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ASSESSMENT OF SOAK AWAY DISTANCE AND INFILTRATION LAYER ON BORE-HOLE WATER QUALITY IN DENSELY RESIDENTIAL AREAS OF OWERRI MUNICIPAL, IMO STATE

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ABSTRACT

Ground water pollution can arise from percolation and infiltration of contaminants through the soil from soak away pits. This study was aimed at assessing the microbiological quality of bore-whole water, its suitability for human consumption, as well as its closeness to soak away pits in densely populated settlements of Owerri Municipal Council of ImoState, Nigeria. The horizontal distance between the soak away pits and bore-holes including soil in filtration layer was determined for all sampling points. Twenty-four samples of bore-hole water were collected and analyzed in the laboratory for microbiological and some selected physico-chemical constituents. Temperature of water samples at the time of collection ranged from 23^0c to31^0c, with sample from Dauglas area having the highest value (31^0c); that of Aladinma had the lowest temperature (23^0c). Water collected from the 12 sampling sites were contaminated with general and/or fecal Coliforms and E. coli at different levels; with exception of five sample sites that had zero E. coli. Furthermore, it was generally observed that water samples which were in close proximity to the soak away pits had relatively higher microbial load. Apart from distance, infiltration layer also affects bore-hole contamination. Therefore, bore-holes and soak away pits should be constructed faraway from one another; at least 15 meters apart and each of them should be lined if possible in order to avoid any fecal contamination from the soak away pits into the bore-holes.

Keywords: Assessment, Soak-Away Pit, Distance, Infiltration Layer, Bore-Hole Water

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INTRODUCTION

Water is the major component of all living beings and it is the major constituent of human cells (Wikipedia, 2016). It is involved in every bodily function from circulation and digestion, to the control of body temperature and the excretion of waste products. Water is, after oxygen, invaluable and vital to the existence of all living things. It is used by all plants and animals in order to provide essential minerals for growth and nourishment. Water in its natural state is colorless, tasteless and odorless. Millions of people in unplanned environments such as developing countries do not have access to adequate and safe water supply. The number is rising greatly as a result of rapid growth in population, much of which is occurring in peri- urban and rural areas. The United Nations projected a rapid population growth in the urban areas between 2000 and 2030, indicating that access to safe drinking water and adequate sanitation in urban areas is likely to worsen (Dzwairo *et. al.*, 2011).

Ground water as an important source of fresh water is found in aquifers. Aquifers are permeable, pervious and porous rocks with connected pore spaces that allow water to flow through them. Aquifers can either be confined or unconfined. In confined aquifer, water flow is restricted but it flows freely in the unconfined aquifer. Ground water is replenished by infiltration and percolation of precipitation and from seepage of stream water into the ground storage system (Press and Siever, 2008). Depending on the rock type and formation, ground water can be found in the ground with in the depth of 100 meters and in some places upto 1000 meters deep (Santoshi, *et. al.*, 2017). Water as a universal solvent reacts with minerals in rocks and changes its constituents as it seeps through the aquifer, when these changes occur beyond certain limits, ground water is considered to be polluted or contaminated by the element or substance in it (Sandhyarami, 2009). Ground water contaminants can be classified into two categories that is, natural sources and anthropogenic sources. Natural sources are substances found naturally in rocks or soils, which are in-organic substances such as iron, manganese, arsenic, chlorides, fluorides, sulphate or radionuclide among others which occur naturally and can become dissolved in groundwater (Santoshi, *et. al.*, 2017). On the other hand, the unscientific disposal of human and animal wastes is found to be the main anthropogenic activity that has led to the contamination of ground water with micro organisms, nitrates, and potassium (Santoshi, *et. al.*, 2011). Contamination of drinking water sources by human activities can occur from raw sewage overflow, pitlatrine, septic tanks, leaking sewer lines, land application of sludge and partially treated waste water. Jay *et. al.*, (2013), noted that septic tank is one of the most common human excreta disposal systems and that approximately 1.77 billion people use soak away as their primary means of sanitation. This is a typical example of a Nigerian culture. Hence, this study will examine the problems associated with soak away pit leak on bore-hole water quality in densely residential areas of Owerri Municipal.

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In Owerri Municipal, ground water is an important water resource. Although in some few places, pipe-borne water is available but not enough to carter for the entire population. This has compelled many of the dwellerstorely heavenly on bore-holes for potable water supply as the major resources of potable water supply. The quality of water is largely dependent on the concentration of biological, physical and chemical contaminants as well as human activities in the area. According to Ray (2011), chemical pollution results from industrial activities while physical pollution can result from erosion and improper disposal of wastes. These sources degrade water quality and make water unfit for human use.

Soak Away Pit Proximity to Bore-hole and Groundwater Pollution

Mukungu (2010), indicates that there is a growing concern about the likelihood of soak away pit effluent infiltration into ground water reservoirs for bore-hole water supply systems. He also indicated that ground water flows in the direction of surface runoff and that there is no lateral soil pollution above the ground water in most of developing countries and that soak away pit contents leach downwards and down slopes for distance that vary per season and soil type.

Pedley and Howard, (2015) indicated that microbiological contamination of ground water has profound and severe implications for public health, particularly in small communities and developing countries where ground water is often the preferred source of drinking water. They said that contaminated ground water can contribute to high morbidity and mortality rates from diarrhea diseases and sometimes leads to epidemics. They reported that the use of poorly constructed sewage treatment works and land application of sewage can lead to ground water contamination close to water supply source.

Mtine, (2010), in his attempt to explain the outbreak of cholerain Zambia and other developing nations, reported that continuous use of water from wells located near a soak away pit was dangerous and exposing the communities to more water borne diseases. He said people compromise their health when they drink from wells located near soak away pits.

Bacteria, viruses and other contaminants such as nitrate in filtrate the surrounding soil through leach ate from soak away pit to ground water. Dillon (2017), asserted that in the pits, the liquid soaks away through the base and side of the pit. That is in the absence of a protective structure between the content in the pit and the soil. Waste materials in pits contain large numbers of enteric micro-organisms that have high concentration of nutrients and a high oxygen demand, all of which may have adverse impact on ground water quality (Dillon, 2017). Atleast, an average adult excrete about 2 billion coli form bacteria each day (Geidrich, 2016). The mass and chemical composition of faeces, urine and the microbial composition of faeces from adult is compose of calcium, carbon, nitrogen, organic matter, phosphorus, potassium, sodium, magnesium, chloride and sulphate (Feachem *et. al.*, 2013; Cancer, 2018).

