Effects of Wastewater Generation and Management on the Groundwater Resources of Dutse-Alhaji Area, Federal Capital Territory, Central Nigeria

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Abstract

Management of wastewater has been identified as a challenge in developing countries. Poor management of wastewater poses a threat to public health, economy, and the environment. The aim of the study was to examine the effects of wastewater on both groundwater and surface water resources of Dutse-Alhaji Area, Federal Capital Territory, Central Nigeria. The methodology adopted involved a study on the geology using the traverse method at a scale of 1:10,000, hydrogeological studies involved determining the depths and water levels of wells and boreholes, information on wastewater generation and effect was done through the administration of structured questionnaires, water quality analysis was determined through sampling of both ground and surface water and wastewater for laboratory analysis. The result showed that the wastewater generated is mostly from bathing and laundry. Most residents dispose their wastewater by pouring on the ground, soak away, septic tanks and open drainages. Shallow hand dug wells and boreholes are the major sources of water. The physico-chemical composition of the sampled water shows that pH has a range of 7.5 and 8.7, Temperature 29ºC and 32ºC, Salinity 1231mg/l and 1529mg/l, Chloride 260mg/l and 300mg/l, Sodium 182mg/l and 200mg/l, Potassium 84mg/l and 100mg/l, Calcium 24mg/l and 50mg/l, Magnesium 26mg/l and 40mg/l, sulphate 10mg/l and 19mg/l, Carbonate 370mg/l and 530mg/l and Bicarbonate 945.75mg/l and 1462.5mg/l. Substances found to be occurring in high concentration are bicarbonates, chloride and sodium. Common ailments that afflict the area are malaria and typhoid. Environmental impacts of wastewater in the area include growth of pathogens like mosquito parasite and groundwater pollution. Residents often come in contact with wastewater directly and indirectly. Wastewater finds its way into the groundwater due to the shallow depth of the water sources and improper management, thereby contaminating it. Improved localised wastewater management is recommended, pending the intervention of the government for a central sewer system. Existing and new Hand dug well should be lined with concrete to reduce infiltration rate.

Keywords: *Dutse Alhaji, wastewater, groundwater resources, management*

INTRODUCTION

Wastewater can be referred to as any water that has been adversely affected in quality by human (Burton and stensel, 2003). Wastewater is composed of contaminants that can degrade water quality. Wastewater includes domestic, industrial, or agricultural liquid waste. Potential contaminant in wastewater includes all materials added to it during its use. Therefore, it is mostly composed of human body waste such as urine and faeces, sullage (liquid waste from washing, laundry, food preparation and the cleaning of kitchen) (Duncan, 2003).

Wastewater that is composed of human body waste such as faeces and urine are referred to as black water. These include water from septic tanks; soak away, lavatories and washing water. Wastewater can be contaminated with pathogens, synthetic chemicals, organic matter, nutrients, organic compounds, and heavy metals which can occur in solution or particulate matter (Idris-Nda *et.al*, 2013).

Wastewater poses serious health challenge, huge economic loss, and environmental deterioration when not properly managed. Environmental impact of wastewater degradation may result in pollution of groundwater, physical changes in receiving water bodies, increased level of dissolved oxygen, bioaccumulation in aquatic life and release of toxic substances (Mahmood and Maqbool, 2006). Bacteria, viruses, and protozoa present in untreated wastewater result in diseases. Many microbial pathogens in wastewater can cause diseases such as typhoid, dysentery and other intestinal disorder (Absar, 2005).

Wastewater management is one of the major challenges facing urban areas in developing countries. Increase in urbanization and population increases the rate of wastewater generated due to human activities (Thomas-Hope 1998). Most cities in Nigeria do not have access to comprehensive system for the collection and disposal of wastewater (Aliyu, 2010). Improper management of wastewater can result in severe health and environmental impacts.

The study was aimed at determining the effects caused by wastewater generation and improper management on the groundwater resources of Dutse-Alhaji Area, Federal Capital Territory, Nigeria.

Study Area

Dutse-Alhaji the study area is in Bwari Area council of the Federal Capital Territory, Abuja. It lies between the latitude 9º7´00´´ to 9º 9´00´´N and longitude 7º21´00´´ to 7º23´00´´E (Figure 1). It has estimated population of about 247,318 (Census, 2006). It is a satellite town, mostly occupied by residential buildings, schools, market and hospital. Accessibility is by major roads and footpaths.

The Federal Capital Territory is central to all parts of Nigeria, and it lies above the hot and humid low lands of the Niger and Benue trough but below the drier parts of the country which is lying to the North (as shown in figure 1).

The area lies within the Guinea savannah vegetation belt and experiences two seasons, namely dry and wet seasons. Like the climate of FCT, Dutse-Alhaji also experiences both dry season and rainy season. The dry season starts in November and ends in March while the rainy season starts from April and ends in October. The area records highest temperature of about 34ºC during the dry season and about 24ºC in the raining season. The annual total rainfall is in the range of 1100mm to 1600mm (Dan-Hassan et. al., 2012).

