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The Impact of Soak Away Pit Leachate on the Spatial Distribution of the Groundwater Quality

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Abstract

Access to safe and affordable drinking water is a fundamental human right, and it is crucial for achieving sustainable development goals. The study precisely focused on the impact of soak away pit effluent on groundwater quality. Groundwater was sampled from five spatial points with different proximities from soak away pits, and their potability degree was determined in accordance with standard approved procedures. The results obtained from the laboratory test shown that the physiochemical properties of the water samples ranged thus: dissolved oxygen from 4.14 - 6.03 mg/L, turbidity from 0.31 - 0.75 NTU, total dissolved solid between 13.80 and 32.1 mg/L , nitrate from 1.37 to 7.30 mg/L, and the salinity from 10.09 - 21.97 mg/L. Similarly, the heavy metals level in the water samples varied this this pattern: cadmium - below detectable level (BDL) to 0.001 mg/L, copper - from 0.03 to 0.54 mg/L, Fe between 0.07 and 1.25 mg/L, lead - from BDL to 0.001 mg/L, zinc from 0.08 to 1.33 mg/L, and sodium from BDL – 1.3 mg/L. Likewise, the results depicted that the water samples collected from the four of the five spatial points, that were close to the soak away pits contained high population of bacteria and coliforms. These results highlight the effect of discharge from human waste on groundwater quality, and the importance of considering the proximity of constructing solid waste management system close to source of domestic water supply. This will reduce the risk of water-borne diseases and protecting the quality of water supplies.

1. Introduction

Water is one of the essential requirements for human and socioeconomic development worldwide. Water is an indispensable material for domestic, agricultural, industrial and transportation processes. Hence, the Sustainable Development Goal number 6 recognized water as of the factors needed to achieve sustainable growth and development [1]. The movement of groundwater within the earth crust in highly dependent on the hydraulic characteristics and physical structure of the soil and underlying rocks. The geological structure of the underlying rocks - faults, fractures, and folds - significantly affect subsurface water flow, as the act as potential pathways or barriers to underground water movement. High pervious materials – coarse grained soil and gravel - allow easy water flow more than impervious materials such as fine grained soils - clay and silt [2].

Pollution stands out as a significant factor that pose a significant threat to water (surface and subsurface) quality globally [3]. Groundwater pollution can result from anthropogenic and non-anthropogenic actions through the percolating of contaminated effluents through the soil profile, and eventually pollute the groundwater [4, 5]. The major anthropogenic activities that usually lead to massive pollution of the environment include: improper disposal of industrial wastes; agricultural chemicals - fertilizers pesticides, and herbicides, poor sewage management structure; petroleum exploration and refining activities, and solid minerals extraction activities [6, 7]. Crude oil exploration, extraction, refining and distribution operations could lead to spills of petroleum products, and these pollutants have the capacity of contaminating the soil, surface and subsurface bodies [8].

Sewage leachate is responsible for most pathogenic microbial pollution of water bodies, as the leachate from sewage (including soak away pits) contains significant amount of pathogenic microorganisms. Pathogenic microorganisms (Escherichia coli, *Norovirus*, *Salmonella spp*., *Shigella spp*., *Vibrio cholera*, *Cryptosporidium spp and Giardiasis*) found in soak away effluent can cause serious and chronic waterborne diseases such as: diarrhea, dysentery, typhoid fever, cholera and abdominal cramps [9-12]. Soak away pits effluent can seep into the water aquifer depending on the permeability of the soil and depth of the water table, leading to the contamination of the aquifer which serves as groundwater reservoir for both domestic and commercial purposes [13-16]. Previous researches had showed the impact of poor waste management system on water qualities [4, 5, 17-19]; but there is information dearth on the influence of soak away pit leachate on the groundwater quality of Delta State University of Science and Technology (DSUST), Ozoro Nigeria. Therefore, this research was conducted to appraise the consequences of soak away pits on the groundwater quality around DSUST student residential hostels and faculty of engineering premises. Information obtained from this research will contribute immensely, to addressing water quality challenges associated with waste disposal in the university's vicinity.