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The presence of bacteria in water indicate the prevalence of pathogenic organisms which causes water related diseases. The pathogenic organisms are the most important sources of serious illness and death especially among young children in poor countries. Water related diseases such as cholera, bacillary dysentery, typhoid, hepatitis, diarrhea and others are all feco-oral in their transmission (Feachen, 2013; Kukkula, 2017; Nassinyama *et. al.*, 2011; Priis-Uston, 2014). Unsafe water and poor sanitation account for 3.7% of the global diseases and 80% of all the diseases in the developing world. Diarrhea alone accounted for the yearly death of 1.6 million people around the world (WHO, 2007). Children under 5 years are the most vulnerable.

Kimani-Murageand Ngindu (2003), in their attempt to explain the impact of proximity of a soak away pit to a well, state that where the distance between wells and soak away pit is not up to 15 meters away, micro-organisms can migrate from the pit to the water in the well and where the soak away pit and wells co-exist visa-vies is the case.

According to Sugden (2016), the farther the horizontal distance the pathogen has to travel from the point of entry into the water table from the point, the longer it is retained and the more likely the pathogen will die.

Impact of Soak Away Pit Proximity to Borehole Well

According to Sugden (2016), the farther the horizontal distance the pathogen has to travel from the point of entry into the water table from the point, the longer it is retained and the more likely the pathogen will die.

Parry-Jones (2010), stated that where the source of drinking water is an aquifer with a high groundwater table, the risk of contamination from soak away pit needs to be considered. (Lewis *et. al.*, 2010) indicates that linear travel of pollution is governed primarily by the groundwater flow velocity and the viability of the organism. A useful and widely accepted guidelines based on this research is that the maximum distance faecal pathogen will move through un fissure soil (including sand) is as far as the groundwater moves in ten days. In low- lying flat areas, with a higher groundwater, the groundwater flow is almost certain to be less than one metre per day, so a distance of ten metres from soak away to source is adequate.

Brandberg (2007), also stated that if it is considered to be a real risk of pollution of groundwater from pit latrine, the risk can be reduced by constructing an artificial sand inner barrier around the pit to create a filter effect. This is an expensive solution and it may often be more practical to develop alternative drinking water sources, at a safe distance from the on- site sanitation facilities. Pathogens are removed within meters of the disposal site. Even so there are cases where pathogens are detected as far away as 30 meters or in very real cases with very specific conditions. As a result, most guidelines and regulation require pit latrine to be 30 meters or more

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from water source such as well and boreholes, streams etc (Fourie *et. al.*, 2015; Crane *et. al.*, 2016).

Liquid in the Soak-away Pits and Ground water Contamination

Majority of disease causing organisms (pathogens) lack the property to propel themselves through the environment in which they live and those that can are not capable of travelling very long distances. Instead pathogens are carried from one point to another within the medium in which they live and the case of water point contamination from soak away pit, this is the liquid that accumulates within the pit. Sugden (2016), states that the smaller the amount of liquid in the pit, the lower the risk of water point contamination. This means with dry pits, the pathogens remain within the pit and water point contamination does not occur.

Still and Nash (2012), stated that waste water in soak away pit percolates down the ground water carrying with it nitrates from organics and waste around the well area. This means that the higher the amount of waste water in the pit, the higher the amount of contaminants that per collate down the groundwater table. Human activities have seriously contaminated water resources including boreholes. According to Efe (2013), water resource is one of the environmental resources that are being threatened either from over exploitation or pollution accelerated by human activities. The principle substances that pollute water resources are mainly produced through human activities. In Nigeria, many studies have shown that water resources are mainly contaminated from anthropogenic activities (Akintola & Agbola, 2017).

Infiltration Layer Between the Bottom of Soak Away Pit and Groundwater Contamination

Vertical separation also known in this context as infiltration layer is the depth of permeable, unsaturated soil that exists between the bottom of a subsurface soil absorption system and some restrictive or limiting layer or feature such as a water table, bedrock unacceptable fine textured soils, or excessively permeable material. In terms of soak away pit, this is the layer between the pit bottom and the water table. A review of typical case study done by Lewis *et. al.*, (2010), shows that water qualities tend to depend on the depth of soil infiltration layer allowed between the soak away pit base and the static water level.

Saturated flow in soil occurs when the water content of the soil is great enough to fill even the largest continuous pores and then moves downward strictly by gravity. This movement is relatively rapid in soils with coarse texture or good structure. Since the pores are filled with water, air is prevented from entering, thereby promoting anaerobic conditions.

Unsaturated flow occurs when water moves through the micro pores and along surfaces of the soil particles by capillary forces. Water moves from the wetter to drier areas and moves much slower than in saturated flow conditions. In addition, the larger pores are filled with air, thus

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promoting aerobic conditions in the soil. It should be noted that there is a continuum from unsaturated to saturated flow, and the definitions here are the extremes of the continuum.

According to Brown *et. al.*, (2016), removal of pathogens is accomplished during slowed passage by their bonding to soil particles and by natural die-off due to an unfavorable environment of aerobic soils and predatory soil organisms. The organic nutrients are metabolized by the soil organisms, a process that is nearly complete under aerobic, unsaturated flow conditions. Removal efficiencies of the various inorganic compounds vary with the compound and the soil conditions. Nitrogen enters the system largely as ammonia, which is oxidized in the aerobic treatment process to nitrate, a highly soluble ion. It then passes through most soils unaltered into the groundwater. Most onsite sewage systems rely on dilution to lower the nitrate concentration to drinking water standards (Brown *et. al.*, 2016).

Phosphate and the other common contaminant of domestic wastewater, is readily absorbed in the soil. Brown *et. al.*, (2016), state that most published field research shows that little or no phosphate moves from the onsite system to groundwater even under saturated conditions.

They further indicate that phosphate contamination is limited to shallow groundwater adjacent to onsite disposal systems where the soil is coarse-textured and low in hydrous oxides, or where there is poor effluent distribution and rapid movement of effluent away from the onsite sewage system. Vertical separation has been shown to be essential for removal of pathogenic and biochemical sewage contaminants to an acceptable level. In order to achieve vertical separation as defined, the hydraulic loading must be low enough so that movement of the wastewater occurs under unsaturated conditions. During unsaturated flow, water moves through the soil by matric forces, which hold the wastewater in close proximity to the soil surfaces and the soil microorganisms, where treatment readily occurs.

