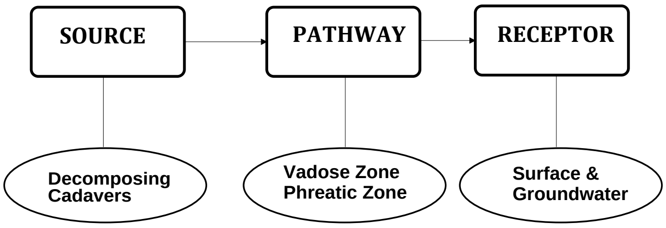

Figure 1: Conventional Approach to Environmental Risk Assessment. (Source; William et al. 2009)

The products of decomposition from human burials can be divided into two broad categories: natural and synthetic. Willam *et al.* (2009). A decomposing body mostly contains contaminants from different sources. These sources could include; chemical substances (arsenic, formaldehyde and methanol) during chemotherapy and embalming procedures, make-up (cosmetics, pigments and chemical compounds), other sources are materials such as fillings, cardiac pacemakers, paints, varnishes, metal hardware elements, iron nails, (Silva & Filho, 2011; Fiedler et al., 2012). Microorganisms that may pollute substrates, surface water and groundwater are also found in these leachates. Bacteria, bacteria, intestinal fungi and protozoa are primarily microorganisms (Trick et al, 2001). Rodriguez and Pachecho, (2003) found higher bacteria concentrations in groundwater samples collected beneath cemeteries than those collected hundreds of metres away.

More recently, Turajo et.al. (2019) in the research on the impact of cemeteries on groundwater around Maiduguri metropolis concluded that; using only water quality parameters as index of an environmental impact of a cemetery, ample evidences of environmental pollution abound, especially from cemeteries around Maiduguri metropolis. This was attributed to site overload and therefore recommended an enactment of legislation to review the sitting methodology, management issues such as; longevity of remains, grave re-use, funeral artifacts and buffer zone, and planning policies as a way of reducing the soil and water resource risk and environmental hazards associated with cemetery operation.

Based on these earlier literatures, cemeteries are undoubtedly a source of concern especially when they are poorly sited. Beyond siting, the main material for cemetery construction is soil and, in most cases, the properties of these soil will either make or mar the functions of cemetery. Attention must be given to proper soil selection which is the main pathway of interaction between cadavers and the groundwater.

Consequently, emphasis will however be placed on the pathway which is the medium by which contaminant flow between the source and the receptor. Therefore, this paper focuses on assessment of the geotechnical and hydrological properties of vadose zone around burial sites in Ede and Iragbiji areas of Osun State, Nigeria. It considers the index and engineering properties of the soil within the vicinity viz-a-viz their suitability for the purpose and impacts of the decay of the human corpse on the physico-chemical, chemical and biological properties of groundwater within the study areas.

2. Study Area

Investigations were carried out in two localities, Ede and Iragbiji areas of Osun State, Nigeria. Ede lies between Lat 7º42'N and 7º47'N and Long.4º21' and 4º27' East of Greenwich Meridian. It has two local government areas namely Ede North and Ede South Local Governments. It is a town with a population of 304,738 persons following the 2006 census figures (Nigerian Populations Commission, 2006). Iragbiji is the headquarters of Boripe Local Government located in Osun State of Nigeria and lies between Lat 7º48'N and 7°53'N and between Long 4º36'E and 4º42'E. Both locations are generally accessible by road Fig. 2. The first cemetery named Alharam Islamic foundation Muslim burial ground, Ede is located off the road linking Abere in Osogbo to Ede. The second cemetery which is in Iragbiji can be accessed via a footpath off the road linking Osogbo to Iragbiji. Hence, both locations have access road link with Osogbo making them busy throughout the year.

The land surface is generally undulating and the drainage system is mainly dendritic and ranges from open water bodies (dams, reservoirs and lakes) to rivers, streams, springs, wells, run-off waters and swamp/wetlands (Audu et al., 2015). Many rivers, including the Osun River from which the state derives its name, have their source in the northern part of the state. Erinle River and Awon River which are tributaries to the Osun River flows across the Ede town. The climate is of the lowland tropical rain forest type with distinct wet and dry seasons. Rainfall pattern of the area is generally characterized by long and short rainy season with short and long dry season (Bamiji, 2012). It is however pertinent to note that the recent rainfall in the area has been of high intensity with a long time range which may be due to the effects of climate change.

The main sources of water supply in the area are hand-dug shallow wells and boreholes fitted with pump power by generator or hand pump. Some of the people depend on stream and rivers for sources of drinking water which are not protected. There is a dam at Ede which serves as source of water to Ede water works and provides water for the municipality. The water works served less than 35% of the urban centre (FMWR, 2004).

