Jimeta-Yola consists of its location on latitude $9^{\circ} 20' 00''$ N and longitude $12^{\circ} 30' 00''$ E at the bank of River Benue of Yola is located within the lower sub-basin of the Upper Benue valley. The sedimentary rock of this area consists of two major stratigraphic units, the Bima Sandstone and the River Course Alluvium. The Bima Sandstone is the oldest and the most extensive sedimentary unit in the study area. It covers about $2/3$ of the area. The River Course alluvium overlies the Cretaceous Bima Sandstone. The sandstones are composed of sand, silty sand, silty clay and pebble horizons. In some areas, the alluvium is composed of river beds and flood plains [9]. The wet season usually starts from April to October while dry season is usually from November to March. The mean annual rainfall for Jimeta is between 700 mm and 1600 mm per annum. Its temperature can be as low as 17°C between December and January while the maximum temperature can be up to 43°C between March and April having evaporation range of between 86.4 – 501.4 mm [10] recorded during the research period.



Source: [8]

Figure 1. Maps of Nigeria showing Adamawa State, and Representative Sampling Points in Jambutu, the Study Area.

2.1 The Geology of the Study Area

The study area is underlain by the Bima sandstone of Albian age, and it consists of moderately consolidated, fine to coarse grained sandstone with intercalations of whitish and red siltstones, mudstones and shales. The sandstones are generally poorly to moderately sorted, well cemented, competent and occasionally cross bedded. Both primary and secondary structures have been observed. The primary structures include cross stratifications, shrinkage cracks, flow marks, ripple marks and pebble accumulation, whereas the secondary structures include faults, folds, joints and fissures. The Bima sandstone overlies the Basement rocks and consists of three beds, namely the Upper beds, Middle beds and the Lower beds [11]. The lower bed is feldspathic but the higher bed, which accumulated as the basin subsided and at greater distance from the granitic basement, generally contains less feldspar. The relatively high permeability of the Bima sandstone, its fractured nature, the weathered topsoil of this formation as well as the intercalation of siltstones, mudstones and shales, provide the hydrologic conditions favouring aquifer formation in the area. Locally, a multi-aquifer system is formed by the localized shales and mudstones which separate the sandstone. The moderately high annual rainfall ensures adequate groundwater recharge [12].