Hansel and Machmeier (1980), state that if the groundwater table or other barrier layer is too close to the bottom of the trench, saturated flow will result. Under those conditions saturated flow results due to groundwater mounding under the drain field. An exception to this general pattern would be where good disposal capability prevents the groundwater mounding, such as when a coarse sandy soil overlies a shallow restrictive layer on a steep slope. Under saturated soil conditions, water flows through the macro pores, and can result in short circuiting of the soil purification process. This is of particular concern in soils overlying creviced bedrock or high water tables. Sill and Chest (2013), compared the movement of coliform organisms with that of the chemical uranin, from polluted trenches intersecting the groundwater (saturated conditions). They found bacteria at the depth of 232 feet and uranin at the depth of 450 feet from the trench.

Yates and Yates (1989), cite a report of viral migration from 1600 meters (5249 feet) in karst terrain (porous limestone with deep fissures) and 400 meters (1312 feet) in sandy soil.

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Romaro (2014), also cites a number of pit privy studies where the pits intersected or were within close proximity to the water table which identify that the elevated bacterial levels were temporarily detected up to 24.4 meters (80 feet) horizontally from the source.

Unsaturated conditions in sand columns were more effective for virus inactivation than saturated conditions (Lance & Gerba, 2009). Stewart and Reneau (2011), reported that the migration of faecal coliform is restricted even during high water periods if the STE (septic tank effluent) is uniformly distributed, the OSWDS (onsite wastewater disposal system) is placed in the more biologically active and aerobic soil horizons, and the unsaturated flow is maximized. Another key factor regulating bacterial removal from wastewater during percolation is the liquid flow regime in the soil.

Meanwhile the USEPA Design Manual recommends a minimum water-unsaturated soil thickness of 24 to 48 inches. In column studies, viral deactivation occurs within 40 centimetres (16 inches) with unsaturated flow (Lance & Gerba, 2009).

Under unsaturated flow conditions, bacteria can be adequately removed within 9 to 12 meters (3 to 4 feet) of effluent travel through soils (USEPA, 1980; Hansel and Machmeier, 1980).

Faecal coliform were reduced to background levels within 61 centimetres (2 feet) of the trench bottom. Low pressure distribution can be used to provide equal distribution over the entire drain field surface where site conditions yield minimal vertical separation. Stewart and Reneau (2011), installed a shallow-placed, LPD (low pressure distribution) system to increase the unsaturated zone in a Typical Ochraquult (high water table) soil. After 2 years, faecal coliform had been detected in only 5% of the 150 samples collected from wells (150 centimetres deep).

Samples that contained faecal coliforms were restricted to periods of high water tables and were confined to the effluent distribution area. Stewart and Reneau (2011), installed and tested a low pressure distribution system in soils with a fluctuating high water table, Few faecal coliform were present at 1.5 meters (5 feet) depth within the OSWDS even during the period of highest water tables, that was January through March of 1982, when macro pore flow was at a maximum.

Brown *et. al.*, (2016), in their work on movement of faecal coliform and virus below septic leach fields noted that most faecal coliform bacteria and coli-phage virus were removed within the first 30 centimetres (1 foot) of unsaturated soil beneath absorption trenches in east Texas Magdoff. (2014), noted complete removal of faecal coliform and fecal streptococci in a 90 centimetres (3 feet) column containing sand underlain by silt loam. Tyler (2007) stated that at a distance of 1 foot into the soil surrounding the trench, there was a 3 log reduction in bacterial numbers and within the second foot counts were to the acceptable range for a fully treated wastewater. Some

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bacteria and viruses in the wastewater are pathogens. Their movement during unsaturated flow is expected to be limited to within a meter (40 inches). Studies have shown that where it is sufficiently unsaturated, 60 to 90 centimetres (2 to 3 feet) of soil is adequate to remove nearly all fecal indicator bacteria and viruses. Lysimeter tests of the impact of septic field leachate on groundwater indicates that coli-phage viruses and fecal coliform bacteria were removed by passage through approximately 100 centimetres (40 inches) of any of the soils tested. Considering chemical treatment in relation to vertical separation, Brown *et. al.*, (2016) reported that heavy metals accumulated immediately adjacent to the point of application in the soil. Phosphates moved only slowly in the soil and their movement was greatest in sandy soils. Under reduced (anaerobic) conditions, ammonia accumulated in the soils and moved only about as far and as fast as phosphates. When the soil was allowed to become oxidized large amounts of nitrogen were converted to nitrate which rapidly leached to the groundwater. Therefore, nitrate leachate was the greatest environmental hazard identified in this study. Reneau *et. al.*, (2013) summarized the research on processes and transport through the soil of nitrogen and phosphorous. They concur with findings of Brown *et. al.*, (2016).

The Risk of Water Point Contamination

Assessing the risk of water point contamination from borehole pit is based on gaining an understanding of the amount of time it would take the water, and the pathogens it contains, to travel from the pit to the water point. The longer it takes, the greater the reduction in the number of pathogens through natural die-off. The overall aim in either sitting a latrine or water point is to ensure that the pathogen die-off has been sufficient to reduce the risk to a level where it is not a public health concern.

The time taken can be used as a proxy indicator for risk of contamination. The Guidelines for Assessing the Risk to Groundwater from On-Site Sanitation (ARGOSS) produced by the British Geological Survey (BGS) in 2001 states that the following times are applicable in assessing risk from microbiological contaminates.

1. Significant Risk: Time taking is less than 25 days

2. Low Risk: Time taking is more than 25 days

3. Very Low Risk: time taking is more than 50 days

AGROSS takes care to stress that the 'low risk' category should provide confidence, but no guarantees, that the travel time would result in levels of micro-organisms which are unlikely to represent a major risk to health. The 'very low risk' category provides a further margin of safety and therefore greater confidence that the water will meet WHO guidelines and that the more persistent pathogens will have been removed.