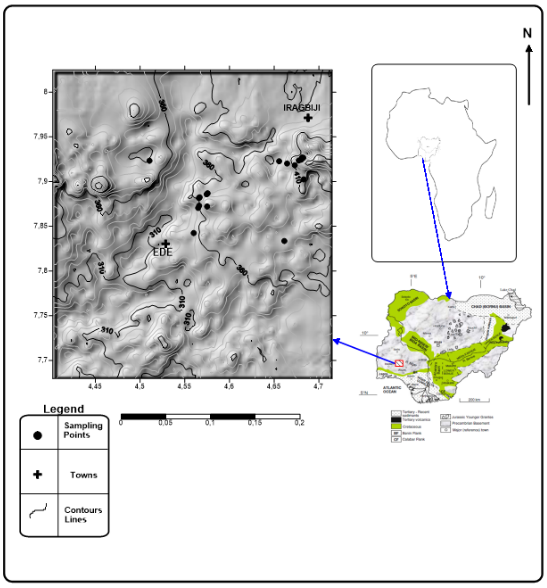

Figure 2: Topographical Map of the Study Area Showing Relief and Sampling Locations

2.1 Geology of the Study Area

Rocks in both locations forms part of the south-western basement complex rocks. Ede is underlined by two main rock types which include pegmatite and Schist. The pegmatites, which occur as near vertical dykes, strike primarily in the direction of NNE-SSW intrudes the older banded gneiss lithology. Banded gneiss occurs as a massive rock consisting of alternating felsic mineral bands, especially plagioclase feldspars and quartz, and dark biotite and hornblende bands. Two main lithologies underlie Iragbiji area which includes granite-gneiss and schist. The geology of the area is presented in Fig. 3 modified after Oyelami and Van Rooy (2016b).

The soils within the study areas belong to the highly ferruginous tropical red soils (lateritic) associated with basement complex rocks. As a result of the dense humid forest cover in the area and the distinct wet and dry seasons prevalent in the area. The soils are generally deep and of two types, namely, deep clayey soils formed on low smooth hill crests and upper slopes; and the sandy hill wash soils on the lower slopes (Bamiji, 2012).

The well drained red soils of the hill crest and slopes are very important, because they provide the best soils for agriculture in the area. Soil degradation and soil erosion are generally not serious in the area, but considerable hill wash is recorded along the slopes of the hills.

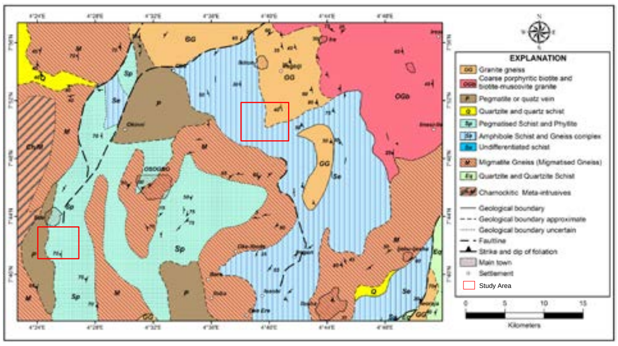

Figure 3: Geological Map of the Study Area (Source; Oyelami and VanRooy, 2018)

3. METHODOLOGY

Following a preliminary visit, 14 (fourteen) water samples were collected from both locations. Each of the study area provides 7 (seven) water samples. 6 (six) of the samples were the main focus of study while the remaining one served as a control. The water samples were collected *in situ* from streams, hand-dug wells of 5-12m deep, rivers and artisan wells using appropriate water sampler with the location coordinates recorded. The control samples were taken from wells at a distance of about 1.5 km from the location of the cemetery. At each sampling point, the water samples were collected in triplicate in a plastic bottle and labelled as A, B and C. These were subsequently transported to the laboratory within 24 hours of collection for cation and anion determination at *FATLAB Nigeria Ltd, Ibadan*. The A samples were acidified using concentrated nitric acid **(**HNO_3**)** and taken to the laboratory to determine the concentration of cations. The B samples were used for anions (HNO_3^-, SO_4^{2-}, PO_4^{3-}) while the C samples are subjected to biological analysis at the microbiology laboratory of Osun State University, Osogbo.

The physico-chemical parameters of the water samples were measured *in-situ* using the appropriate instruments such as pH, temperature, TDS and EC meters.

Soil investigation involved the collection of 12 bulk soil samples from 4 hand dug pits in both locations. The soil samples were recovered at depths ranging between 2-4 metres which provides 3 soil samples from each pit. The physical as well as textural properties of the soil were studied *in-situ*. Soil samples were later taken to the laboratory with samples for moisture content determination kept in polythene bags to prevent loss of moisture on exposure to air. Geotechnical investigations of the soil were carried out at the Geology Laboratory of the Federal University of Technology Akure, (FUTA). The tests include; grain size analysis, specific gravity, Atterberg limits, compaction and permeability tests. All tests were carried out according to the British Standard BS 1377 (1990) procedures with small modifications where necessary.

4. RESULTS

4.1 pH, Temperature and Electrical Conductivity

The geographical location and the physical properties of the water sampled around the vicinity of both cemeteries are presented in Table 1 while their physic-chemical properties are presented in Table 2. The pH of the water samples collected from the vicinity of the cemetery at Ede ranges 5.57- 6.53 with an average of 6.19. It was observed that the water bodies that surrounds the cemetery are acidic in nature as they fall below the neutral point. Silva (1995), concluded that acid leachates from nitrogen (N), phosphorous (P), chlorine (Cl), and bicarbonate (HCO_3^-) are produced from the decomposition of the human body include ions, hence, the possibility of acidic nature of water around the present study area may be due to the decomposition of the human body. However, control well records a pH of 5.57 (most acidic of all the samples taken) and is located about 1.5 km from the cemetery. This suggests that the acidic nature of the water bodies may be from other sources apart from the decomposition of the human body. Such sources may be from the use of pesticides, fertilizers for agricultural practices, bed rock geology of the area. Iragbiji cemetery on the other hand has a pH range of 5.51 to 8.16 with an average of 6.57. According to WHO (2006) and Standards Organisation of Nigeria, (SON) on drinking water quality standard (NSDWQ, 2007 and 2015) (pH;6.5-8.5), most water samples within the vicinity of Ede cemetery is not safe for domestic use with the exception of well 4 (pH of 6.53). Iragbiji on the other hand may be useful in terms of pH except wells 7 and 9 with high degree of acidity.