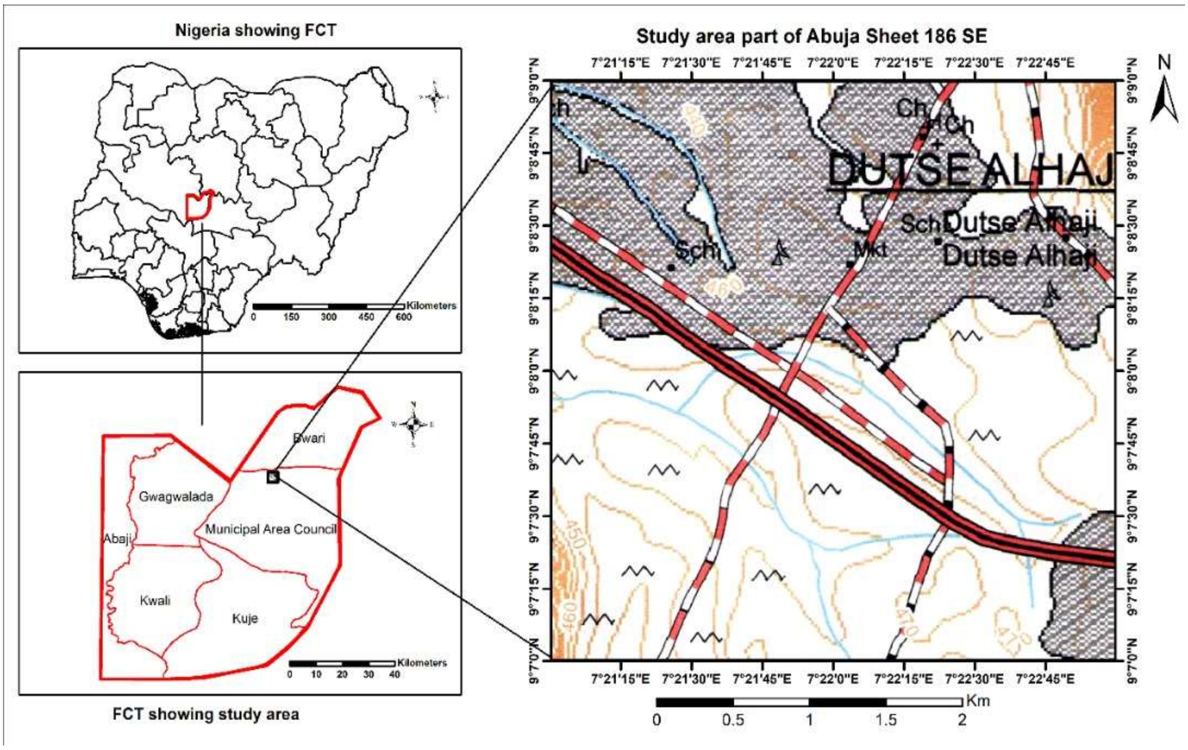


Figure 1: Location map of the study Area (Dutse-Alhaji) and environ.

The most common health hazards associated with domestic wastewater includes disease caused by viruses, bacteria and protozoa that may get washed into drinking water supplies or receiving water bodies (Kris, 2007). Microbial pathogens have been identified as critical factors contributing to numerous waterborne disease outbreaks. Many of these pathogens found in domestic wastewater can cause chronic disease with long term health effects such as stomach ulcer and degenerative heart disease. Cost of detection and identification of the microbial pathogens in wastewater are always expensive, difficult and time consuming.

Environmental Impact of wastewater Discharge

Wastewater is composed of contaminant that can pollute the water source when it comes in contact with it (Eikelboom and Draaizer, 1999). Water source pollution include both boreholes and wells. This has created negative environmental impacts and increased the health risk of the residents. Wastewater that is directed to the environment is the prime breeding sites for mosquitoes, houseflies, rodents, and other vectors of communicable diseases such as dysentery, diarrhoea and. The two fundamental reasons why wastewater should be properly managed includes the prevention of pollution of water sources and the protection of public health by safeguarding the environment against the spread of diseases. Wastewater management is presently poorly done or even non-existent in Nigeria and most other developing countries (Idris-Nda *et.al*, 2013).

Wastewater form stagnant pool in the neighbourhood due to blocked or absence of drainage channel. This pool of water gathers at the foot of the buildings commonly along fence lines, building frames and foundations leading to cracks and eventually collapse of the structure. The wastewater drains are often blocked due to mixture with municipal solid waste thereby serving as breeding ground where mosquitoes and other pests breed in blocked drains and ponds, spreading diseases.

Characteristics of Wastewater

The effective management of any wastewater flow requires an accurate knowledge of its characteristics. These characteristics are necessary to facilitate the effective design of wastewater treatment and disposal system, and to enable the development and application of water conservation and waste load reduction strategies (Burks and Minnis, 1994). The quality of wastewater may be defined by its physical, chemical, and biological characteristics. Physical parameters include temperature, pH, electrical conductivity, colour, odour, and turbidity. Insoluble contents such as oil and grease, solids (suspended or dissolved) and inorganic fractions also fall into this category (Burks and Minnis, 1994).
Chemical parameters associated with the organic content of domestic wastewater include Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Organic Carbon (TOC) and Total Oxygen Demand (TOD). Inorganic chemical parameter include alkalinity, salinity, hardness, acidity as well as concentrations of cations such as Manganese, Iron, and anions such as sulphates, chlorides, nitrates, and phosphates. Bacteriological parameters include faecal coliforms, coliforms, algae, protozoa, specific pathogens, and viruses (Metcalf and Eddy, 2003).

MATERIALS AND METHODS

Primary and secondary sources of data were used for this study. Primary data include administration of structured questionnaire, fieldwork, and sampling. Secondary data were obtained from both published and unpublished information and government agencies.