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STATEMENT OF THE PROBLEM

It has been observed that ground water which is one of the freshest and safest drinking water in Nigeria is highly contaminated and not safe for human consumption. This might not be unconnected with the indiscriminate sinking of boreholes and wells which are the major sources of potable water close to soak away pits, unprotected pit latrines and waste dumpsites (WHO and UNICEF, 2010)

This is the case of Owerri Municipal where shallow bore-holes are the important sources of domestic water supply due to the fact that pipe borne water is not readily available and coupled with the high water table in the area. Non availability of land space has made individual house owners to include both soak away and bore-holes in the same plot hence, causing ground water to be contaminated in the long run leading to water borne diseases and possibly epidemics. Evidence from most of the previous studies on ground water contamination in Nigeria are centered on the effect of leach ate from waste dumpsites with little or no reference to the site sanitation conditions especially on the effect of soak away pits and infiltration layer. Therefore, it becomes imperative to embark on the study of the assessment of soak away pit distance and infiltration layer on bore-holes water contamination in Owerri Municipal with the aim of analyzing the microbial and some selected physico-chemical properties of bore-hole water in the area.

AIM AND OBJECTIVES

The aim of this study is to assess the effects of soak away pit distance and soil infiltration layer on the quality of bore-hole water for human consumption. To achieve this aim, the following specific objectives were pursued to:

I. Determine the micro-biological and some selected physico-chemical characteristics of bore-hole water in Owerri Municipal Council.

II. Examine the factors responsible for bore-hole water contamination in the study area.

III. Determine whether distance between bore-holes and soak away pits have a significant effect on the quality of bore-hole water.

IV. Compare the quality of bore-hole water in the area with the National water quality standards for consumption.

MATERIALS AND METHOD

Sampling Technique and Analysis of Samples

In order to assess the quality of the bore-hole water in the study area, samples of borehole water were collected from each of the selected residential ward for laboratory analyses. Two samples were collected from 12 sample sites in Owerri Municipal Council which has the highest concentration of residents. Two samples were collected from each bore-hole, one for physico-chemical analysis and another for microbiological analysis. This gave a total of 24 samples all together. Purposive sampling was used; hence areas that are more densely populated were selected. The more densely populated areas were selected based on the population census record of study area. To get the sampling sites, simpler and sampling was adopted by naming all the individual household interviewed on a piece of paper which was folded into tiny pieces and put into a container, the container was shook rigorously and one out of the ten pieces of paper was picked for the sampling site, the same procedure was adopted for all the rest of the wards.

The distance between soak away pits and bore-holes were reached by the use of a measuring tape from the edge of the pit to the edge of the bore-hole. The12 water samples were marked as samples 1 (Ws1), sample 2 (Ws2) samples 12 (Ws12) with the tags indicating the names of their respective wards. The soil in filtration layer was taken as the layer between the soak away bottom and the static water level that is in a case where the water table is below the soak away base, this was done by subtracting pit bottom elevation from static water level elevation (Dzwairo *et. al*., 2016).

Sample Collection and Storage

The water samples analyzed for this study were collected during wet season period within the months of, July and August 2022. Sampling materials used include 250 mm plastic non transparent bottles. Two (2) plastic funnel, distilled water, rope tape, thermometer and pitcher. The bottles were oven-dried at 40°C for 30 min and later rinsed with ethanol (for sterilization) after which the samples were added and labelled. The samples were then inserted into an icy cooler and transported for laboratory analysis immediately after sample collection. For physio chemical analysis, the sample bottles were rinse with distilled water and later with a little quantity of the sample. Parameters such as temperature, odour, colour and taste were measured in situ. Analysis for Nitrate, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO) and pH were analyzed in the laboratory, after the samples were collected. The water samples that were collected for this study were analyzed at the Institute of Pollution Control Laboratory, Rivers State University Port- Harcourt.

Physical Analysis for Bore-holes

Test for colour, odour and taste were physically carried out in the field by the use of sense organs of smell and taste.

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Temperature

The temperature was taken in-situ with the use of capillary filled thermometer. The thermometer was first suspended in the air to know the temperature of the environment (R). After this, it was inserted in all the samples to know their various temperatures. Temperature was measured immediately the water was collected.

Laboratory Tests

pH Level

pH level for the water samples were determined by the use of pH meter which was connected to power supply and the power supply button turned on. The mode for which the experiment was performed is set, that is pH mode. The electrode was then inserted into the samples; readings were then taking and recorded.

Dissolved Oxygen

Dissolved Oxygen level was determined by the use of D02 machine. The electrodes were inserted into the samples; readings were observed until it stopped counting. The final reading was recorded in Mg/L.

Turbidity

Data Logging Spectro photo meter was used in determining turbidity level of the samples. A Program number for determining turbidity was entered, that is 750 and the knob adjusted to 860 nm, after which a control sample was inserted into the spectro photo meter square box and zeroed. The test sample was there after put into the square box and the Read button was pressed to display the result.

Total Dissolved Solids (TDS)

This was achieved by the use of TDS meter, the electrode was inserted into each samples, from here, the knob on the measuring machine was adjusted at intervals and readings observed. The knob was continued to be adjusted until the pointer moves to detect a reading, the result of the reading was then recorded by multiplying it with the adjusted number in the rotatable knob.

Total Suspended Solids (TSS)

Data Logging Spectrophotometer was also used. The program number (630) for determining TSS was entered by pressing the button. The adjustable node, adjusted to 880 nm and the control sample was put into the square box space and zeroed. The sample to be tested was there after put into the box space and the read button pressed to record the reading in mg/l

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Nitrate

A content of the sample water was poured into a test tube and a sachet of nitrate pillow powder added, the test tube was covered and shook vigorously until the content evens out. This was then poured into 25ml spectrometer test bottle, the sample was after wards put into the square box space and the Read button turned on to observe the result which is in Mg/L.

Biological Oxygen Demand

Equal volumes of water were obtained from the area and each sample diluted with a known volume of distilled water which was then thoroughly shaken to insure oxygen saturation. After this, an oxygen meter was used to determine the concentration of oxygen within one of the samples. The remaining sample were then sealed and placed in darkness and tested five days later. BOD was then determined by subtracting the second meter reading from the first.

