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The Efficiency of Grey Water Treatment by Using Selected Sand Bed Bioreactors in South West Nigeria

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ABSTRACT

In drinking or treated water, filtration plays a relevant role in the multi barrier approach used for the removal of pathogens. The presence of suspended solids and other particulate matter in grey water increases the resistance of most microbes to disinfection. These study aimed to determine the most suitable sand that can be utilized in the construction of sand bed bioreactor in grey water treatment. The bioreactor is expected to remove significant amount of grey water physical properties (odor, color, turbidity), physicochemical properties (pH, total solids, total dissolved solids, hardness, Nitrate, Magnesium, etc) and heavy metals (Iron, Cadmium, Chromium, Biological Oxygen Demand or BOD, Chemical Oxygen Demand or COD). Sand samples are collected from four different locations in southwest Nigeria to serve as the filter media in the bioreactor. Soil physical property test is carried out on all sand samples that was collected across southwest. The result of the study showed an improvement in physical property, about 80% improvement in physicochemical property and heavy metals. Eleyele soil sample effectively improved water quality compared to other soil samples.

Keywords: Filtration, Pathogens, Sand Bed Bioreactors, Grey Water, Physicochemical, Biological Oxygen Demand.

INTRODUCTION

In a world where there is a daily increase in the consumption demand of water, there is a need for diversification in waste water management. Generally, there shouldn't be lack in the availability of water has it has been proven that the earth itself is made up of 71% (Peter, 1993) of water which it's either in its liquid, solid or gaseous state. Contrary to the research above, Egbinola (2017) water has always been the most sourced natural resources (Hofkes, 1981). Rijswljk (1981) estimated the groundwater resources in Nigeria at 0–50m depth to be 6 x 106 m3 while Nwankwoala (2011) estimated the total surface water resources to be 224 trillion litre per year (l/yr). There is a need for effective management and recycling of what to meet the daily rose in the demand for water in Nigeria. Waste water treatment is very important in achieving the required water demand in the country. Several methods such as aeration and oxidation ponds can be used for the treatment of waste water but a sand bed bioreactor promises to give a positive result in the design of a bioreactor for treatment of waste water (Yadu et al., 2016). Effective sand grain size and analysis for laboratory will establish this. A sand bed bioreactor is constructed in a water-tight basin to remove toxic and waste elements from wastewater. There is a comparative reduction in operation cost, though at large capacities, they do not compare favourably with column reactors. Effective sand grain size and analysis for laboratory will establish this. A sand bed bioreactor is constructed in a water-tight basin to remove toxic and waste elements from wastewater. There is a comparative reduction in operation cost, though at large capacities, they do not compare favourably with column reactors (Sahariah et al., 2016). Also, when the degree of agitation is large, the bioreactor get detached from the particle surface.

This study aimed at determining the most suitable sand that can be utilized in the construction of a sand bed bioreactor in grey water treatment. The objectives are to, collect sand samples from available sand deposit zone in the south western parts of Nigeria, carry out physical property tests on collected sand samples in accordance with standard specifications and to recommend a reference standard sand in the southern western part of Nigeria that can be used as a sand bed for bioreactors in waste water treatment plants. Sand and media bioreactors respond well to gradual increases in grey water loading. Therefore, they

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are very appropriate for new developments with a gradual build-out rate. These bioreactors also tolerate fluctuations in flow, especially changes from a negligible flow to very high flows. In this way, they are appropriate for seasonal use and recreational areas. Research shows that sand bioreactors receiving no grey water for 4–6 months can immediately treat grey water when put back into service (Kang et al., 2007)**.** The area loading rate of the bioreactor is the third design criteria. In general, the higher the area loading rate, the more likely the bioreactor is to clog and back up. Once clogged, the bioreactor must be rested for four to six months (Wolfe, 2000; Ohio Department Of Natural Resources, 1995). Sand effective size and uniformity coefficient affect filter performance. BODs and ammonia removal are a function of effective size. If the bioreactor effluent will be discharged to a stream, very low CBODs and ammonia effluent concentration are typically required.

This study aimed to determine the most suitable sand that can be utilized in the construction of sand bed bioreactor in grey water treatment.

MATERIALS AND METHODS

Source, description and preparation of samples

Grey water is used water. In homes, this includes water from sinks, showers, bathtubs, toilets, washing machines and dishwashers. Businesses and industries also contribute their share of used water that must be cleaned. The first stage of the research involved the collection of our sand to be used for testing. The scope of the project limits the research geographically to the south western regions of Nigeria; (Lagos (Aja), Ibadan (Eleyele), Osun (Ipetu-Ijesa) and Ondo (Igbokoda). G.P.S (Global Positioning System) was used to record the locations where the samples are gotten from. Soil sample collected along the banks of Eleyele river (located in Ibadan, Oyo state in Ido local government area) with exact G.P.S coordinates of Latitude 7.4149˚ N, Longitude 3.38512˚ E. Another alluvial soil sample was studied from Ondo state. The sample was collected along the banks of Ofara river (located in Igbokoda town, along ayetoro in ilaje local government area) with exact G.P.S coordinates of latitude 6.3505˚ N, Longitude 4.8069˚ E. Soil sample collected along the banks of Ipetu Ijesa river located in Oriade local government area in Osun state. G.P.S corodinates was gotten as latitude 7.466˚ N, longitude 4.890˚ E. Soil samples collected from Marine beach, Apapa local government area, Lagos state. G.P.S coordinates were gotten as latitude 6.44707 N and longitude 3.35114 E