2.0. Materials and Method

2.1. Description of the study area

This research was streamlined to the confined of DSUST located in Ozoro community of Delta State, Southern Nigeria. DSUST is located in rainforest vegetation zone of Nigeria, and has two distinct climatic seasons (rainy and dry season) with mean annual rainfall of approximately 1700 mm [5]. Geologically, the university community has Global Positioning Systems (GPS) coordinates of latitude 5.549^o N and 5.570^o N, and longitude 6.241^o E and 6.249^o E. DSUST is susceptible to seasonal flooding which occurs during the rainy season, while the topsoil is mainly modified alluvial type with moderate infiltration rate. The major anthropogenic activities in the university are sewage from residential and administration buildings, agricultural operations and solid waste dumpsites [20]. Borehole water is the major source of domestic and laboratory water source within the school, and most of these boreholes are sited without proper environmental factors assessment.

2.2. Water sampling

The groundwater was sampled from five boreholes within the faculty of engineering and student hostels environs in DSUST, during the rainy season (June) of 2023. A GPS device was used to take the geological coordinates of all the spatial points. The description of the sample points are summarized in Table 1. All the sampling points are prone to very high water table using the rainy season. The water was taken directly from the borehole (and not from the storage tank) directly into sterilized plastic containers (Figure 1). All the specimens were coded accordingly, placed inside an ice cooled container and taken immediately to the laboratory, for physicochemical, heavy metals and microbial load analyses.

Table 1: Description of the sample points

Spatial point	Geographical coordinates	Remarks
Point A	Lat. 5.559^{0}N; Long 6.249^{0}E	5 m away from the soak away pit, with poor sanitary condition
Point B	Lat. 5.559^{0}N; Long 6.250^{0}E	15 m away from the soak away pit
Point C	Lat. 5.558^{0}N; Long 6.251^{0}E	10 m away from the soak away pit, with poor sanitary condition
Point D	Lat. 5.561^{0}N; Long 6.249^{0}E	20 m away from the soak away pit
Point E	Lat. 5.561^{0}N; Long 6.249^{0}E	40 m away from the soak away pit
Point F	Lat. 5.466^{0}N; Long 6.206^{0}E	500 m away from the soak away pit, agricultural activities

Figure 1: Collection of a water sample from a point proximate to soak away pit

2.3. Laboratory analysis

2.3.1. Physicochemical analysis

A turbidity meter (model: HF Scientific M100+, manufactured in America) was employed to measure the water turbidity in accordance with ASTM D7315 procedure [21]; the water dissolved oxygen (DO) was determined in agreement with ASTM D888 guidelines [22]; biochemical oxygen demand (BOD) was tested in harmony with ASTM D6238 procedure [23]; total dissolved solids (TDS) and hardness levels of the water were measured by adhering to ASTM D5907 and ASTM D1126 recommendations, respectively [24, 25]. The laboratory Multi-Meter (model SKU: TS-T910) was used to determine the DO, BOD, TDS and hardness of the water specimens. Consequently, the chloride was tested in accordance with ASTM D512 [26], nitrate content was measured in agreement with ASTM D3867 [27], phosphate and sulphate levels in the water were determined by using the chromatography technique as described by Odiyo [28].

2.3.2. Determination of the heavy metals concentration

The water was digested before the measurement of the heavy metals level in the water. During the digestion, the water was sifted with a 0.45µm gauge filter paper, and 100 mL of the water was acidified five drops of nitric acid to stabilize the metal content, and evaporated to 15 mL volume in a water bath [29]. After digestion, the iron, nickel, copper, sodium lead, and cadmium concentration in the water sample were measured in accordance with ASTM International procedures, by using the Atomic Absorption Spectrophotometer (AAS). The laboratory tests were carried out at ambient laboratory temperature of 28±4°C. All tests were done in triplicate and the average values recorded.

2.3.3. Microbial Load Analysis

The specimens total bacteria and coliform count were determined in harmony with American Public Health Association “APHA” approved procedures for testing water and wastewater [5, 30].