Coliforms and Aerobic Mesophilic Bacteria

The Most Probable Number (MPN) method was used in determining coliform and aerobic mesophilic bacteria in the samples. Serial dilutions of 10-1 and 10-11 were prepared by picking 1 ml of the sample into 9 ml sterile distilled water. One milliliter aliquots from each of the dilutions were inoculated into 5 ml of MacConkey Broth (1:5) with inverted Durham tubes and incubated at 35^{o}C for total coliforms and 45^{o}C faecal coliforms for18-24 hours. Tubes showing colour change from purple to yellow and gas collected in the Durham tubes after 24 hours were identified as positive for both total and faecal coliforms. Counts per 100 ml were calculated from the appropriate Most Probable Number (MPN) tables with 9 test tube readings.

Ecoli (Thermotolerant Coliforms)

From each of the positive tubes identified a drop was transferred into a 5 ml test tube of tryptone water and incubated at 44^{o}C for 24 hours. A drop of Kovacs're agent was then added to the tube of tryptone water. All tubes showing a red ring colour development after gentle agitation denoted the presence of indole and were recorded as presumptive for the motolerant coliforms (Ecoli). Counts per 100 ml were calculated from Most Probable Number (MPN) tables with 9 test tube readings. The results from the analysis were compared with WHO and NSDWQ Standards for drinking water while cross tabulation analysis was done on the effect of distance and infiltration layer on bore-hole contamination.

Field Measurements

The distance between soak away pit and borehole was reached by the use of tape measurement. The depth from the ground surface to the static water level or water table was determined for all

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sampling points using a long rope tied to a stone and then measure with a tape. The depth of soak away pits at all sampling points were acquired through consultation with the ward heads, Landlords and the soak away pit constructors of the various soak away pits prior to measurements with a rode and tape. The soil infiltration layer was taken as the layer between the pit latrine bottom and the static water level that is in a case were the water table is below the pit latrine base, this was done by subtracting pit bottom elevation from static water level elevation (Dzwairo *et. al.*, (2011).

RESULTS AND DISCUSSIONS

Table 1: Micro-biological Content of the Sampled Bore-hole Water

Sample Site	Coliform (Cfu)/100ml	E.coli (Cfu/100ml)	AMB (Cfu/100ml)
World Bank	460	21	1480
Umuororonjo	2400	3	1160
Federal housing Egb	150	12	1155
Concord Area	7	0	1030
Prefab Housing	240	14	1315
Umuoyima	210	37	1050
Amawom	1100	35	1165
Ikenegbu	75	0	1162
Umuonyeche	1100	38	1241
Works layout	15	0	1476
Aladinma	15	0	1280
Okigwe Road layout	93	0	1353
NSDWQ	10	0	Nil
WHO	0	0	Nil

Source: Laboratory Analysis 2022

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Coliform count from the table 1 above shows that the samples exceeded the zero coliform count set by WHO (2014) standard for drinking waterquality. Only samples from Concord area, falls within the NSDWQ (2007) standard. High coliform count indicates that water from such bore-hole is faecal contaminated. The water samples from Umuororonjo, Umuonyeche and Amawom have the highest coliform count. This finding is related to the high population and close proximity of the bore-holes to soakaway pits found in the study area. This indicates that sewage can slowly see pin to underground water, there by polluting it. However, E. coli was detected in seven out of the twelve samples tested and they exceeded the limit set by WHO and NSDWQ of zero cfu/100ml. This indicates that water from these sampled bore-holes are faecal contaminated. Hence the detection of faecal contamination in drinking water is highly recommended as pathogenic micro organism from human faeces and poses the greatest danger to public health. Likewise, the presence of E. coli in these samples showed that people that use these water sources are pronetourinary tract infections, bacteraemia, diarrhoea, acuterenal failure and haemolyticanaemia (NSDWQ, 2007).

Table 2: Results of Some of the Physiochemical Characteristics of the Sampled Bore-Hole Water.

Sample Site	pH	D.O	Turbidit	TDS	TSS	Nitrate	BOD	Temperature
World Bank	8.5	7	35	4500	32	4.3	3.5	29
Umuororonjo	7.5	5.1	14	1200	9	1.2	2.3	31
Fed.Housing	7	4.1	5	1100	2	1.1	1.1	29
Concord Area	7.5	6.4	6	360	3	0.3	3.2	30.4
Prefab	7.2	5.2	10	2000	7	1.3	2,4	28
Umuoyima	7.3	7.8	*2*	2600	1	0.5	5.2	29
Amawom	7.1	5.9	*2*	6000	2	1.4	4.4	30
Ikenegbu	7.2	5.4	122	750	84	3.3	2.3	28.9
Umuonyeche	7.3	5.5	50	870	28	1.2	4,2	29.5
Works L/Out	7.5	6.3	13	3600	4	1.3	5.2	28.7
Aladinma	7	7.5	42	700	20	1.3	6	29.5
Okigwe Road	6.9	9.3	55	3000	28	1.3	7,4	
NSDWQ	6.5-8.5	Nil	5	500	Nil	50	1-3	Ambient
WHO	6.5-9.2	Nil	5-25	500-1500	Nil	50	Nil	25^0c

Source: Lab. Analysis. 2022

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The table 2 above shows the results of the physico-chemical parameters of water samples tested from 12 wards in Owerri Municipal compared with the standard limits set by the national and international standards of each parameter, which is Nigerian Standard for Drinking Water Quality (SON, 2007: World Health Organization, 2008). The result indicates that temperature of water samples at the time of collection ranged from 31^0c to 28.7^0c, with water samples from Umuororonjo having the highest temperature of 31^0c while that of Aladinma had the lowest temperature of 28.7^0c. Temperature tends to exert great control over the growth of bacteria in water bodies. If the overall water temperature of a system is altered, there will be an adverse organism shift to be expected. In water, where temperature is above 30^0c, a suppression of all benthic organisms can be expected. That is different pathogenic group tends to flourish under different water temperatures. For example, coliform group will multiply at 37^0c while thermo tolerant coliform that is E. coli will multiply rapidly at a higher temperature of 44.2^0 (Wait *et. al.*, 2017). The temperatures of the entire samples are above the WHO standard. High temperature equally encourages the growth of taste and odours which can later produce organism that affect human health by causing intestinal irritation (Ezemonye, 2009).