Temperatures of the water samples are as presented in the Table 2. Most bacteria and viruses according to WHO (2006) can survive in soils and water at temperatures of between 5°C and 30°C and die off at rapidly increasing rates of about 10°C. Temperatures in both cemeteries are less than 30 °C, which implies a conducive environment for bacteria and viruses to thrive.

Ede has an average electrical Conductivity (EC) of 480μS while Iragbiji has 1210μS, The EC indicates the amount of dissolved solute which invariably is an indication of the extent of possible contamination within an environment. There is more potentials of contamination around Iragbiji cemetery than Ede, this is reflected in the result of the EC. However, based on the findings of Adedeji and Ajibade (2005), that lower conductance in water indicates the abundance of Ca^{2+} while higher conductance indicates the abundance of Na^+ and K^+, the high conductivity observed around Iragbiji cemetery might be linked to the farming activities around the cemetery. The control well reflects a high EC as well suggesting high levels of Na+ and K+ which might be as a result of decomposition of human body combined with nutrients from the fertilisers used in crops around the area.

Table 1: Water samples collected around the cemetery at Ede.

Locality	Well no	Coordinates	Description
EDE	1	N 7° 44.537’ E 4º 27.420’	Clear, Pumping well
	2	N 7º 44.553’ E 4º 27.452’	Stream channel, muddy
	3	N 7º 44.503’ E 4º 27.418’	Stream, Clear water
	4	N 7º 44.500’ E 4º 27.450’	Surface water
	5	N 7º 44.393’ E 4º 27.396’	Gaining stream
	6	N 7º 44.494’ E 4º 27.414’	Stream channel
	Control well	N 7º 44.684’ E 4º 27.218’	Hand-dug well
IRAGBIJI	7	N 7º 48.456’ E 4º 36.297’	Artisan well, turbid
	8	N 7º 48.457’ E 4º 36.292’	Swampy, lake
	9	N 7º 48.369’ E 4º 36.299’	Hand-dug well
	10	N 7º 48.426’ E 4º 36.263’	Stream channel
	11	N 7º 48.433’ E 4º 36.232’	Hand-dug well, Milky
	12	N 7º 48.121’ E 4º 36.221’	River water, muddy
	Control well	N 7º 48.442’ E 4º 36.200’	Hand-dug well, clean

4.2 Cations (Fe^{2+}, K^+, Mg^{2+} and Na^+)

The observed concentrations of cations within the study areas are as presented in Table 2. Most cation appears to be within limits as recommended by WHO (2017) and Nigerian Standards of Drinking Water Quality (2015) except Fe^{2+}. Emphasis here will be on the high concentration of Iron (Fe). Generally speaking, high concentration of Fe is expected within this environment, being a tropical environment where leaching of mobile elements are very common due to alternating dry and wet seasons. The question is, why is Fe occurring as high as 7.99mg/L in areas close to a cemetery, that might be a possible indicator to a near surface aquifer that is very rich in organic materials. Organic decomposition will lead to depletion of oxygen which creates a reducing environment enriching the Fe^{2+} ion. This indicates a possibility of contamination around the cemetery areas.

Table 2: Physio-chemical results of the water samples collected around cemetery at Ede and Iragbiji

Location	Well no	pH	T(ºC)	EC(µS)	K^+	Na^+	Fe^{2+}	Mg^{2+}	NO_3^-	Cl	PO_4^{3-}	HCO_3
EDE	1	*6.42*	30.6	370	0.41	8.21	0.301	5.796	5.776	90	1.722	91.5
	2	*6.4*	28	410	2.11	19.34	*0.803*	7.102	3.325	90	0.061	91.5
	3	*6.31*	33.4	650	2	21.05	0.046	9.083	4.959	198	0.009	61
	4	6.53	28.9	400	2.1	20.03	*0.987*	6.387	1.283	90	0.032	122
	5	*6.45*	29.7	630	2.23	23.54	*0.413*	7.894	2.263	90	0.003	122
	6	5.66	30.4	530	1.62	23.01	*0.904*	8.083	0.057	126	0.027	152.5
	Control well 1	*5.57*	27.1	390	2.32	24.56	0.304	3.303	34.289	108	0.05	152.5
IRAGBIJI	7	*5.51*	29.4	670	24.01	23.65	*7.996*	8.125	5.858	126	1.463	122
	8	6.52	28.2	*1,430*	1.93	8.8	0.151	14.442	24.485	90	0.078	61
	9	*5.46*	26.9	300	6.29	22.07	*0.802*	12.842	0	108	0.05	152.5
	10	6.75	26.9	650	43.42	125.02	*1.335*	8.947	1.201	198	0.153	183
	11	8.16	28.4	*2,770*	40.11	100.5	*1.979*	9.254	28.815	126	0.788	183
	12	6.72	28.6	660	42.13	126.04	0.138	8.201	2.018	54	0.211	61
	Control well 2	6.87	28	*1,970*	2.8	25	0,000	12.374	0	108	0.113	*274.5*
	WHO [29]	*6.5-9.5*		*1000*	*250*	*200*	*0.3*	-	*45*	*250*	*3*	-
	SON [30]	*6.5-8.5*		*1000*	*250*	*200*	*0.3*	*20*	*50*	*250*	-	*250*