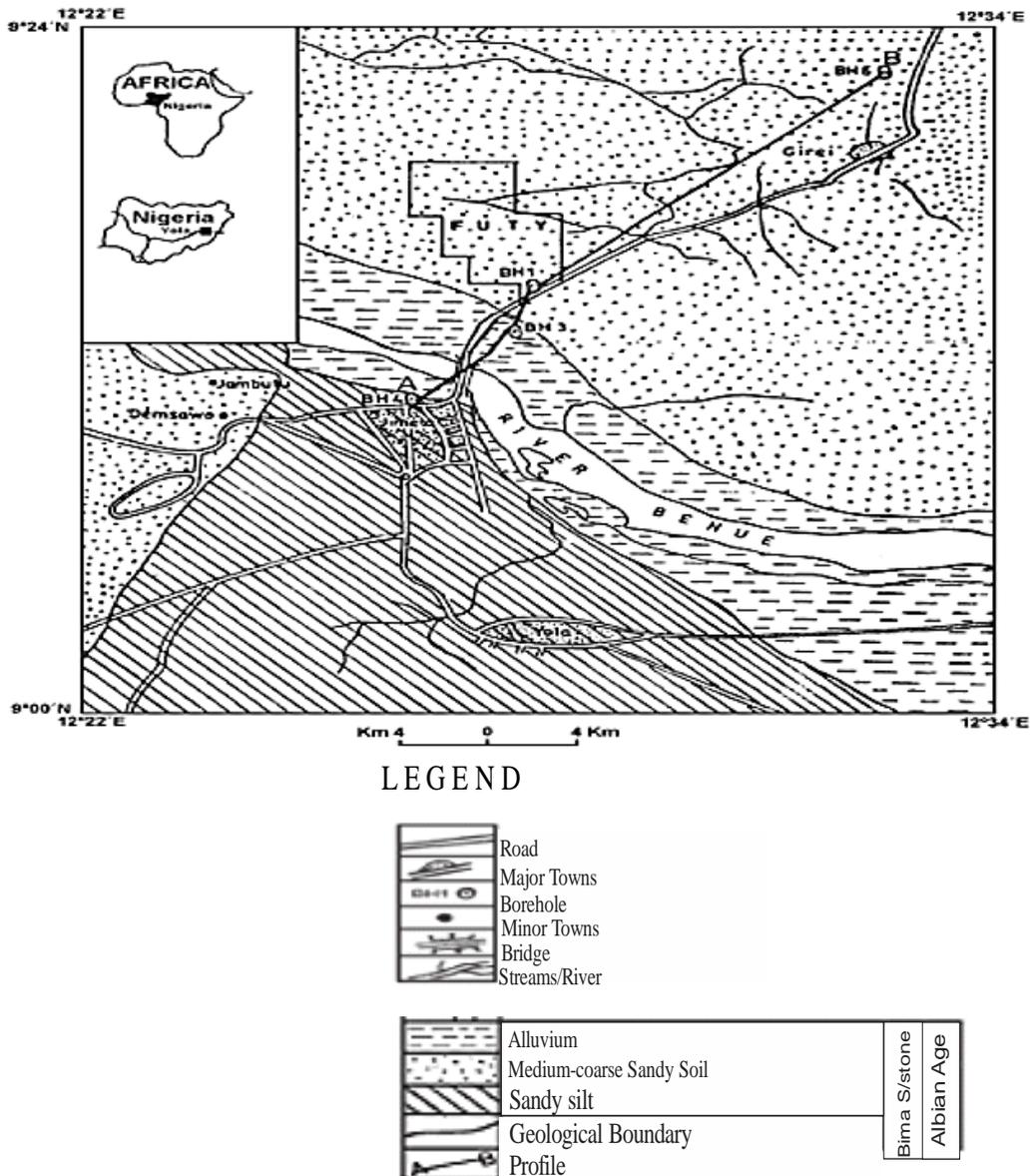


Figure 2. Geological Map of the study area, Adopted from [8].

3 MATERIALS AND METHODS

3.1 Research Design

Water samples were collected from boreholes randomly selected using systematic sampling technique in the informal settlement of Jambutu and was tested in the laboratory of Adamawa State Ministry of Water Resources, Microbiology Department, MAUTech, Yola and Biochemistry Department, Gombe State University. To avoid decomposition, the water samples were transported to the laboratory in a cooler box with ice cubes. Results of laboratory tests from sampling points with varying distances from OSS facilities were compared with [13] standard guidelines for drinking water quality. The parameters tested were: the physical, chemical and bacteriological parameters.

3.2 Sampling Procedure

Systematic Random Sampling technique was used for sampling in this investigation. It is a type of probability sampling which select samples by following some rules set by the researcher which involves selecting the K th element where the random start is determined. Systematic random sampling is based on selection of units situated at a certain predetermined interval called the sampling interval. The sampling interval was calculated by using the formula [10].

$$k = \frac{N}{n}l \quad (1)$$

Where: k = sampling interval, N = total number of functional boreholes in the population, n = sampling points proposed (sample size).

Sampling points were identified through systematic random sampling technique. GPS was used to determine northern and eastern grids values and then used to estimate the lateral distance of each sampling point from the pit latrines, septic tanks or soakaways. The following formula was used to estimate the lateral distances of OSS from water sources as used by [10].

$$D = \sqrt{(\delta N)^2 + (\delta E)^2} \quad (2)$$

Where: D = lateral distance in metres, δN = change in northern grids values from GPS, δE = change in eastern grids values from GPS.