The pH of the samples ranged from 8.5 to 6.9 with World Bank having the highest record and Okigwe road having the lowest. Although the result of the pH level shows that all the samples fall within the allocated standard set by WHO and NSDWQ which may be attributed to the absence of gas flaring in the study area. The result indicates that from all the samples, the pH level of the water is not highly acidic neither highly alkaline and that qualifies the water to be good for human use. Water samples from Ikenegbu has the highest turbidity level of 122 NTU while Umuoyima and Amawom both have the lowest turbidity level of 2 NTU. Only one out of the 12 samples tested fell within the standard limit set by the NSDWQ and WHO that is Fed. Housing. The turbidity level of the rest of the samples were not in conformity with the NSDWQ and WHO. High turbidity level is often associated with higher level of diseases causing microorganism such as bacteria and other parasites (Shitu *et. al.*, 2008).

Total Dissolve Solid (TDS) of all the samples are not in accordance with the standard limit set by NSDWQ while Ikenegbu, Umuonyeche and Aladinma including Ikenegbu met the limits of WHO. The pal at ability of drinking water has been rated by the panels of tasters in relation to its Total Dissolve Solid as follow: Excellent, if less than 300mg/l: Good, between 300 and 600mg/l: Fair if between 600 and 900mg/l: Poor, between 900 and 1200mg/l and Unacceptable, if greater than 1200mg/l (Bruvolold and Ongerth, 2015). High concentration of TDS in drinking water causes aesthetic problems for consumers such as undesirable and salty bitter taste.

The Total Suspended Solid (TSS) from the sampled sites ranges from 84mg/l in Ikenegbu to1mg/l in Umuoyima. Though, there is no recommended standard for TSS on drinking water set by NSDWQ and WHO, high concentration of Suspended Solid decreases the effectiveness of

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disinfecting agent in water by allowing micro-organisms to hide from disinfectants within solid aggregates. Nitrate for all the sample points ranged from 4.3mg/l in World bank to the lowest 0.3mg/l in Concord area. The samples were all within the 50mg/l of both WHO and NSDWQ guideline value. High level of nitrate in drinking water is directly associated with methaemoglobinaemia or Blue baby syndrome, an acute condition which is mostly frequent among bottle fed infants of less than three months of age. Nitrates have been suggested as causing methaemoglobinaemia and also as possible carcinogens by a number of researchers (John & Lawrence, 2013; Lewis, *et. al.*, 2010). From the table above, Biological Oxygen Demand (BOD) ranges from Okigwe road having the highest record of BOD with 7.4 mg/l to Fed. Housing with the lowest record of BOD, which is 1.1mg/l. There is no standard set by NSDWQ (2007) and WHO (2008) for drinking water quality with regards to BOD. But generally, when BOD level is high, there is a decline in dissolved oxygen level. This is because the demand for oxygen by the bacteria in the water body is high, which will result in the excessive use of oxygen dissolved in the water. If there is no organic waste present in a water body, there won't be as many bacteria to decompose it and thus, the BOD will tend to be lower and the dissolved oxygen will be higher. This result conforms to the findings on a similar study by Ekwure (2011).

Table 3: Some Sites and Pit Characteristics of Sample Sites

Borehole Sites	**Distance b/w Soak away & Bore-hole(m)**	**Depth of ground level(m)**	**Static water(m)**	**Infiltration layer (m)**	**unlined pit**
World Bank	2.2	7.3	7.6	2.1	2
Umuororonjo	1.3	5.1	5.2	0.1	2
Concord Area	9.3	7.2	8.2	1	2
Prefab	9.3	7.5	11.2	3.7	2
Umuoyima	1.7	8.5	10.6	2.1	2
Amawom	1.4	6.8	8.2	1.4	2
Ikenegbu	'1.5	7.3	7.6	0.3	2
Umuonyeche	1.6	6.7	8.8	2.1	2
Works layout	7.5	6	6.2	0.2	2
Aiadinma	5.1	6.5	9.4	2.9	1
Okigwe Road	7.5	8.1	13.4	5.3	1
Fed housing	5.5	5.8	7.8	2	2

Source: Field Measurement, 2022.

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From the table (3) above, the lateral separation or distance between soak away pits and bore-holes are not in accordance with the general standard set by the Imo State Ministry of Housing which is 15 meters' interval. The result shows that concord has the highest lateral separation of 9.3 meters while Umuororonjo has the lowest lateral separation of 1.3 meters which is totally unhygienic. The depth of soak away pit and static water level or water table has no standard limit, but the researcher took their measurement in other to come up with the infiltration layer. The infiltration layer ranges from 5.3 meters in Okigwe rd to 0.1 meters in Umuororonjo. The fact that there is little or no soil infiltration layer between the soak away pit bottom and the static water level or water table meant that effluent is seeping into and contaminating the well water. Are view of typical case study done by Lewiset. Al, (2010), shows that water quality tends to depend on the depth of soil infiltration layer allowed between the pit bottom and the static water level. Only two sample points have their pits lined with clay to prevent through flow from pit to well where as all the rest of the sample points are unlined. According to Brandberg (2007), the construction of an inners and barrier around the pit creates a filter effect that reduces the risk of bore-hole water contamination.

Table 4: Cross Tabulation Analysis of Factors Affecting Bore-Hole E. coli & Coliform Contamination

Sample Site	Distance to pit (m)	Infiltration layer (m)	E.coli (Cfu/Iooml)	Colifonn (Cfu/I00ml)	Condition of pit & well
Amaworn	1.3	0.I	3	2400	unlined
World Bank	2,2	2.1	14	240	unlined
Umuorornjo	1.3	0.3	35	1100	unlined
Umuoyima	1.7	0.2	38	1100	unlined
Okigwe Road	7.5	5.3	0	15	lined
Umuonyeehe	1.6	0.6	21	2360	unlined
Ikenegbu	4.5	2	0	93	unlined
Aladinma	5.1	1	12	150	lined
Fed. Housing	5.5	2.1	0	75	unlined
Works Layout	7.5	2.9	0	15	unlined
Prefab	8.2	1.4	37	210	unlined
Concord Area	9.3	3.7	0	7	unlined

Source: Field survey. 2022

From the data in table 4 above, the horizontal distance between bore-holes and soak away pits and ground water contamination indicates that the lateral distances between the soak away pits and the bore-holes in the sampled areas were below the stated guideline for constructing soak