A closed ended questionnaire was designed and used as a tool for data collection. The questionnaire was designed in a standard form to receive exact answers from respondent. This made the data collection method a reliable one. The questionnaire was divided into sections which include population (information in each household), water generation and usage and public health. Possible answers were provided as options in which the respondents were required to choose appropriately.

A comprehensive field survey exercise was carried out to gather information about the study area. Information considered include accessibility (access road), condition of wastewater drainages, housing types, water sources, major health challenge, environmental hazards, and potentially polluted areas. Geological and hydrogeological studies were carried out (rock types, structural features, Depths and location of wells and boreholes in the area were determined). Representative samples of water (wastewater, hand dug well and drilled well) and soil were taken for laboratory analysis.

Topographical map was obtained from the Nigerian Geological Survey Agency (NGSA). Hospitals within the area were visited to obtain reports on health challenge due to wastewater pollution in the area.

A hand-held GPS was used for the study to identify the sample point and water source (wells and Boreholes) point. Frequency percentage method was adopted for data analysis. This method was chosen because it is principally the most suitable method for analysing questionnaire. Data presentation was in form of tables, charts, and graphs. Interpretations, inferences, and deductions were based on the responses made by the respondents. Hydrogeological investigation was carried out on a total of 25well (19hand dug wells and 6 boreholes). Measurements taken at each hand dug well are coordinates, well depth, elevation, and water level. For each borehole, the coordinates and elevations were also measure while the depths were determined based on interview response.

RESULTS AND INTERPRETATION

Figure 1 shows that the area is predominantly underlain by rocks belong to the basement complex and consists of basically granite and migmatite. The rocks are highly weathered in some areas and only fairly weathered in others. Table 1 is a summary of responses to questionnaires administered to respondents in the area.

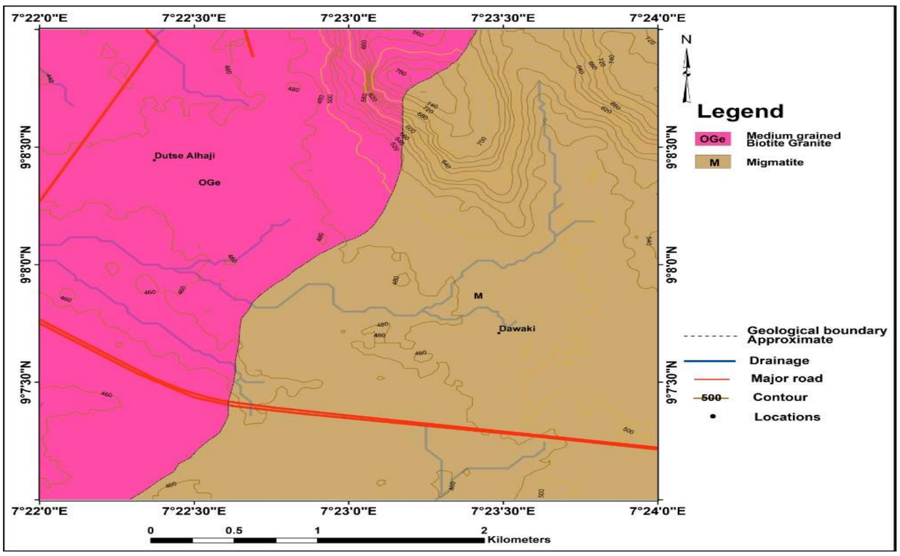


Figure 2: Geological map of parts of Dutse Alhaji area, FCT.

Demography and wastewater generation

Population parameter in the questionnaire include size of the household, size of family, ratio of male to female, composition of household and number of children. These parameters are important in the study of the population of this area. It reveals the component of the population. Hence, it helps in the estimate of the population size and wastewater generated.

Size of household includes the category of structures in the area. It ranges from single room to four bedrooms apartment. Twenty one percent of the respondent live in a single room apartment, fifty eight percent in two-bedroom apartment, seventeen percent in three-bedroom apartment and four percent in four-bedroom apartment. This reveals that average of the respondent lives in a two-bedroom apartment.

Size of family describes the number of persons per family. The range of people living in a household is categorize into; one person, two-four people, four-six people, six-eight people, and above eight people, results indicate that an average of 4-6 people leave in a household. Composition of each household was also considered by categorizing the people in each household. Categories include single, one parent family, two parents' family and married with kids. Figure 4.1e shows that four percent of the respondent are single, twelve percent are one parent family, forty percent are two-parent family, while forty-four percent are married with children. Number of children in each household ranges from 7 to 1, with an average of 4 children per household.

Water source identified are Boreholes, water board (tap water), well water and water vendor (Meiruwa). Most of the inhabitants (69%) depend on boreholes, 3% use water board, 8% use well water, 20% depend on water vendors. Oral interview reveals that the water vendors also source their water from wells and boreholes. This result shows that the major source of water in this area is boreholes and hand dug wells. In terms of water use, 24% percent of the inhabitants use larger portion of their water for cooking, 5% for dish washing, 40% for laundry and 31% for bathing. This analysis shows that most of the wastewater generated has soap from bathing, laundry, and dish washing.

Wastewater is discharged into the environment through drains and sometimes just poured onto the surface of the ground. 24% percent of the inhabitants dispose wastewater into public drainage, 24% percent into soak away, 29% percent pour on the open surface, while 23% percent into septic tank which is normally constructed to simply hold the water to enable it infiltrate or evaporate into the atmosphere, sometimes it requires evacuation.