Polyethylene bottles (300 ml) were washed and rinsed with distilled water to disinfect them; were used for sampling. Three samples were taken from each of the boreholes in the sample size to reduce error, and their mean values were used for dry (March) and rainy (August) seasons. The physico-chemical parameters were analysed by following the standard protocol. The physical quality analysis involved performing tests for; pH, TDS, TSS, EC and DO. pH was analysed using Jenway 350 pH meter, EC and TDS were analysed with HI 9835 EC/TDS/NaCl meter (Hanna instrument), TSS through weighing balance, oven and filter paper and DO with HI 9143 Dissolved Oxygen meter (Hanna instrument). The chemical quality analysis involved performing tests for nitrates, nitrites, chlorides, ammonia, Potassium, Phosphorus and heavy metals such as lead (Pb), copper (Cu), Chromium (Cr^6), Nickel (Ni) and cobalt (Co). Nitrates, Nitrites and Phosphorus were analysed using Cecil 7400 UV/Vis Spectrophotometer, chlorides and ammonia were analysed by titration method and Potassium by flame photometer. Heavy metals were analysed using Flame Atomic Absorption Spectrophotometer (AAS Buck Scientific 205 model). Bacteriological quality involved test for total coliform, faecal coliform and Escherichia coli. The bacteriological quality parameters were analysed by Membrane Filtration (MF) medium, m-ColiBlue24 Broth, USEPA Approved for Drinking Water Method No. 10029.

3.3 Data Collection and Analysis

The data collected were analysed using Mat Lab. Correlation analysis was used to determine the degree of relationship between pollutants in groundwater sampled boreholes with lateral distances between the sampling points and the OSS facilities.

4 RESULTS AND DISCUSSIONS

4.1 Correlation Analysis between distance and physical contaminants in dry and rainy seasons

The result of correlation analysis between mean distance (23.48 m) and physical contaminants indicated negative correlations for pH (-0.6348) rainy season, EC (-0.2748) dry season, TDS (-0.4378,-0.4768) and TSS (-0.2158,-0.4291) both dry and rainy seasons respectively. Positive correlations for pH (0.0021) dry season, EC (0.2100) wet season and DO (0.0091, 0.2005) in dry and wet seasons respectively and their matrix (Figure 3). There was a relationship between mean distance and the levels of all the contaminants in the groundwater of the area. Negative correlation implies movement in opposite direction, which means as the distance between water source and OSS increases the level of those pollutants in the borehole decreases and vice versa. The high negative correlation of pH (-0.6348) in rainy season revealed the magnitude of the relationship of distance of water source from OSS on the acidity and alkalinity in the groundwater of the study area, especially in rainy season which could be attributed to leaching from OSS and easy transport of such leachates to water sources. This is in agreement with the findings of [13]. Positive correlation implies movement in the same direction, which means as the distance between water source and OSS increases the level of those pollutants in the borehole also increases and vice versa. This could only be possible if the pollutants are leached by perennial flash floods into the boreholes.