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away pits. The ministry of environment sets the housing guideline limit for Constructing soak away pits to be between the minimum of 15m and maximum of 30m from wells. From the analytical test performed, the results indicated that there are not much variation between the lateral distance and coliform and E.coli counts in water. In the work of Fattal *et. al.*, (2017), to determine the organism that can indicate faecal contamination stated that, of the indicators (coliform, enterococci and Escherichia coli) Escherichia coli is the most predictive indicate or for enteric disease symptoms. In the Words of Kay *et. al.*, (2014), compared to other indicators (total coliform and Escherichia coli), E. coli are the best indicator of gastrointestinal symptoms. The Escherichia coli might there forebear better faecal determinant than the total coliforms. It was generally observed that water samples which were in close proximity to the pit latrines had relatively higher microbial counts. Sudgen (2016), stated that the further the horizontal distance the pathogen had to travel from point of entry in to the water table to the water point, the fewer the concentration of the contaminants. The data in the table also reveals that not only the proximity of soak away pit to bore-hole and the distance between the static water level and the depth of soak away pit (infiltration layer) that determines the level of contamination of bore-hole water but conditions of the bore-hole and soak away pit also matters. For instance, the sample site in World Bank shows the proximity as 1.5m, infiltration layer is 2.1 m but the E. coli is 14Cfu/100ml and Coliform is 240Cfu/100ml while the condition of soak away pit and bore-hole is unlined, this signifies the effect of distance impacted more on the level of contamination than any other factor; Also the sample site in Okigwe road shows the proximity as 3.8m, infiltration layer is 5.3m but the E. coli is nil and Coliform is only 15Cfu/100ml while the condition of soak away pit and bore-hole is lined, this signifies that condition of pit and bore-hole impacted more on the level of contamination than any other factor while the sample site in Aladinma shows that the proximity is 5.1m, infiltration layer is 1m but the E. coli is 12Cfu/100ml and Coliform is 150Cfu/100ml while the condition of soak away pit and bore-hole is unlined, this signifies the effect of infiltration layer impacted more on the level of contamination than any other factor.

CONCLUSION AND RECOMMANDATION

Water as an essential part of human life should be free from contaminants as stipulated by world Health Organization (2006). The aim of water quality assessment has usually been to know the suitability of water for use as compared with water quality standards in order to ensure that it does not exceed the levels which are detrimental to human health.

Coliforms and E. coli which occur as a result of presence human feaces were found in almost all the samples. This can be attributed to the closeness of the bore-holes to soak away pits in the study area. This impact negatively on groundwater quality. All the selected bore-holes tested positive for Coliformwhile58.3%ofthe bore-holes tested positive for E. coli. According to WHO

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guidelines (2007), water should have a value of 0Cfu/100ml (zero per 100ml unit of water) in order for that water to be considered safe for human consumption. The presence of indicator coli forms in bore-hole water indicates that the water in the wells have come in to contact with faeces from humans. Generally, the results of this study show that soakaway pits were the major sources of ground water contamination in the study area; however, there may be other sources. These sources may include among others; open air defecation, run-off water, and unhygienic human practices at the bore-hole sites. It was also found that all the sampled areas did not satisfy the separation distance between soakaway pit and bore-holes which is 15ma part. However, among all these factors considered in this research, the lateral separation and the infiltration layer were seen to have the greatest impact on bore-hole contamination by soak away pits.

In a view to amelio rate the risk of bore-hole contamination by soak away pits, the following recommendations were made:

i. Government should ensure the implementation of lateral separating distances between soak away pits and the water points.

ii. Regular monitoring of borehole water quality in the area in order to check the pollution level as the area is prone to E. coli and coliform contamination.

iii. Basic treatment of water at the household level by chemical disinfection using chlorine, filtration-using simple household filters and boiling should be promoted.

iv. Lined soak away pits and other low-cost technologies could be considered as an alternative to unlined pits, because they minimize the risk of releasing soak away pit effluent flow across the infiltration layer.

REFERENCES

[1] Akintola, F.O. & Agbola, G.L. (2017). Effects of Pollution on Physicochemical Properties of Soil in Izombe, Oguta L.G.A. Pollution Reports, 3(2) 21-32

[2] Brandberg, B., (2007). Latrine Building: A Handbook for Implementing the Sampler System. Retrieved On 10/06/22 From Http://www.ScholarSearch.Google.Com/Scholar?Q=Brandberg+B+(1997)+Latrine+Building&H/=En&As-Sat

[3] Bruvolold, K. W., & Ongerth, H. W. (2015). The Movement of Salts, Nutrients, Fecal Coliform and Virus Below Septic Leach Fields in Three Soils. Journal of American Society of Agricultural Engineering, 5(3), 721-729.

[4] Brown, K. W., Slowey, J. F. and Wolf, H. W., (2016). Vertical Separation: A Review of Available Scientific Literature and a Listing from Fifteen other States.

[5] Washington State Department of Health; Environmental Health Programs. Retrieved from www.doh.wa.gov.ehp/ts/uw/vert.sep.

[6] Cancer, L. W.(2018). Groundwater Quality Protection. Michigan: Lewis Publisher's Inc,

[7] Brown, K. W., Slowey, J. F. and Wolf, H. W., (2012). "Vertical Separation: A Review of Available Scientific Literature and a Listing from Fifteen other States". Washington State Department of Health; Environmental Health Programs. Retrieved from www.doh.wa.gov.ehp/ts/uw/vert.sep.

[8] Dillion, F.(2017). Groundwater Pollution by Sanitation in the Tropical Regions International Journal of Sanitation Management, 6(11), 56-72.

[9] Dzwairo, B., Hoko, Z., Love, D. & Guzha, E.,(2011). Assessment of the Impacts of Pit Latrines on Groundwater Quality in Rural Areas in Mawendera District. Journal of Groundwater Pollution, 31, 779-788.

[10] Efe, S.I. (2013).An Appraisal of the Quality of Rain and Groundwater in Nigeria: A case study of Warri metropolis. A. Ph.D seminar paper Department of Geographic and Urban Regional Planning, Delta State University Abraka.

[11] Ezemonye, M.N. (2009). Surface and Groundwater Quality of Enugu Urban Area. Unpublished Ph.D thesis Department of Geography, university of Nigeria Nsukka, Nigeria.

[12] Fattal, B., E. Peleg-Olevsky, T. Agursky, & H.I. Shuval, (2017). The Association between Seawater Pollution as Measured by Bacterial Indicators and Morbidity among bathers in Mediterranean Bathing Beach, Israel. Journal of Chemosphere. 16, 565-570

[13] Feachem, R. G., Bradley, D. J., Garelick, H. & Mara, D. D.,(2013). Sanitation and Disease: Health Aspect of Excreta and Waste Water Management. World Bank studies in water supply and sanitation. U.K: John Wiley and Sons.