Hydrogeology

Water level elevation map was constructed (figure 2) from the data acquired. Measurements taken at each hand dug well were coordinates, well depth, elevation, and water level. For each borehole, the coordinates and elevations were also measure while the depths were determined based on drilling log report. The water level elevation shows two major flow directions in the NE-SE and NW-SE, indicating groundwater flow towards a discharge area, the minor flow component is in the NE-SW direction (Figure 4.2). The indication here is that groundwater flow is controlled by both the weathering intensity and elevation. Depth of boreholes range from 50m to 170m. while hand dug wells range from 3m to 10m depending on the weathering profile. While the boreholes yield water all year through, the hand dug wells tend to be seasonal.

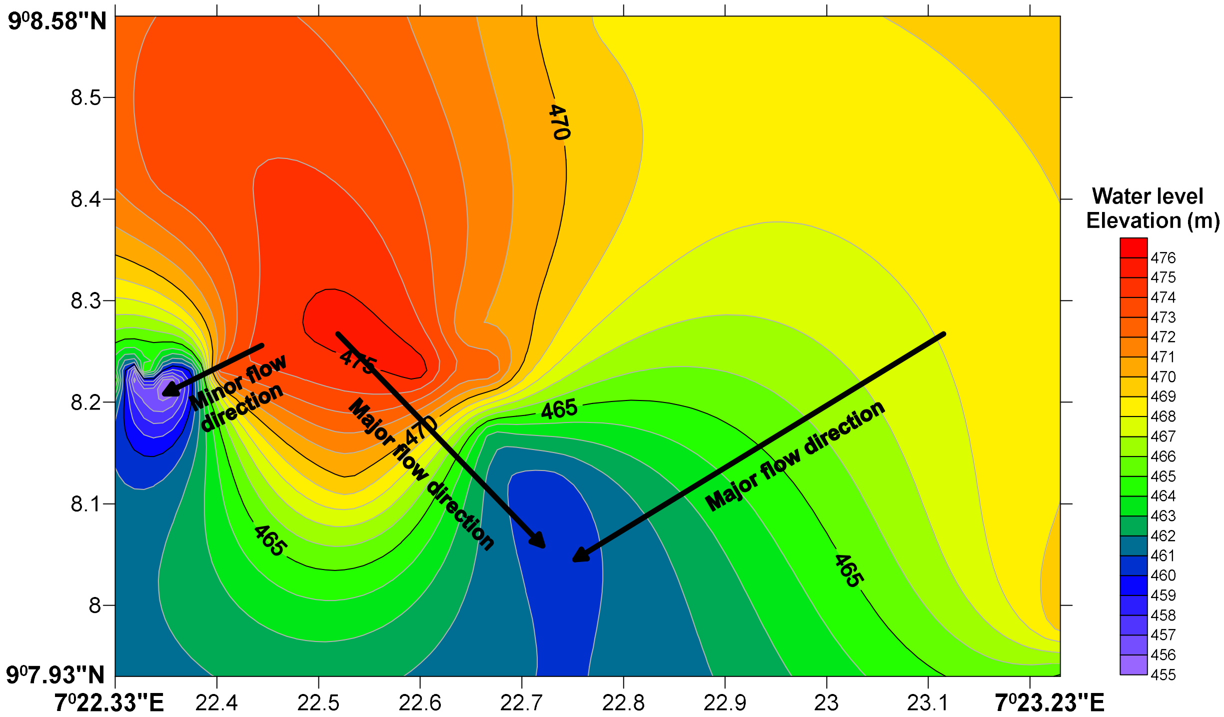


Figure 2: Water level Elevation Map

Water Quality

Conductivity, total alkalinity, and total hardness were the physical parameter with high value in the analysed drilled well sample. The physical parameter of wastewater sample is generally higher than drilled well, with Chemical Oxygen Demand (COD) as the highest parameter, then conductivity and salinity. Hand dug well sample had a similar trend as wastewater with high value of COD, Conductivity and Salinity. Comparing the physical parameter of the three water sources, wastewater and Hand dug well has a similar trend with higher values of parameter while drilled well is low (Figure 3).

Most important anions and cations were analysed for in the water samples. The analysed factors include Sodium, Calcium, Potassium, Magnesium, Copper, Iron, Nitrite, Sulphate, Phosphorous, Phosphate, Bicarbonate and Carbonate.

Bicarbonate, Carbonate and Chloride are higher in the chemical parameter of wastewater and hand dug well with lower concentration in drilled well (Figure 4.3.2b). Comparison of the three samples as seen in Figure 4 shows a similar trend in the chemical parameter of wastewater and hand dug well whereas, drilled well is lower.