3.0. Results and discussion

3.1. Physicochemical parameters

Table 2 presents results of the physicochemical analysis of the water sampled from the five spatial points. The results depicted that across the five spatial locations, the water dissolved oxygen (DO) varied from 4.14 to 6.03 mg/L, turbidity ranged from 0.31 to 0.75 NTU, total dissolved solid fluctuated between 13.80 and 32.1 mg/L , nitrate varied from 1.37 to 7.30 mg/L, and the salinity ranged from 10.09 to 21.97 mg/L. The results indicated that despite the variation in the parameters concentration, their levels in the water fell below the maximum permissible limits approved by WHO for drinking water. The higher nitrate content and lower DO levels recorded in the water sampled from Location A and C can be linked to the impact of the leachate from the soak away pit on these parameters. Discharge from organic materials – particularly human waste- tends to reduce the dissolve oxygen content, and increase the nitrate concentration of water bodies [5]. Similarly, Lwimbo [31] in the research into the influence of human-induced activities on water potability stated that, leachate associated with the discharge from organic materials and agricultural activities greatly increased the concentration nitrate and other physiochemical parameters of water bodies.

Table 2: The physicochemical parameters of the water samples

Spatial point	Physicochemical parameters					
	DO (mg/L)	Turbidity (NTU)	TDS	Hardness (mg/L)	Nitrate (mg/L)	Salinity (mg/L)
A	5.44	0.31	13.80	28.0	7.30	15.95
B	6.03	0.56	14.55	17.73	5.10	21.07
C	4.85	0.62	28.76	27.55	5.49	19.94
D	4.14	0.75	45.98	23.09	3.00	17.48
E	6.70	0.71	35.30	32.1	1.37	13.33
F	5.12	0.44	22.01	29.43	4.63	10.09
WHO [38]		**5.0**	**500**	**500**	**10.0**	**100**

3.2. Heavy metals (HMs) concentration

The results of the HMs level in the water aquifer are given in Table 3. The HMs concentrations recorded across the six spatial points varied thus: Cd from below detectable level (BDL) to 0.001 mg/L, Cu from 0.03 – 0.54 mg/L, Fe between 0.07 and 1.25 mg/L, Pb from BDL – 0.001 mg/L, Zn from 0.08 to 1.33 mg/L, and Na from BDL – 1.3 mg/L. These findings depicted a wide spatial distribution of the HMs within the studied region. Leachate from soak way pits is probably the potential anthropogenic source for these contaminants, as human waste management is the main anthropogenic activity within the region under investigation. Similar results were obtained by Yahaya [17] during their investigation into the water potability in selected areas in Lagos state, Western Nigeria. Water sampled from aquifers close to toilet facilities recorded higher toxic elements level when compared to water collected from regions with greater distances from soak away pits locations [17,18].

It was noted that apart from the iron content in the specimen sampled from spatial Point A that exceeded the WHO maximum Fe allowable limit for drinking water; interestingly, the HMs concentrations were within the allowable concentration approved by Nigeria Industrial Standards (NIS), irrespective of the sampling location. Excessive Fe concentration recorded at Location A cannot be attributed directly to the effluent from the human waste, but likely to anthropogenic factor such as leachate from metallic objects. High iron level in water can altered the water aesthetics properties, lead to diabetes and stomach problems [32]. Furthermore, leachate from agricultural activities – inorganic manure application - can be responsible for the amount of sodium detected in spatial point F within the studied area. Buvaneshwari [33] reported that some fertilizers (mostly potash-based and sodium-based fertilizers) have the potential of elevating water Na concentration; and rate the seepage from these fertilizers impacted the water quality is dependent on the soil texture, structure and hydrogeological conditions [34].

Table 3: Heavy metals levels in the water samples

Spatial point	**Heavy metal**					
	Cd (mg/L)	**Cu (mg/L)**	**Fe (mg/L)**	**Pb (mg/L)**	**Zn (mg/L)**	**Na (mg/L)**
A	BDL	0.31	1.25	BDL	0.08	1.3
B	BDL	0.03	0.53	BDL	0.21	BDL
C	0.001	0.54	0.72	BDL	1.17	0.03
D	BDL	0.08	0.07	BDL	1.33	BDL
E	BDL	0.07	0.41	BDL	0.26	BDL
F	0.001	0.32	0.22	0.001	0.95	0.04
WHO (2021)	**0.003**	**1.5**	**1.0**	**0.05**	**15.0**	**0.05**