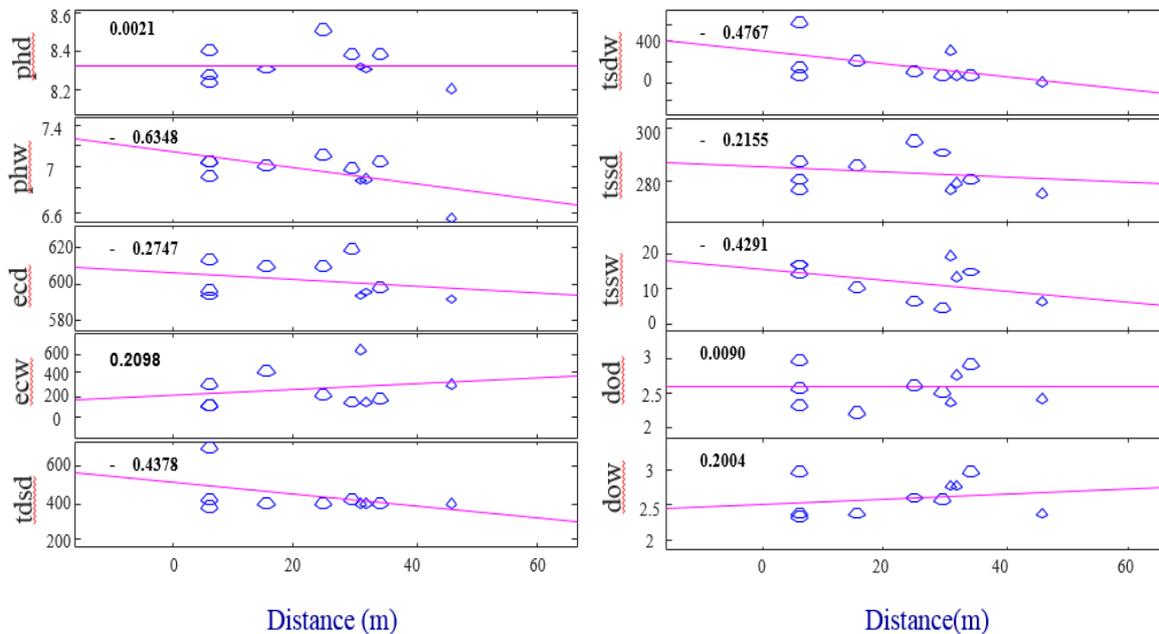


Figure 3. Correlation Matrix of Physical Parameters and Distance

Phd & phw, pH in dry & wet seasons; ecd & ecw, electrical conductivity in dry & wet seasons; tdsd & tdsd, Total dissolved solids in dry and wet seasons; tssd & tssw, Total suspended solids in dry and wet seasons; dod & dow, dissolved oxygen in dry and wet seasons.

4.2 Correlation analysis between distance and bacteriological contaminants in dry and wet Seasons

The result of correlation analysis between mean distance (23.48 m) and all the bacteriological contaminants and their matrix (Figure 4) in both dry and rainy seasons indicated positive relationships, TC (0.0290, 0.1103), FC (0.1412, 0.3575), E.coli (0.1817, 0.5731) in dry and rainy seasons respectively, revealing that mean distance (23.482 m) of water source from OSS has a relationship with the level of contaminants (total coliform, faecal coliform, and E.coli) in boreholes water of the area. Contrary to [14] who reported that there was no relationship between groundwater quality and the distance from borehole to soakaway. [15] suggested that in order to protect the boreholes from OSS contamination regardless the distance between them, boreholes should be uphill

from OSS in relation to the soil type and the hydrogeology of the area. The positive correlation implies movement in the same direction, which means as the distance of borehole from OSS increases, the levels of contaminants also increases and vice versa. This could therefore be attributed to the leachates from OSS as a result of perennial flash floods in the area [12].