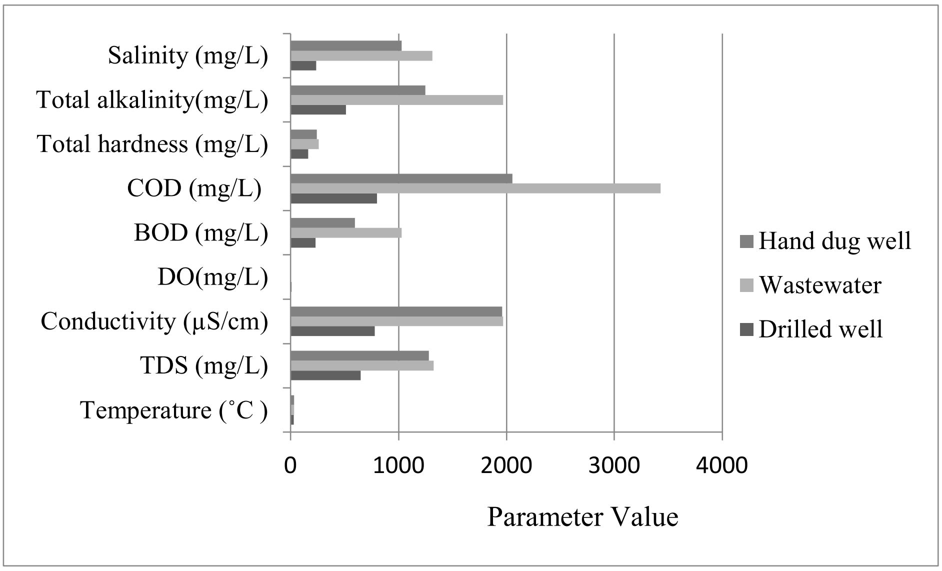


Figure 3: Comparison of physical properties of Wastewater, drilled well and Hand dug well.

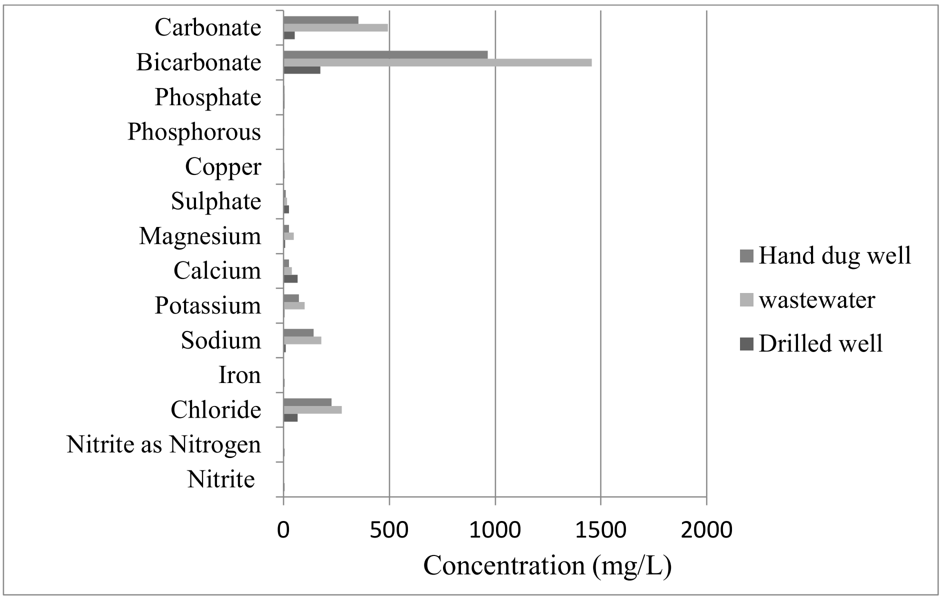


Figure 4: Comparison of Chemical Composition of the water sources

There is absence of Faecal streptococci and E. coli with little quantity of Total coliform and Faecal coliform in the drilled well sample. Wastewater had the highest value of the bacteriological parameters while hand dug well also show appreciable quantity of the parameter. Comparison of the three water sources shows wastewater to have the highest value of bacteriological parameter, while hand dug well showed a similar but lower value whereas drilled well has the least value (Figure 5).

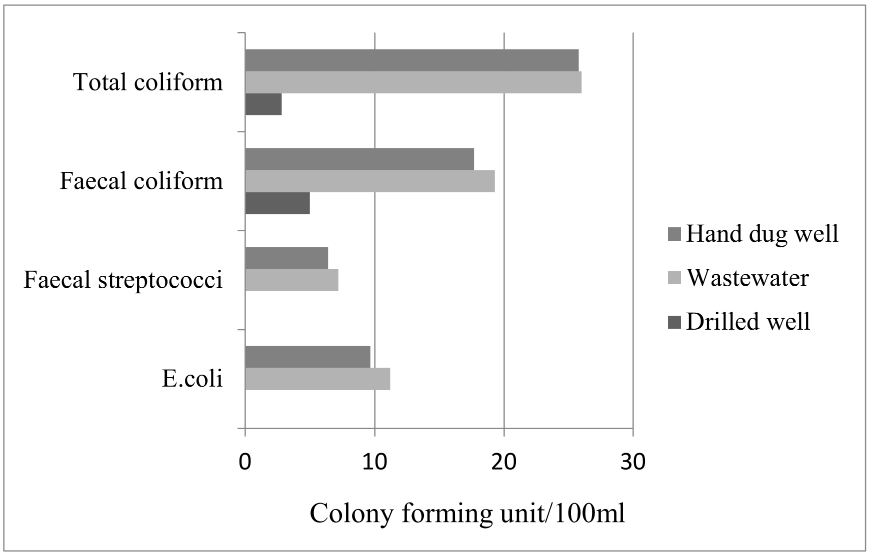


Figure 5: Comparison of Bacteriological properties of various water sources

Hydrochemical Facies

The Piper plot is basically used for classification of water into its water type and Hydrochemical Facies. Piper diagram was constructed to further analyse the hydrochemical data by the plots of the major ion concentration in milliequivalent per litre (meq/L) for the three water sources.

Drilled well samples characterize as Normal Earth Alkaline with prevailing HCO_3 and SO_4 or Cl. All the Drilled well water samples also characterised as Ca^{2+}-Mg^{2+}-HCO_3^- Facies. All the Wastewater and well water samples fall under the Alkaline water with prevailing SO_4-Cl water type classification. Similarly, all the wastewater and well water samples characterised as Na^+-K^+-Cl^-- SO_4^{2-} Hydrochemical Facies.