3.3. Microbiological evaluation of the groundwater

The results of the microbiological loads of the specimens are presented in Table 4. It was observed that the TBC of the groundwater sampled from Locations A, B, C, D, E and F were 1500, 620, 1400, 1070, 440 and 10 cfu/ml, respectively; while the total coliform level in the water samples were 9, 0, 3, 1, 2 and 0 cfu/ml at Locations A, B, C, D, E and F respectively. As presented in Table 4, water samples collected from spatial Points A, B, C and D were laden with bacteria and coliforms, and the microorganisms' populations were higher in the samples closer to the soak away pits. This specified that a strong correlation existed between the proximity to the soak away pits and higher populations of bacteria and coliforms. The findings depicted that the coliforms population in sampled groundwater from Locations A and C exceeded the World Health Organization (WHO) recommended threshold of 0 cfu/ml for water meant for human consumption. Elevated levels of bacteria and coliforms in water samples can pose serious health dangers to human beings [5].

These results are similar to observations made by Olatunji [35], during the authors' investigation into the impact of poor sanitary condition on the groundwater. The distance of the borehole from the contamination source (soak away pit), and its depth in relation to the water table are critical factors that can influence the pollution rate of borehole water [35, 36, 40]. Suleiman [37] assessed the effect of soak away effluent on designated aquifer, and reported that the rate of microbial contamination of borehole water is directly proportional to the borehole distance from the soak away pit. These findings align with the common understanding that proximity to contamination sources can significantly influence the groundwater potability.

Table 4: Microbial load of the water samples

Spatial Location	Total bacterial Count (cfu/ml)	Total coliform count (cfu/ml)
A	1500	9
B	620	0
C	1400	3
D	1070	1
E	440	2
F	10	0

4.0 Conclusion

This study was conducted to evaluate the impact of human waste management on the groundwater quality. Groundwater was sampled from different spatial points, and the water quality was determined in harmony with American Society for Testing and Materials (ASTM) and American Public Health Association (APHA) approved procedures. Results obtained revealed that water samples collected from boreholes around the soak away pits tend to contain higher physiochemical, heavy metals and microorganisms when compared to boreholes sited in areas far away from the contamination point. With regards to the biological properties of the groundwater, the water sampled from the neighborhood of the soak away pits have presence of coliform population that exceeded the WHO and NIS threshold (0 cfu/mL) for drinking water. This highlights the importance of considering the proximity of borehole to major waste management structures. Additionally, the microbial population recorded in this study was not classified into beneficial and pathogenic microorganisms; therefore, further research should be conducted to properly classify the microbial load in groundwater. This research finding has practical implications for solid waste management in promoting sustainable and safe water management practices.

References

[1] Khatri, N. & Tyagi, S. (2014). Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Front. Life Sci.* 8, 23–39.

[2] Roy, S & Bhalla, S.K. (2017). Role of geotechnical properties of soil on civil engineering structures, *Resources and Environment*, 7(4), 103-109.

[3] Akhtar, N., Syakir Ishak, M.I., Bhawani, S,A. & Umar, K. (2021). Various natural and anthropogenic factors responsible for water quality degradation: A review. *Water*, 13(19), 2660 – 2671.

[4] Malgwi, G.S. & Sunday, A.W. (2021). The effect of soak-away on subsurface water quality at Doubelli Ward, Yola North Local Government Area, Adamawa State, Nigeria. *International Research Journal of Advanced Engineering and Science*, 6(2), 164-168.

[5] Uguru, H., Akpokodje, O.I., Rokayya, S., Amani, H.A., Almasoudi, A. & Abeer, G.A. (2022). Comprehensive assessment of the effect of various anthropogenic activities on the groundwater quality. *Science of Advanced Materials*, 14: 462–474

[6] Agbemafle, R., Elsie Aggo, S., Akutey, O. & Bentum, J.K. (2019). Heavy metal concentrations in leachates and crops grown around waste dumpsites in sekondi-takoradi in the western Region of Ghana. *Research Journal of Environmental Toxicology*, 14(1), 16–25.

[7] Nyiramigisha, P. & Sajidan, K. (2021). Harmful impacts of heavy metal contamination in the soil and crops grown around dumpsites. *Reviews in Agricultural Science*, 9(0), 271–282

[8] Uguru, H. & Udubra, E.A. (2021). Optimizing the bioremediation of petroleum hydrocarbons contaminated soil. *International Journal of Innovative Environmental Studies Research* 9(3),47-53.