4.3 Anions (NO_3^-, Cl^-, PO_4^{2-}, HCO_3^{2-})

Most anions tested are within the limits as specified by WHO (2017) and NSDWQ (2015) except for Bi-carbonate in the control well around Iragbiji cemetery. HCO_3 occurs naturally in groundwater from the reaction of rain water and soil pH. Bi-carbonate is equally a function of pH and salinity, which anthropogenic activities within an area could influence greatly, therefore, the high concentration of HCO_3 in the control well is related to the anthropogenic sources around the well. Equally, concentration of Nitrate within the study area though within limits but varies considerably within locations. Presence of Nitrate is within the study area is linked more with fertilised agricultural land and waste disposal rather than contamination from the cemetery.

4.4 Biological Organisms

This involves the direct culturing of the water samples to identify the probable micro-organisms present in the samples. The probable micro-organisms in the wells are presented in Table **3** below. They include the following micro-organisms; *Proteus spp.*, *Enterobacteriaceae spp.*, *Shigella spp., Salmonella spp., Chryseomonas cloacae, Citrobacteria, Serratia spp., Edwardsiella spp.*

Some of these micro-organisms are used as indicators for contamination in water and can affect human health when such water is taken into the body. *Salmonella typhi* is known for typhoid fever when present in water beyond the standard limit. Other organisms such as *shigella*, *serratia* can cause dysentery. However, the most prominent indicator organisms for contamination are the coli form bacteria such as *E.coli*. *E.coli* is a prominent species of a larger family of *Enterobacteriaceae*. According to WHO (2006), the coli form bacteria must not be detected in any 100ml of water intended for drinking. *Salmonella spp., Shigella spp., Proteus spp., Serratia spp., Edwardsiella spp.,* all belongs to the family of E*nterobacteriaceae. Salmonella spp.* is widely distributed in the environment. According to WHO (2006), the pathogens gain entry into water systems through faecal contamination from sewage discharges, livestock and wild animals. The most common infection is typhoid fever and can be fatal. *Shigella spp*. can cause serious intestinal diseases including bacillary dysentery. Humans and other primates appear to be the only natural host for the *shigellae*. According to WHO (2006), the bacteria remain localized in the intestinal epithelial cells of their host and is predominantly transmitted by the faecal-oral routes. *Escherichia coli.* is a generally reliable index for *salmonella spp.* and *shigella spp.* in drinking water samples. *Proteus spp.* are commonly found in the human intestinal tract as part of the normal intestinal flora, along with *Escherichia coli* of which *E.coli* is the predominant resident. They are commonly responsible for urinary and septic infections (Guz, 2018).

Table 3: Probable micro-organisms present in the water samples

		Ede	Iragbiji		
Well	**Isolates**	**Prob. Organisms**	**Well**	**Isolates**	**Prob. Organisms**
1	3	*Proteus spp.*(3)	7	5	*Proteus spp.* (3), *Salmonella spp. (1), Serratia spp. (1)*
2	2	*Proteus spp.*(2)	8	3	*Proteus spp.(2), Salmonella spp.(1)*
3	4	*Proteus spp.*(1), *Enterobacteriaceae spp.* (1), *Shigella spp.*(1), *Salmonella spp. (1)*	9	2	*Shigella spp.* (1), *Edwardsella spp. (1)*
4	3	*Proteus spp.* (2), *Enterobacteriaceae spp.*(1)	10	1	*Shigella spp.* (1)
5	2	*Proteus spp.* (2)	11	2	*Proteus spp.* (1), *Serratia spp. (1)*
6	3	*Chryseomona, Cloacae (1), Proteus spp(1), Citrobacteria (1)*	12	2	*Proteus spp.* (1), *Enterobacteriacaea spp. (1)*
Control	1	*Proteus spp.* (1)	Control	2	*Proteus spp.* (2)

4.5 Geotechnical Properties

4.5.1 Index Properties of Soil

The results of the index properties of the sample soil are as presented in Table 4. The natural moisture contents of the soil reveal the impact of the topography as it slopes towards Pit 2 around Ede cemetery and towards Pit 3 around Iragbiji cemetery. The conceptual model illustrates the situation in both study areas, using Pits 1 and 2 as a model, while Pit 3 can substitute for Pit 2 in the model and Pit 4 for Pit 1. The ground surface slopes downward towards Pit 2 and Pit 3 in Ede and Iragbiji respectively and following the principle that water level is a replica of the ground surface, both pits have a shallow water table. This ranked Pits 2 and 3 as undesirable for cemetery constructions because of direct interaction between leachates and groundwater. Hence, soils with high moisture content having a shallow water depth and are not suitable for a standard cemetery. It can thus be said that only the soils that occur at Pit 1(Ede) and Pit 4 (Iragbiji) are suitable for a standard cemetery based on the moisture content.