Pollution Indices

Durov plot (1948) was used to determine the pollution indices of the analysed water samples. Durov is a complex design that consists of two ternary figures where the milli-equivalents proportions cations are outlined versus the anions. The edges structured a mid-rectangular, twofold plot of sum cation to sum anion concentration. Durov plot defines the hydrochemical procedures concerned with water variety.

All drilled well water samples were characterized with dominance of HCO_3 and Ca ions. All wastewater and Hand dug well samples had Na^+ as dominant cation and Cl^- as dominant anion. The basic hydrochemical process responsible for the water chemistry from all the sources (drilled well, wastewater and hand dug well) is through “Simple dissolution or mixing”. Figure 7 shows the Durov Plot for wastewater while Table 1 shows the pollution indices for groundwater of Dutse Alhaji area.

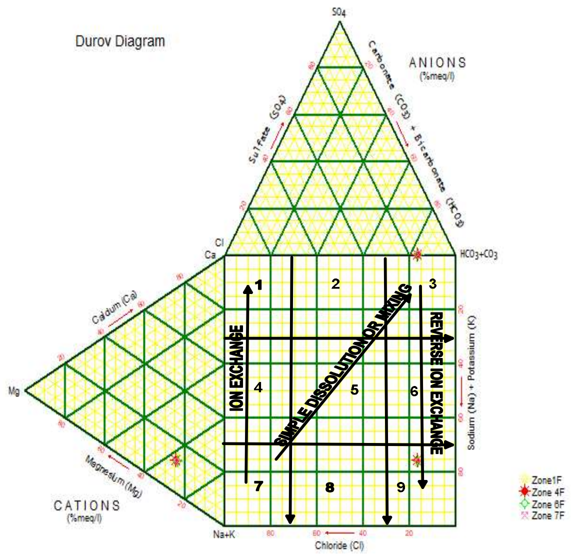
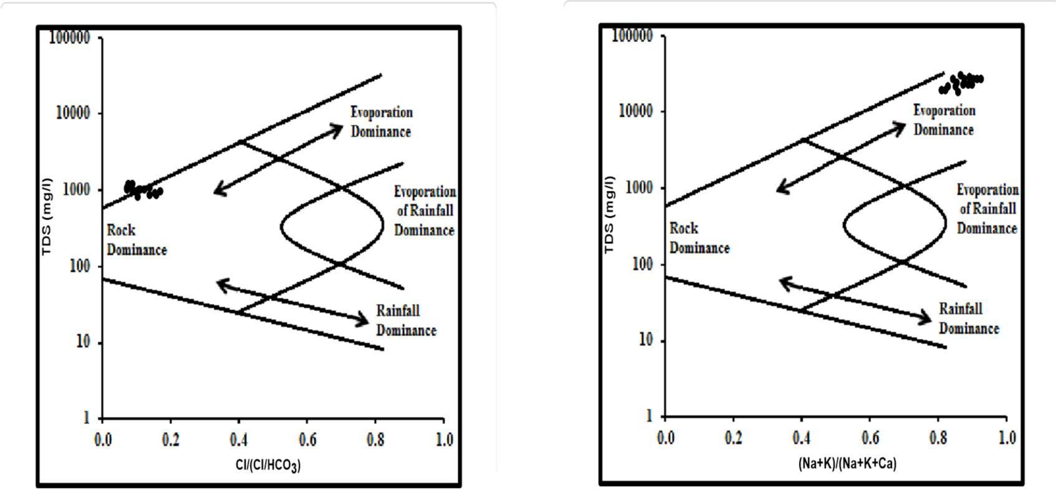


Figure 7: Plot of wastewater Pollution Indices ((after Durov 1948)

Table 1: Plot of Pollution Indices Interpretation (after Durov 1948)

Field No	Water Types and Relevant Explanation	No of samples
1	HCO3 and Ca leading, often designates waters recharging in sandstone, limestone, and numerous other aquifers	
2	This water type is occupied by ions of Ca and HCO3. Relationship with dolomite is acknowledged if Mg is important. Nevertheless, the samples having significant Na, an imperative exchange of ion is supposed	All borehole samples
3	HCO3 and Na are prevailing, usually suggests water of ion exchanged, even though the production of CO2 at distance downward can create HCO3 where Na is leading under definite situation.	
4	SO4 controls, or anion discriminant and Ca leading, Ca and SO4 leading, regularly signifies water recharge in lava and gypsiferous deposits, or else mixed water or water that display easy dissolution possibly will be denoted.	
5	No dominating anion or cation, signifies water that exhibits easy dissolution or amalgamation.	
6	SO4 leading or anion distinguished and Na control; is a water type that is not regularly came across and shows likely mixing or rare influences of dissolution.	
7	Cl and Na leading is often come across if not pollution by cement is exhibited. If not, the water could be product of reverse ion exchange of waters of Na-Cl.	
8	Cl leading anion and Na leading cation, designate that the ground waters be linked to reverse ion exchange of waters of Na-Cl.	
9	Cl and Na leading often signify end-point downward slope waters through dissolution	All waste water and well water samples