[9] Tsvetanova, Z. & Najdenski, H. (2017). Pathogenic bacteria in waters and drinking water-associated biofilms. *Ecological Engineering and Environment Protection*, 50–61

[10] Gómez-Duarte, O. G., Bai, J., & Newell, E. (2009). Detection of Escherichia coli, Salmonella spp., Shigella spp., Yersinia enterocolitica, Vibrio cholerae, and Campylobacter spp. enteropathogens by 3-reaction multiplex polymerase chain reaction. Diagnostic microbiology and infectious disease, 63(1), 1–9. https://doi.org/10.1016/j.diagmicrobio.2008.09.006

[11] Ramírez-Castillo, F. Y., Loera-Muro, A., Jacques, M., Garneau, P., Avelar-González, F. J., Harel, J., & Guerrero-Barrera, A. L. (2015). Waterborne pathogens: detection methods and challenges. Pathogens (Basel, Switzerland), 4(2), 307–334. https://doi.org/10.3390/pathogens4020307

[12] Magana-Arachchi, D. N., & Wanigatunge, R. P. (2020). Ubiquitous waterborne pathogens. Waterborne Pathogens, 15–42. https://doi.org/10.1016/B978-0-12-818783-8.00002-5

[13] Banda, L.J., Mbewe, A.R., Nzala, S.H. & Halwindi, H. (2014). Effect of siting boreholes and septic tanks on groundwater quality in St. Bonaventure Township of Lusaka District, Zambia. *International Journal of Environmental Science and Toxicology Research*, 2(9), 191-198.

[14] Keegan, M., Kilroy, K., Nolan, D., Dubber, D., Johnston, P.M., Misstear, B.D., O'Flaherty, V., Barrett, M. & Gill, L.W. (2014). Assessment of the impact of traditional septic tank soakaway systems on water quality in Ireland. *Water science and technology : a journal of the International Association on Water Pollution Research*, 70(4), 634–641.

[15] Ahaneku, I. (2014). Impact of Pit Latrines on Groundwater Quality of Fokoslum, Ibadan, Southwestern Nigeria. British Journal of Applied Science & Technology, 4(3), 440–449. https://doi.org/10.9734/bjast/2014/5079

[16] Islam, M. S., Mahmud, Z. H., Islam, M. S., Saha, G. C., Zahid, A., Ali, A. Z., Hassan, M. Q., Islam, K., Jahan, H., Hossain, Y., Hasan, M. M., Cairncross, S., Carter, R., Luby, S. P., Cravioto, A., Endtz, H. Ph., Faruque, S. M., & Clemens, J. D. (2016). Safe distances between groundwater-based water wells and pit latrines at different hydrogeological conditions in the Ganges Atrai floodplains of Bangladesh. Journal of Health, Population and Nutrition, 35(1). https://doi.org/10.1186/s41043-016-0063-z

[17] Yahaya, T.O, Bashar, D.M., Liman, U.U., Umar, J., Abdulrahim, A. & Gomo, C.B. (2023). Effects of pit latrines on borehole and well water in Maryland, Lagos, Nigeria. *J Adv Environ Health Res*, 11(1), 20-27

[18] Okhuebor, S. O. (2020). The Quality And Effect Of Borehole Water Proliferation In Benin City, Nigeria And Its Public Health Significance. Advances in Microbiology Research, 4(1), 1–5. https://doi.org/10.24966/amr-694x/100013

[19] Imarhiagbe, E. E., Oriakhogba, E., & Osayande, A. G. (2023). Assessment of Water, Sanitation and Hygiene (WaSH) Status and Water Qualities Using Physicochemical and Bacteriological Indices at Automobile Spare-Parts Markets in Benin City, Nigeria. African Scientist, 24(1), 105–113. https://doi.org/10.26538/africanscientist.24.1.202303014

[20] Uguru, H., Akpokodje, O.I. & Agbi, G.G. (2021). Assessment of Spatial Variability of Heavy Metals (Pb and Al) in Alluvial Soil around Delta State University of Science and Technology, Ozoro, Southern Nigeria. *Turkish Journal of Agricultural Engineering Research (TURKAGER)*, 2(2), 450-459.