The cemetery soils were further classified using Unified Soil Classification System (USCS). The results correlated with that of the natural moisture content. The soils from both areas are well graded, mainly clayey sands with few inorganic clays of high plasticity (See fig 4). They are expected to have considerable amount of porosity and permeability due to the presence of sandy particles. This suggests that such soils may not be desirable for a standard cemetery. However, soils of pit 3 at Iragbiji are mainly of the fat clay type with high plasticity based on the USCS classification. The amount of fine (%) is a measure of the clay and silt content in the soils. Thus, soils of pit 3 are expected to be higher in clay as they show above average % of fines (57.8% on the average). Clays are generally desirable in geotechnics for a standard cemetery due to their low permeability and because they can act as natural filters helping to attenuate leachates. Although their suitability may be questioned as it relates to aeration and natural process of decomposition of human remains. In terms of plasticity index, soil samples from the study areas ranges from low plasticity (Pit 1) to medium (Pits 2 and 4) and high plasticity (Pit 3).

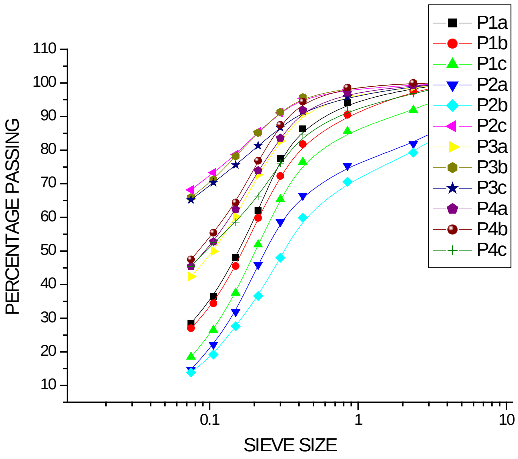

Figure 4: Grain Size Distribution Curves of the Soil Samples

Soils with shrinkage limits of less than 5 are of believed to be of good resistance to shrinkage, between 5 and 10% are of medium resistance, 10 and 15% are poor while less than 15% are of very poor resistance to shrinkage. This shows that in terms of resistance to shrinkage, Pit 1, Pit 2 and Pit 4 soils are of poor resistance to shrinkage while soils of Pit 3 (average, 8.46) is of medium resistance to shrinkage. The lower the shrinkage limit, the better the soil as material for cemetery siting.

The average specific gravity of the soils around both cemeteries are 2.66, 2.65, 2.66 and 2.66 for Pits 1 to 4 respectively. The specific gravity of clayey soils is 2.6-2.9 while that of sands is 2.65-2.67. This shows that most of the soils around both cemeteries are of clayey sands. The high specific gravity of the soil also suggests that the soils are rich in mineral matter and may have originated from the parent rock of the study areas. Higher specific gravity implied higher soil strength and more stable walling for cemetery holes.

4.6 Engineering Properties of Soils

In order to fully understand the behaviour of soils used in cemetery construction, the strength parameters and permeability characteristics are very critical. Hence, Table 5 presents the summary of the engineering properties of the soils within the vicinity of the cemeteries. The maximum dry density (MDD) is mainly of interest from the compaction test. Ede has a MDD of 2037kg/m^3 and 1933kg/m^3 for Pits 1 and 2 respectively while Iragbiji has 1616kg/m^3 and 1937kg/m^3 for Pits 3 and 4 respectively. According to Hall and Hanbury (1990) cited in Dippenaar (2014), suitability of soils for cemetery, based on their MDD are good to excellent if MDD is greater than 1800kg/m^3, less than 1800kg/m^3 are ranked fair, less than 1700kg/m^3 are poor and less than 1500kg/m^3 are ranked very poor. In light of this, it can be suggested based on MDD that Pit 1 contain excellent soil, Pits 2 and 4 contain good soils while Pit 3 contain poor soils for use as a standard cemetery.

Permeability of soils is function of the grain size and textural characteristics. The average coefficient of permeability (KT) of the soils around the cemetery at are as follow; Ede has 8.86 X 10^{-6} m/s for Pit 1 and 1.01 X 10^{-5}m/s) for pit 2. Iragbiji with 6.94 X 10^{-9}m/s for Pit 3 and 1.35 X 10^{-8}m/s for pit 4. Ramamurthy and Sitharam (2015) classified soils based on their coefficient of permeability (KT). Soils of permeability of between 0.01 to 1m/s are gravels, between 10^-5 and 0.01m/s are sands, between 10^-8 to 10^-5 are silts, and < 10^-8 are clays. This shows that pit 1 and pit 2 contain mainly silts, pit 3 contain mainly clays and pit 4 contain silty clays. Correspondingly, soils of KT values < 10^{-7} are rated Impermeable and are good soils for cemeteries, between 10^{-7} and 10^{-6} are rated relatively impermeable and are excellent soils, between 10^{-6} and 10^{-5} are rated relatively permeable and are fair soils, while soils of KT values < 10^{-5} are rated permeable and are poor soils for cemeteries (Dippenaar, 2014). In light of this, it can be said that pit 1 and pit 2 contains fair soils, while pit 3 and pit 4 contain good soils for use as cemeteries in terms of their permeability.