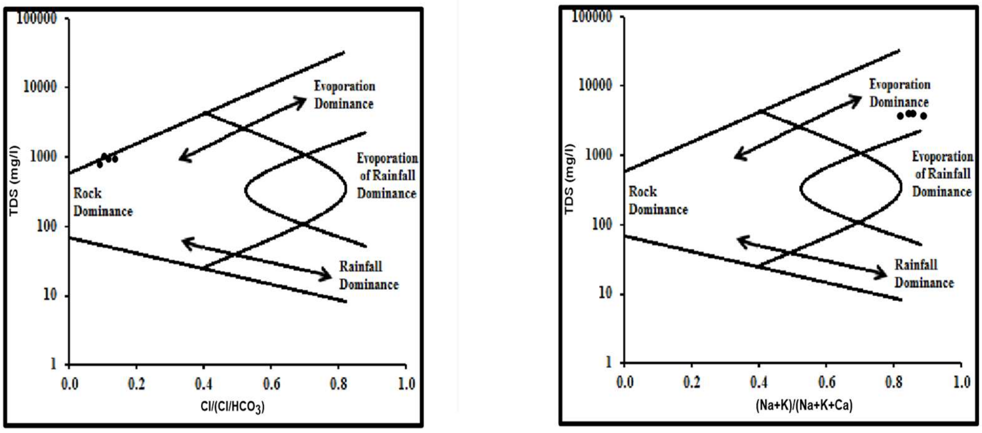
Gibbs (1970) plot uses two plots to analyse the procedures of hydrogeochemistry with veneration to precipitation, atmospheric, interaction of rock water and evaporation over the management of groundwater geochemistry. Gibbs plot is a chart of proportion of cation [(Na+K)/(Na+K+Ca)] and anion [Cl/(Cl+HCO$_3$)] against TDS. Plots of Gibbs for the wastewater and the well water indicated that the geological processes responsible for the chemistry of the water samples is rock weathering (from the plot using the anions) and evaporation (from the plot using cations) as seen in Figures 8 and 9.



AnCl$^-$ and

HCO$_3$ Cations Na^+, Ca^{2+} and K^+

Figure 8: Ratio of Anion and Cation vs Total Dissolved Solids Plot (after Gibbs 1970) for Hand dug well samples



Anions Cl^- and HCO$_3$ Cations Na^+, Ca^{2+} and K^+

Figure 9: Ratio of Anion and Cation vs Total Dissolved sloid Plot (after Gibbs 1970) for Wastewater samples

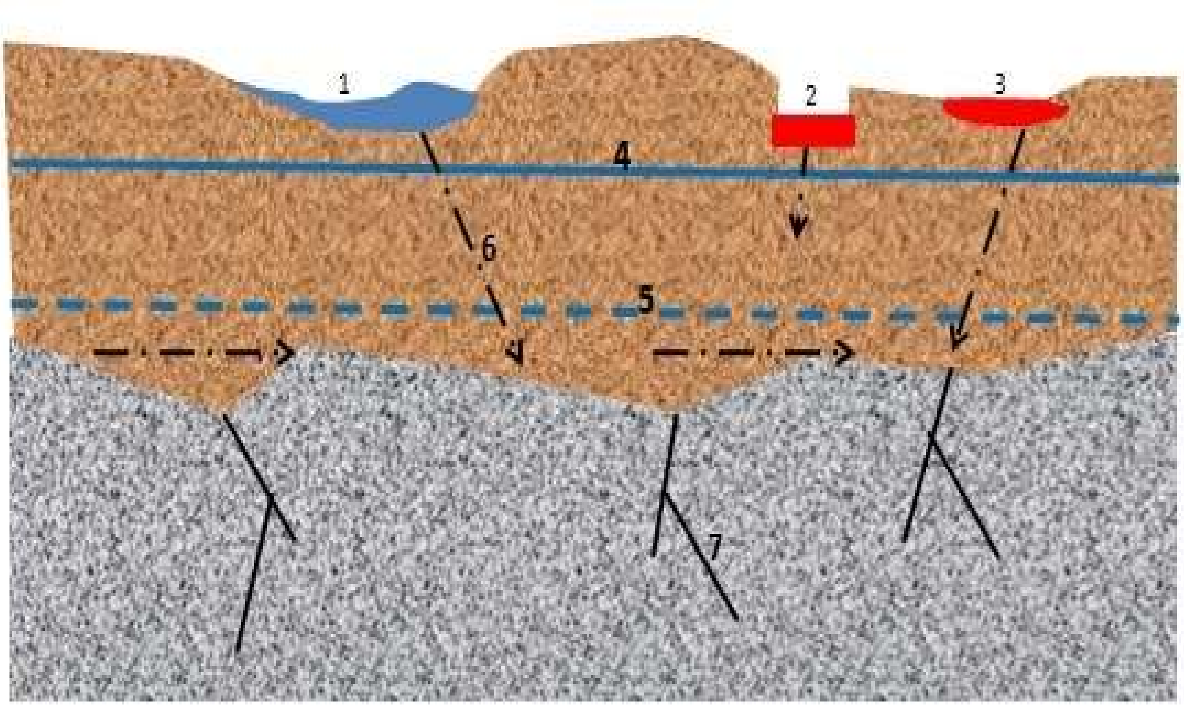


Figure 10: Schematic diagram of Wastewater movement into the environment

Figure 10 is a summary chart showing the relationship between the wastewater and groundwater. Considering the high hydraulic conductivity of the area; (1)–wastewater flow to the surface water, (2) –wastewater in drains, (3) –ponded wastewater) at the surface penetrates the overburden (6-water movement) and reaches the rainy season water table (4). With time, the infiltration increases to the dry season water table (5) and finally find its way to the basement fractures (7).