[14] Fourie, A. B. & Vanrynelveld, M. B., (2015). A Strategy for evaluation the environmental impact of Onsite Sanitation System. Department of Civil Engineering, University of the Witwatersrand; Water SA, 23(4), 64-78.

[15] Geldreich, W. S., (2016). Microbiological Quality of Source Waters for Water Supply. In G.A., MO festers (Ed.), Drinking Water Microbiology: Progress and Recent Developments. New York: Springer-Verlag

[16] Hansel, M. J., & R. E., Machmeier, (1980). Onsite Wastewater Treatment on Problem Soils; Journal of Water Pollution Control Federation, 52(3):548-552.

[17] Jay, P., Graham, Matthew, L., & Polizzotto, (2013). Pit Latrines and Their Impacts on Groundwater Quality. Journal of Environ Health Perspective, 8(6), 43-48.

[18] Kay, A.I., Rossiter, H. M. A., Owusu, P. A., Richards, B.S. & Awuah, E., (2014). Physico-chemical water quality in Ghana. Prospects for Water Supply Technology Implementation. Journal of Desalination,4(7),193-203.

[19] Kimani-Murage E. & Ngindu A.M., (2003). Quality of Water the Slum Dwellers Use in Korgan Slum. Urban Health Journal, 84(6):829-38

[20] Kukkula, M., Arsila, P., Klossner, L., Marnuale, L., Bonsdorff, C. H, & Jaatinen, P., (2017).Water borne outbreak of viral gastroenteritis. ScanInfecDisease,29, 415-418.

[21] Lance, J. C. & Gerba, C. P. (2009). Virus Movement in Soil Columns Flooded with Secondary Sewage Effluent. Applied Environmental Microbiology 32:520-526.

[22] Lewis, J.W., Foster, S.D. & Draser, B.S., (2010). The Risk of Groundwater Pollution by on-Site Sanitationin Developing Countries. Switzerland: Duebendorf Pub.

[23] Magdoff, F. R. (2014). Columns Representing Mound-Type Disposal of Septic Tank Effluent: II. Nutrient Transformations and Bacterial Populations. J. Environmental Quality 3:228234.

[24] Mtine, A. I. (2010). Surface Water Resource Management Strategies in the Metropolitan Kano, Nigeria. J. Environmental Quality 3:228-234.

[25] Mnkungu, T.E., (2010). Bacterial and Chemical Quality of Water Supply in the Dertig village settlement. Water S.A 25 (2), 215–220.

[26] Nassinyama, G.W., McEwen, S.A., Wilson, J. B., Waltmer-Tower, D., Gyles, C.L. & Opuda, J. (2010). Risk Factors for Acute Diarrhea Among Inhabitants of Kampala District Uganda. S.A Med. J., 90(90): 891-898.

[27] NSDWQ, (2007). Nigerian Standard for Drinking Water Quality, Nigeria Industrial Standard, Approved by Standard Organization of Nigeria Governing Council. ICS13. 060. 20: 15-19.

[28] Pedley, S. & Howard, G., (2015). Public Health Implications of Coliforms in Water Microbiological Geology and Hydrology,30(2), 67-81.

[29] Parry-Jones, S. (2010). On-Site Sanitation in Areas with a High Groundwater Table Sandy Caimcross; Well Fact sheet. Retrieved On 9/06/22 from http://www.lboro.ac.uk/well/resource/fact-sheets/fact-sheet-htm/

[30] Press, F. & Siever, R., (2008). The Earth. NewYork: Freeman, Co.

[31] Pruss, J.C. & Uston, B. (2014). The Movement of Viruses Through Porous Media. Journal of Pollution Groundwater, 8(4):37-48.

[32] Ray, J.K (2011) Water Resources in Kwara State Ilorin. Matanmi and Sons Printing co Ltd

[33] Reneau, R. B. (2013). Fate and Transport of Biological Contaminants from On-site Disposal of Domestic Wastewater. J. Environ. Qual. 18 (2):135-144.

[34] Romaro, H. C. (2014). The Movement of Viruses through Porous Media. Groundwater, 8(4):37- 48.

[35] Santoshi K.G., Rajahwari, G. & Ranjni,G.,(2017). Environmental Studies and Ecological. Oxford: CABI Publishing.

[36] Sangharami, A.Y., (2009). Consideration on Contamination of Ground water by Waste Disposal Systems in Nigeria. Environmental Technology.14, 957-964.

[37] Shittu, A.N. (2008). Groundwater Pollution Near Shallow Dumps in Southern Calabar, South Nigeria. Global Journal of Geological Sciences, 2(2),199-206.

[38] Still, D.A. & Nash, S.R., (2012). Ground water Contamination Due to Pit Latrines Located in a Sandy Aquifer in Maputaland. Retrieved On 11/06/22 from http://www.ssw.info/sites/default/files/references-eattachments

[39] Stewart, L. W. & Reneau, R. B. Jr., (2011). Septic Tank Effluent Disposal Experiments Using Non-Conventional Systems in Selected Coastal Plain Soils; Final Report to Virginia Dept. of Health Blacksburg, VA.: Virginia Polytechnic Institute

[40] Sugaden, S., (2016). The Microbiological Contamination of Water Supplies, Sandy Cairncross. International journal of Regional Science, 21(6). 43-48

[41] Tyler, E. J. (2007). The Soil as a Treatment System; Home Sewage Treatment, American, Michigan: Society of Agricultural Engineers Publication,

[42] Waite, W.M., (2012). Association of Water Supply in Relation to the Incidence of Crypto sporidioses in Tordy. Wallingford: CABI Pub.

[43] World Health Organization (2004).Guidelines for Drinking-Water Quality. Switzerland: World Health Organization.

[44] WHO/UNICEF, (2010). Progress on Sanitation and Drinking Water 2010 Update. Retrieved on Nov. 2022 from www.unicef.org/eapro/JMP-2010Final.pdf.

[45] Yates, M. V. and Yates, S. R., (2009). Septic Tank Setback Distances: A Way to Minimize Virus Contamination of Drinking Water. Ground Water 27(2):202208.