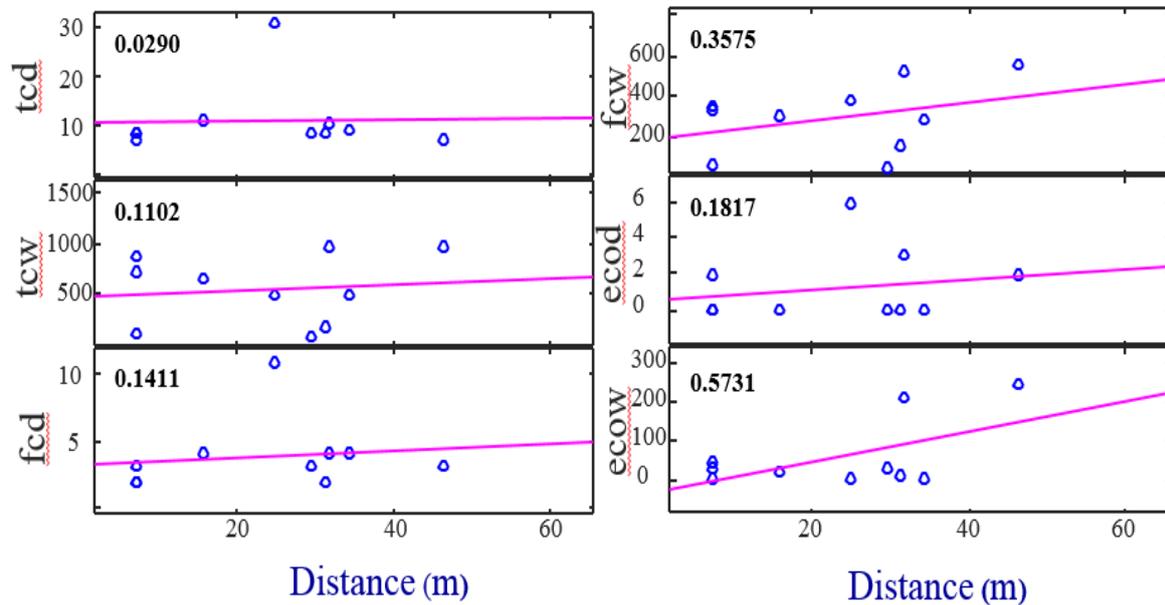


Figure 4. Correlation Matrix of Bacteriological Parameters and Distance

Tcd & tcw, Total coliform in dry & wet seasons; fcd & fcw, Faecal coliform in dry and wet seasons; ecod & ecow, E.coli in dry & rainy seasons.

4.3 Correlation analysis between distance and chemical pollutants in dry and rainy seasons

The result of correlation analysis between mean distance (23.48 m) and chemical pollutants and their matrix (Figure 5) revealed high negative correlations with Cl^- (-0.7665) dry season, NH_3 (-0.7811, -0.5353) both dry and rainy seasons. Low negative correlations of NO_3^- (-0.0417) dry season, K (-0.2133) dry season, Cu (-0.3407) dry season. High positive correlation with NO_3^- (0.6584) wet season and a low positive correlation with NO_2^- (0.2635, 0.2041) in both dry and rainy seasons. Implying that distance between water source and OSS has a relationship with all the pollutants. These results are quite similar with the findings of [7] where there was close relationship between OSS and water sources. High negative correlations with Cl^- (-0.7665) dry season, NH_3 (-0.7811, -0.5353) both seasons, low negative correlations with NO_3^- (-0.0417) dry season, K (-0.2133) dry season, Cu (-0.3407) dry season, revealed that distance between water source and OSS had a strong relationship with the levels of Cl^- in dry season, NH_3 in both dry and rainy seasons, a low relationship with the levels of NO_3^- , K, and Cu in dry season boreholes in the area. Negative correlation implies movement in opposite direction, which means as the distance between borehole and OSS increases the levels of those pollutants in the borehole decreases and vice versa. Positive correlation implies movement in the same direction, which means as the distance between water source and OSS increases the levels of those pollutants in the water source also increases and vice versa. The positive correlations of NO_3^- (0.6584) rainy season and NO_2^- (0.2635, 0.2041) in both dry and rainy seasons suggest that boreholes in Jambutu were polluted by leachates from perennial flash floods.