Discussion of Results

Wastewater generation and usage, public health and environmental effect of wastewater were determined through the questionnaire analysis. Geological and hydrogeological studies were carried out by traversing the area during field work exercise.

Wastewater management in the area includes the use of septic tanks, unplanned and partially planned open drainage system. 47% of the respondents dispose their wastewater into septic tanks or soak away, while the remaining 53% disposed it to the surface or public drainage system that ends up forming stagnant pool of water at the terminal end, since there is no system to collect the wastewater. Majority (70%) of the respondent are not concerned about how wastewater is been discharged in the area if it has been conveyed from their residence. This implies that majority of the people are not aware of any consequences of wastewater as a threat to them and the environment.

91% of the respondents are not aware of any government regulations on wastewater management in the area. This has made management of wastewater to deteriorate in the area since there are no regulations guiding it. This also implies that government has not been doing much in terms of wastewater management in the area. Common health problems identified in the area are malaria and typhoid, with few cases of Dysentery, Diarrhoea, and cholera. These have been found to be directly or indirectly linked to wastewater, because stagnant pools of wastewater promote vector reproduction and growth. Exposure of wastewater in the area is also associated with unpleasant odour and awful sight which of concern to the inhabitants of the area.

91% of the respondents agree that the wastewater infrastructure in the area is in a poor state. Even though there is a new treatment plant in the neighbourhood, there are no infrastructures to channel the wastewater for treatment and reuse.

Water source in the area is majorly from borehole and well. Boreholes and well are shallow and are believed to be recharged by the overburden water. This implies that wastewater can potentially find its way into the groundwater and contaminate it.

Geological mapping of the area reveals that it is underlain crystalline rocks of Nigerian Basement Complex System. Outcrops are not well exposed in the built-up part due to construction and other activities. Rock types include Biotite Granite and migmatite. There is a massive exposure of these rock types towards the northeast of the area with boulders at the base. Most houses built at the base of the outcrop, source their water from wells and boreholes in the built-up part.

Hydrochemical composition of the analysed water samples reveals high concentration of bicarbonate, chloride, and sodium. Comparison of the physical, chemical, and bacteriological concentration of the three types of water samples (wastewater, hand dug well and drilled well) shows evidence of infiltration of the wastewater into the well as concentrations are similar while drilled well concentration is relatively lower.

Various source of sampled water (Drilled well, Hand dug well and Wastewater) were characterized using piper (1944) trilinear diagram, Durov (1948) plot, Gibb's plot, and Stiff plot. Drilled well samples characterize as Normal Earth Alkaline with prevailing HCO_3 and SO_4 or Cl (Compartment B on the piper's plot). All the Drilled well water samples also fall in Field IV of the Piper plot corresponding to the Ca^{2+}-Mg^{2+}-HCO_3^- Facies. All the Wastewater and well water samples fall under the Alkaline water with prevailing SO_4-Cl (Compartment F on the Piper's plot) water type classification. Similarly, all the wastewater and well water samples fall in Field II of the Piper plot corresponding to the Na^+-K^+-Cl^-- SO_4^{2-} Hydrochemical Facies. The basic hydrochemical process responsible for the water chemistry from all the sources (drilled well, wastewater and hand dug well) is the "Simple dissolution or mixing".

The result of the hydraulic conductivity with depth was relatively high, hence account for high infiltration rate from surface to groundwater.

CONCLUSION

The essence of wastewater management is to create and maintain a condition in the environment that will prevent disease, protect the environment, and improve maximum use of water resources. Wastewater management includes generation, transportation, collection, treatment, and reuse of wastewater. The preservation of public health and the aesthetic of the environment should be of paramount consideration in wastewater management. Considering the volume of wastewater generated in this area, couple with the poor management measures and the challenges posed to the environment and inhabitants, there is a need to manage the wastewater generated to avoid future disease outbreak and environmental pollution. This study has examined the wastewater generation and management in the area and has shown that wastewater management system is inadequate in Dutse-Alhaji.

Recommendation

The following recommendations are suggested to reduce the groundwater pollution in the study area.

I. **Sensitization:** this research exercise has revealed that most of the resident of this area are not aware (some less concerned) about the environmental effects of wastewater in the area, hence the first recommendation is for appropriate bodies (Ministry of Environment and community leaders) to educate her residents on the possible effect of wastewater to her environment and water quality. This step is important, as it will enable the resident take necessary precautions in the management of wastewater in the environment.

II. **Localised wastewater management system:** due to the absence of a central sewer system in this area, it is recommended that the resident should adopt improved, well planned, and structured localised management systems (such as continuous open drainages lined with concrete, well designed septic tanks), pending the intervention of the government for a central system. Regular routine check and maintenance of existing systems should be done frequent. When adequate localized wastewater management system is in place, then a reuse plan can be proposed to conserve water.

III. **Construction of improved wells:** existing hand dug wells without concrete lining or stone pitch should be restructured to have one to reduce the rate of infiltration contaminants. Likewise, newly, or proposed hand dug well should be designed for appropriate lining. Drilled well on the other hand should be cased down and when necessary, cement grouting should be done.

IV. Wastewater treatment and re-use is recommended as a complement for water use and as a disaster risk reduction strategy. The wastewater can be collected in planned collection systems comprising of pipe networks, treated using primary and secondary treatment systems and can be reused for fire protection, irrigation/fish farming and for aquifer recharge

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