[21] ASTM D7315 (2023). Standard Test Method for Determination of Turbidity Above 1 Turbidity Unit (TU) in Static Mode. https://www.astm.org/d7315-17.html

[22] ASTM D888 (2018). Standard Test Methods for Dissolved Oxygen in Water. https://www.astm.org/d0888-18.html

[23] ASTM D6238 (2017). Standard Test Method for Total Oxygen Demand in Water. https://www.astm.org/d6238-98r17.html

[24] ASTM D5907 (2018). Standard Test Methods for Filterable Matter (Total Dissolved Solids) and Nonfilterable Matter (Total Suspended Solids) in Water. https://www.astm.org/d5907-18.html

[25] ASTM D1126-17. Standard Test Method for Hardness in Water. https://www.astm.org/d1126-17.html

[26] ASTM D512 (2004). Standard Test Methods for Chloride Ion In Water. https://www.astm.org/d0512-04.html

[27] ASTM D3867 (2021). Standard Test Methods for Nitrite-Nitrate in Water. https://www.astm.org/d3867-16r21e01.html

[28] Odiyo, J.O., Mathoni, M.M. & Makungo, R. (2020). Health risks and potential sources of contamination of groundwater used by public schools in Vhuronga 1, Limpopo province, South Africa. *Int. J. Environ. Res. Public Health* 17, 6912.

[29] Uguru, H., Akpokodje, O.I., Agbi, G.G., Essaghah, A.E., Sami, R., Amani, H.A., Al-Meshal AS, Rasha, A.A., Waad. A., Alotaibi, A., Doaa, M.J. & Mahmoud, H. (2023). Evaluating the spatial distribution of some toxic substances concentration with the microbial contamination of wetland water, sediment and fishes, and their potential health hazards. *Journal of Biobased Materials and Bioenergy*. 16: 864–882.

[30] American Public Health Association – APHA (2012). Standard Methods for Examination of Water and Wastewater, 22nd ed.; APHA, Washington, DC, USA.

[31] Lwimbo, Z.D., Komakech, H.C. & Muzuka, N.N. (2019). Impacts of emerging agricultural practices on groundwater quality in Kahe catchment, Tanzania. *Water* 11, 2263 - 2278

[32] Ghosh, G. C., Khan, M. J. H., Chakraborty, T. K., Zaman, S., Kabir, A. H. M. E., & Tanaka, H. (2020). Human health risk assessment of elevated and variable iron and manganese intake with arsenic-safe groundwater in Jashore, Bangladesh. Scientific reports, 10(1), 5206- 5221

[33] Buvaneshwari, S., Riotte, J., Sekhar, M., Sharma, A. K., Helliwell, R., Kumar, M. S. M., Braun, J. J., & Ruiz, L. (2020). Potash fertilizer promotes incipient salinization in groundwater irrigated semi-arid agriculture. Scientific reports, 10(1), 3691 - 3712

[34] Ogbaran, A.N. & Uguru H. (2021). Evaluating the contamination degree and risk assessment of heavy metals around active dumpsite environment: A case study of Ozoro Community, Delta State, Nigeria. *Physical Science International Journal*. 25(1), 39-51.

[35] Olatunji, J. J. & Oladepo, K. T. (2013). Microbiological quality of water collected from unlined wells located near septic-tank-soakaway and pit latrines in Ife North Local Government Area of Osun State, Nigeria. *Transnational Journal of Science and Technology*, 3, 10-11

[36] Owoeye, J. A., & Akinneye, J. O. (2018). Assessment of well water pollution by sewage contaminants: A case study of Akure South, Ondo State, Nigeria. *Brazilian Journal of Biological Sciences*, 5(10), 549–575. https://doi.org/10.21472/bjbs.051030

[37] Suleiman, A.O., Sangari, D.U. & Ogah, A.T. (2021). Effect of distances between soakaway and borehole on groundwater quality in Mararaba, Karu LGA, Nasarawa State, Nigeria. *African Scholar Journal of African Sustainable Development*. 23(2),73 -84

[38] World Health Organization –WHO (2011). Guidelines for Drinking-Water Quality. 4th ed. WHO Library Cataloguing-inPublication Data, Malta Publisher; Gutenberg, Salt Lake City, UT, USA, 1-541.

[39] Oladepo, J.J. & Oladepo, K.T. (2013). Microbiological quality of water collected from unlined wells located near septic-tank soak away and pit latrines in Ife north local government area of Osun State, Nigeria. *Transnational Journal of Science and Technology*, 3(10), 8-20.