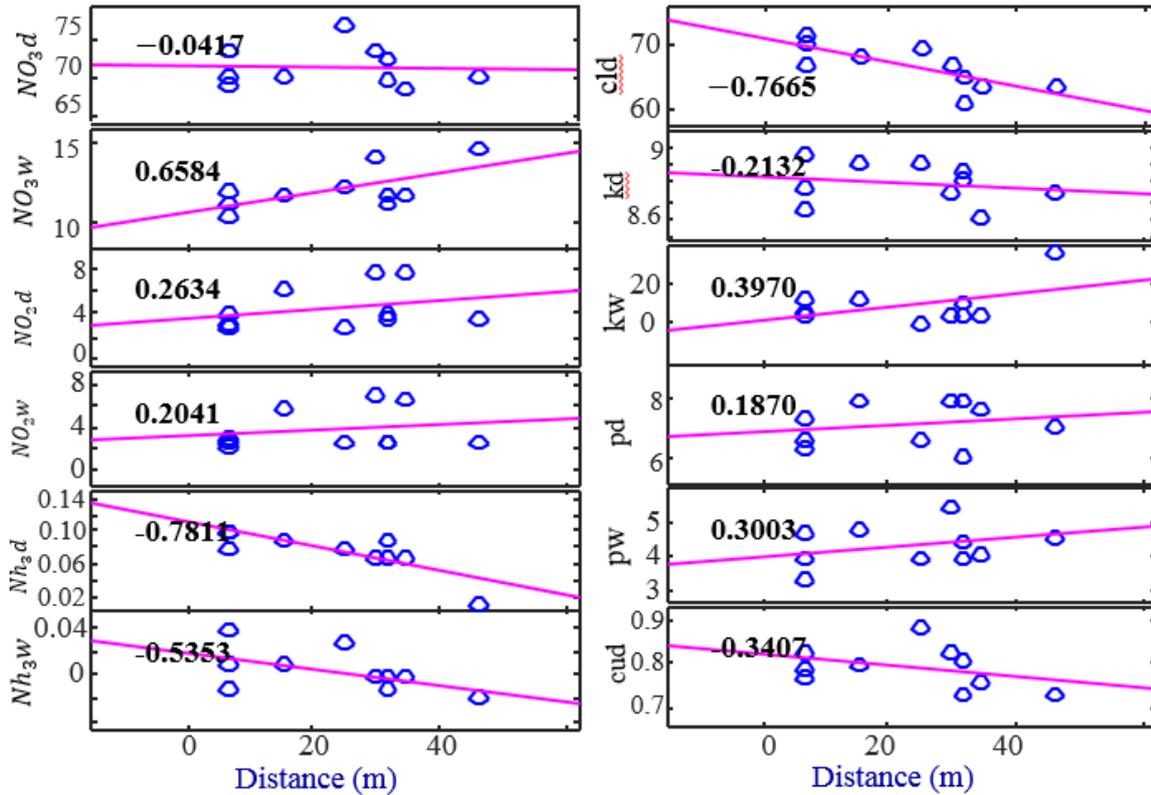


Figure 5. Correlation Matrix of Chemical Parameters and Distance (cld)

Chloride in dry season; no₃d & no₃w, Nitrate in dry and wet seasons; no₂d & no₂w, Nitrite in dry and wet seasons; nh₃d & nh₃w, Ammonia in dry and wet seasons; kd& kw, Potassium in dry and wet seasons; pd & pw, Phosphorus in dry and wet seasons; cud, Copper in dry season.

5 CONCLUSIONS

The groundwater of the study area was polluted and not suitable for human consumption unless it is treated. The pollutants include: physical, chemical and bacteriological. Total microbial load was more in rainy season than dry season which is an indication of presence of leachates from perennial flood waters. Correlation analysis of physical contaminants, pH rainy season had a high negative correlation with distance (-0.6348), TDS in both dry and rainy seasons (-0.4378 and -0.4768) and TSS in rainy season (-0.4291) have medium negative correlations while TSS dry season (-0.2158) had low negative correlation. Correlation analysis of chemical pollutants, Cl⁻ dry season (-0.7665) and NH₃ both seasons (-0.7811 and -0.5353) have high negative correlations with distance, Cu (-0.3407) had medium negative correlation, while NO₃⁻ (-0.0417) and K (-0.2133) have low negative correlations in dry season. Correlation analysis of bacteriological contaminants, all the contaminants have positive correlations with distance. TC (0.0290 and 0.1103), FC (0.1412 and 0.3575), E.coli (0.1817 and 0.5731) dry and rainy seasons respectively. It is recommended that, 1) Further research should be carried out in the area to investigate safe borehole depth that will reduce the risk of groundwater contamination. 2) Design of OSS structures for flood prone areas like Jambutu to eliminate or reduce escape of waste from the structures or design of centralised conventional sewerage system as a new sanitation method.

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