5. Discussions

The pathway serves as the most important bridge between the contaminant source and receptor. This in most cases has to with siting, engineering construction and geo materials. Assessment of pathway as it relates with burial practices and siting of cemeteries should begin with the location of the cemetery. European Union (1998) recommended a 250m distance away from any well or borehole in the case of human or animal burial, a place of interment should be at least 30m away from spring or any watercourse and a minimum of 1m bottom clearance of burial pits above the highest natural water table. Following this recommendation, within the context of the study areas, the cemetery in Ede lacks in every standard. It is built within a residential community (see fig. 5) and it slopes directly into a river. Iragbiji cemetery on the other hand is a bit fair as it relates to distance to residential area and sources of potable water supply. Apparently, the salient feature of a pathway within an environment such as Ede cemetery has been obliterated. The pathway serves as the most important bridge between the contaminant source and receptor. This in most cases has to with siting, engineering construction and geo materials. The implication of these as a pathway is discussed below.

Table 4: Index Properties of Cemetery Soils

Location	Sample No	MC (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	*% Fine*	*% Coarse*	LL	PL	PI	USCS	SL	SG (%)
EDE	1A	8.7	1.5	70	19.5	9	*28.5*	*71.5*	30	22.5	7.55	SC	12	2.655
	1B	6.8	2.4	70.6	13.3	13.7	*27*	*73*	34	23.5	10.55	SC	12	2.672
	1C	8.2	8.1	73.4	12.7	5.8	*18.5*	*81.5*	23.8	19.9	3.9	SM	14.4	2.656
	2A	10.1	18.1	67.2	11.8	2.9	*14.7*	*85.3*	33.8	23.5	10.35	SC	12	2.648
	2B	20.9	20.6	65.5	8.8	5	*13.9*	*86.2*	32.2	21.6	10.6	SC	12.5	2.657
	2C	18.9	0.6	31.2	19.7	48.5	*68.2*	*31.8*	54.8	24.3	34.15	CH	7.7	2.668
Iragbiji	3A	9.3	1.3	56.3	17	25.4	*42.4*	*57.6*	35.2	19.5	15.7	SC	11	2.649
	3B	19.3	0	34.1	20.6	45.3	*65.9*	*34.1*	62.4	25.5	36.9	CH	7.2	2.666
	3C	17.9	1	33.8	19	46.2	*65.2*	*34.8*	65.2	25.2	40.05	CH	7.2	2.674
	4A	9.4	0.8	53.8	17.6	27.8	*45.4*	*54.6*	34.6	21.3	13.35	SC	11.5	2.662
	4B	7.4	0	52.5	16.5	30.9	*47.5*	*52.5*	36.3	22.6	13.7	SC	10.6	2.67
	4C	8.8	3.2	51.4	22.7	22.7	*45.4*	*54.6*	35.4	22.6	12.8	SC	10.6	2.677

SC; Clayey Sand, SM; Silty Sand, CH; Inorganic Clay with high plasticity, MC; Moisture Content, LL; Liquid Limits, PL; Plastic Limits, PI; Plasticity Index, USCS; Unified Soil Classification System, SL; Shrinkage Limit and SG; Specific Gravity.

Table 5: Engineering Properties of Cemetery Soils

Sample No	MDD (kg/m^3)	OMC (%)	KT (m/s)	K20 (m/s)	Dippenaar (2014)
1A	2011	14.6	2×10^{-6}	1.65×10^{-6}	Relatively impermeable
1B	2017	14.4	2.79×10^{-6}	2.32×10^{-6}	Relatively impermeable
1C	2082	12.2	2.18×10^{-6}	1.80×10^{-6}	Relatively permeable
2A	2098	11.7	1.35×10^{-6}	1.12×10^{-5}	Relatively permeable
2B	2107	11.4	1.67×10^{-5}	1.38×10^{-5}	Relatively permeable
2C	1595	28.1	6.75×10^{-10}	5.59×10^{-10}	Impermeable
3A	1893	18.4	1.97×10^{-8}	1.63×10^{-8}	Impermeable
3B	1490	31.6	5.28×10^{-10}	4.38×10^{-10}	Impermeable
3C	1465	32.4	5.96×10^{-10}	4.94×10^{-10}	Impermeable
4A	1921	17.5	1.78×10^{-8}	1.48×10^{-8}	Impermeable
4B	1936	17.0	1.08×10^{-8}	8.98×10^{-9}	Impermeable
4C	1955	16.4	1.19×10^{-8}	9.89×10^{-9}	Impermeable

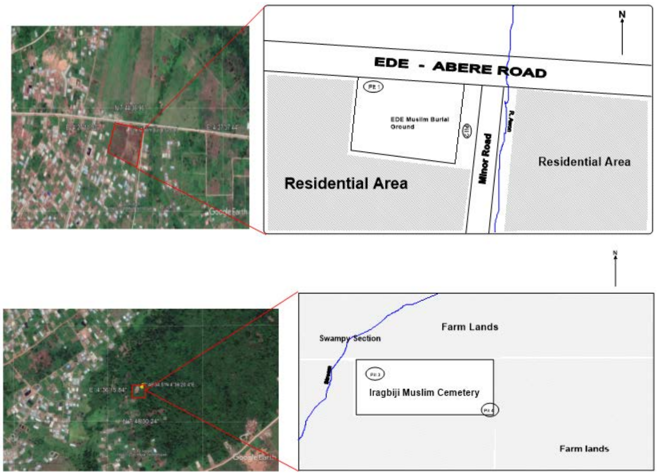

Figure 5: Illustrative Layout of Cemeteries in Ede and Iragbiji

In siting a cemetery, index properties of soil in terms of its grain size, packing density, permeability and degree of porosity dictates to a large extent the rate and ease of fluid movement within a medium. For instance, coarse grained soil present in most of the study areas would allow rapid infiltration of fluid which invariably transmits decomposition fluid to the underlying formation or increase the potentials of groundwater contamination within the subsurface. This could conceivably be a cause of local epidemics from waterborne diseases where the surface or groundwater is used as a water source. Characteristic of soils primarily control the potentials of unsaturated zone in acting as a filter of wastes and cadavers buried within it. The prevailing particle size distribution of the soil influences the hydrogeological characteristics of the formations. It controls the porosity and permeability which are the key parameter for percolation and movement of fluids within the unsaturated vadose zone. Other important factors lacking in both study areas, are the slope and distance of cemeteries to water abstraction points. Watershed areas should be considered before siting cemeteries. In other words, areas of high topography which may likely slope into streams and rivers should be avoided completely. Figure 6 illustrates the conceptual model of potential flow of contaminants within a typical cemetery close to rivers or streams. Pit 2 as observed in the field has a shallow water level of less than 3m which makes that section of the cemetery water-logged. Not only water-logged but a source of visible leachates from the cemetery. The proximity of shallow aquifers to cemeteries pose a great danger to the environment, as this reduces the time needed for mobile waste production to degrade completely and for the geological subsurface material to purify the potential pathogens. Evidence of this is presented in figure 6 showing a leachate flow right from inside the cemetery flowing to a water body (see traces in arrow according to figure 7) at about 20m away from the cemetery. This clearly portends danger for inhabitant of that environment. Additionally, contamination can be increased where corpses are buried in direct contact with the groundwater, causing reduction in the time taken for mobile degradation to reach the subsurface, or with an increase in the number of burials (Engelbrecht, 2000). Closely related to this is another important factor of weather and climate which play an important role in the risk of water contamination by cemeteries. Cemeteries sited in places with high rainfall intensity, shallow water tables, fractured rocks, and any other high permeability are highly susceptible to contamination. It was reported earlier that the current study area fall within the tropical evergreen rain forest area of south-western Nigeria, which makes it more vulnerable to contamination. The question here is; what will be the fate of inhabitants in an unfortunate event of flooding?

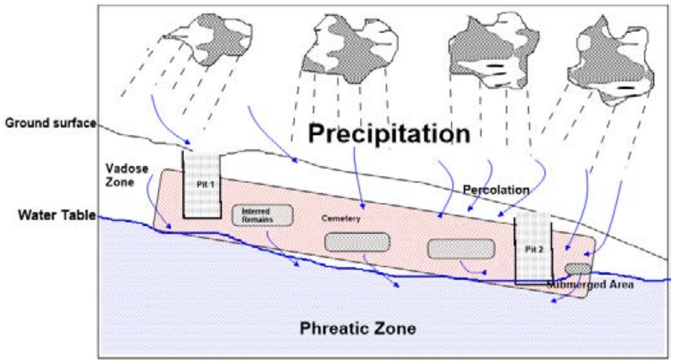

Figure 6: Conceptual Model Flow of Contaminants within a Typical Cemetery Close to a Flowing River.

Figure 7: Field Pictures of Flow of Leachate from Cemetery to A Body of Water.

Safety of cemeteries against transmission of infectious diseases have been questioned recently, published data supports the fact that most infectious diseases would not survive burial below certain depth. However, few researchers supports the idea that various organisms including anthrax, smallpox, infective *Clostridia* spp. and HIV are capable of surviving burial, possibly in anaerobic, environments for some time (Yates et al., 1985, Turnbull, 1990; 1996b; Haagsma, 1991). The situation may be more precarious within the present context based on the topography and hydrogeological setting of the cemetery (See fig 6). In this kind of instance, given the uncertainties of the cemetery environment and burial practices, these organisms may be brought to the surface from the grave due to overland runoff or flood. Closely related to this is the case of natural enteric and thoracic bacteria of human, which, when exposed to favourable conditions may multiply and spread in groundwater. In line with Rudolfs et al. (1950), *Salmonella typhi* can survive up to 100 days while *E. coli* up to 5 years in soil, this is evident in the number of isolates found in wells sampled around cemeteries.

Finally, in a bid to assess the physical and sanitary aspects of the cemeteries, results of the present study were ranked according to conditions for safe cemetery siting as compiled by Hall and Hanbury (1990) in Dippenaar (2014). Table 6 shows the assessment carried out on the soils that surround the cemeteries. The rankings are based on geotechnical parameters. The assessment ranked Pit 4 in Iragbiji *'poor with precautions needed' (67 out of 100)*, Pit 1 Ede was ranked *'poor with precautions needed' (65 out of 100)*, Pits 2 and 3 were *'unacceptable'* based on ranking of *57 and 47* respectively. Geotechnical parameters shows that the soils in Pits 1 and 4 are mainly sandy clay, with low to medium plasticity, medium to high compaction value, and medium to low permeability. Based on the ranking and geotechnical parameters, it could be concluded that clayey soil with low permeability and porosity are most suitable for cemetery siting.

Table 6: Physical and Sanitary Aspects for a Cemetery Site Investigation, (After, [1 – 2])

	Assessment		Rating Score			
			Pit 1	**Pit 2**	**Pit 3**	**Pit 4**
Excavatability						
Pick and Spade	Geological pick causes slight indentation.		10	10	10	10
Stability						
Over break	Overbreak between 1.3 and 1.8m		15	15	15	15
Workability	**USCS**	**MOD ASSHTO(kg/m^3)**	**Pit 1**	**Pit 2**	**Pit 3**	**Pit 4**
Excellent to good	SC	>1800	10	10	-	10
	CH	>1700	-	-	2	-
Water table		**Water table depth(m)**	**Pit 1**	**Pit 2**	**Pit 3**	**Pit 4**
Possibly perched water table		0-4	5	-	-	5
Waterlogged soil		0-4	-	0	0	-
Subsoil permeability		**Approx. Permeability(m/s)**	**Pit 1**	**Pit 2**	**Pit 3**	**Pit 4**
Impermeable		<10^-7	-	-	15	-
Relatively impermeable		10^-6 – 10^-7	15	15	-	20
Backfill permeability		**Unified class**	**Pit 1**	**Pit 2**	**Pit 3**	**Pit 4**
Impermeable		OH,CL,CH	10	-	5	-
Relatively permeable		GC,SC,MH	-	07	-	07
Final ranking			**65**	**57**	**47**	**67**
Final ranking		**Suitability**				
>90		Very good				
75-90		Satisfactory				
60-75		Poor- precautions required				
<60		Unacceptable				

6. Conclusions and Recommendations

In a bid to establish the suitability of two Muslim cemeteries in Ede and Iragbiji, a detailed geotechnical and hydrological assessment were carried out at both cemeteries with a view to establishing the critical role a pathway plays in attenuating potentials of contamination and pollution. Results from the study revealed the very critical role of soil characteristics and concludes clayey sand with good compaction characteristics coupled with low permeability are best suitable for siting a cemetery. The study identified a public health challenge around the vicinity of Ede cemetery with every indicator pointing to negative in terms of location, topography, shallow water level, nearness to drainage channels and a flowing river. Although it has been established that human corpses may not cause groundwater pollution due to any specific toxicity but rather pollution comes through concentration of any naturally organic and inorganic substance to a level sufficient to render groundwater unusable. Pollution is a function of time and mostly due to negligence and poor choice of location and geo-materials. Results revealed a few cases of probable contamination, evident in the mainly in the concentration of Fe^{2+} and the nature of leachates from Ede cemetery. This contamination may be accelerated with time leading to full scale pollution which is adverse to human health. Electrical conductivity seems to be higher in the wells around Iragbiji than that of Ede suggesting a greater extent of contamination. Chemical analysis of the wells show natural levels of Mg^{+}, NO_3, and PO_4 ions compared with the WHO standards. High EC values in Iragbiji may be partly associated with decomposition of human corpse but other anthropogenic activities such as use of fertilizers and pesticides in agricultural land near the cemetery are suspected as responsible. Temperature conditions are generally favourable for the survival of bacteria and other micro-organisms in the water samples taken from both cemeteries. The water samples shows probable occurrence of the families of *enterobacteriaceae (Salmonella spp., Proteus spp., Serratia spp., Shigella spp.,)* which are naturally present in the human body and may be released into the ground water by decomposition of the human corpse and other sources such as feacal contamination from sewage discharge, livestock and wild animals. Such bacteria are responsible for infections such as typhoid, dysentery, urinary infections. These findings coupled with the prevailing weather condition and high intensity of rainfall may portend a great danger to public health. According to Pacheco et al. (1991) in William et al.(2009) "Cemeteries are a potential risk that can become a real risk if previous geological and hydrogeological studies are not consulted".

6.1 Recommendations

Findings from the present study have strengthened the fact that geological characteristics of potential cemeteries are assessed critically before siting. Based on the prevailing conditions in the two (2) cemeteries, that is, being a Muslim cemetery, where coffins are not used, a condition leading faster decomposition and putrefaction of the human remains. The following specific and general recommendations are made to protect the groundwater and safeguard the public health especially of the residents living in the vicinity of cemeteries, as well as to preserve the natural environment for future generations.

- Government should enact regulation guiding the establishment or siting of public cemetery.
- Existing cemeteries should be subjected to constant monitoring in terms of water and soil quality assessment to ascertain level of contamination and/or pollution.
- Efforts should be made to adhere to the EU (1998) recommended guidelines in terms of minimum distance of cemeteries from well (250m), springs or watercourse (30m) and at least 1m clearance from the grave bottom to the highest water level within the potential cemetery. A higher clearance distance if the substrate has a permeability ranging from 10^{-5} to 10^{-7} cm/s.
- Extra regulation should be established to cater more for the peculiarities of Muslim cemeteries where interred remain are in direct interaction with grave soils. For instance, careful selection of sites rich in swelling clay minerals like smectite.

- Cemeteries should be located on gentle slopes or flat terrains as higher slope gradients creates favourable conditions for surface flow, flooding of graves, leaching and migration of decomposition products.
- Cemeteries should be located where clay mineral content ranges between 20 and 40%.
- Cemeteries should not be located in areas where:
    a) The groundwater level is shallow
    b) Seasonal or ephemeral floods occur.
    c) The substrate is very permeable (e.g. sands and gravels, fractured rocks, karst structures).
- Cemeteries should be surrounded by buffer zones composed of trees with deep root systems.
- In the case of high permeability of the soils, clay lining should be adopted as precaution.

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