Standard requirement for biofilter media

Typical standard filter media properties as described in the (ANSI/AWWA standard No. B100-01) is given Table 1 and are the expected outcomes of this research. There are certain standard requirements for sand treatment media. These requirements should conform with descriptions in the ASTM (C136-01), (BS 812112:1990), (BS 812110:1990). Sieve Analysis; this test method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing. Accurate determination of material finer than the 75-µm (No. 200) sieve cannot be achieved by use of this method alone. Soil porosity refers to the fraction of the total soil volume that is taken up by the pore space (Nimmo, 2005). The porosity of each sample was calculated using the specific gravity values to attain the volume of solids (V_s). The volume of voids (V_v) was then calculated from values of the volume of the sample (V) and volume of solids (V_s).

Table 1. Standard Requirement for biofilter media

Physical Property	**Value**
Effective size, mm	0.3–0.6
Uniformity coefficient	1.5–2.5
Porosity	0.40–0.47
Specific gravity	2.55–2.65

Tests on water

The original grey water sample and the four effluent samples were all tested for certain metal and physical properties. This was done to compare the filtration quality of the four soil samples and study chemical and physical changes from the original grey water sample. Most of the physio-chemical parameters are determined by standard methods prescribed by ASTM (2003) and APHA (1985); Trivedy and Hand (1986). They include, Physical Test; Color, Odor, Turbidity. Chemical Test; pH Conductivity, Total Solids, Total Dissolved Solids, Total Suspended Solid, Nitrate, Phosphate, Sulphate. Heavy metals (Iron,Cadmium, Chromium, Biological Oxygen Demand, Chemical Oxygen Demand).

Figure 1. Grey water collection from drainage pipes in Adeniyi hostel, FUTA.

RESULTS AND DISCUSSIONS

Moisture content

Percentage values for moisture content test carried out on all four soil samples are shown in table 2

Table 2. Moisture content of sail samples.

Soil sample (location)	Moisture content (%)
Igbokoda Sample	4.95
Eleye Sample	24.19
Apapa Sample	7.25
Ipetu Ijesa Sample	17.34

Results obtained shows that moisture content in the Eleyele sample has the highest value for moisture content percentage while that of Igbkoda has the lowest moisture content as shown in the chart (Figure 1).

Specific gravity standard range between 2.55-2.65 (ASTM C128-15 2015), this indicates that all samples falls within the range except Igbokoda sample which goes to prove its classification of a silty sand (Table 3).

Uniformity coefficient result suggests that Ipetu Ijesa and Eleyele is very close to standard which ranges from 0.3-0.6. Also, uniformity coefficient has a standard of 1.8-2.5 (ASTM C136 2019), this suggests that all samples falls within the standard (Table 4).

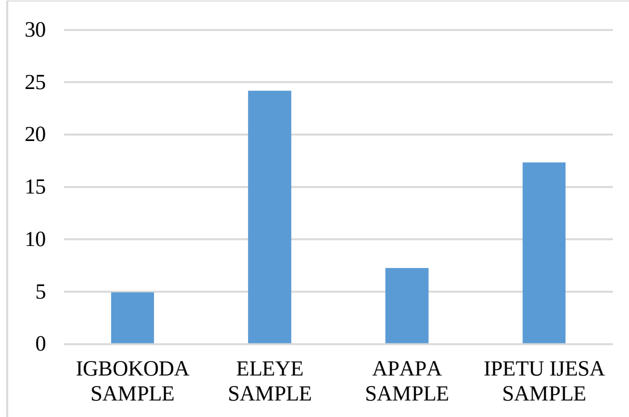

Figure 2. Moisture content distribution on bar chart

Table 3. Specific gravity of soil samples

Soil Sample	Specific Gravity
Eleyele	2.62
Igbokoda	2.69
Apapa	2.64
Ipetu Ijesa	2.65

Table 4. Respective effective sizes and uniformity coefficient value of each soil sample

Soil Samples	Effective Size (Cc)	Uniformity Coefficient (Cu)
Eleyele	0.28	2.39
Igbokoda	0.08	1.85
Apapa	0.24	2.48
Ipetu ijesa	0.25	2.33

Table 5. Water quality standard

Parameters	WHO Drinking Standard	Fishery and Aquaculture Life Standard (Europe)
pH Cond. (Mg/L)	6.5-8.5	-
Turbidity (NTU)	5	-
BOD (mg/L)	-	3-6
COD (mg/L)	-	20
TSS (mg/l)	-	25
Nitarte (mg/L)	50	-
Nitrite (mg/L)	3(p)	-
Sulphate (mg/L)	250	-

Grey water effluent analysis

Four different samples that was collected was analyzed by passing it through the sand bed that was collected from different locations and the result is analyzed in other to know the best sand that could be suited for a sand bed bioreactor in sought west Nigeria. All units are in mg/L, except turbidity (NTU) and temperature (Celsius).

Turbidity. As shown in figure 3, The result shows that turbidity values decreased after filtration through each individual soil sample. The turbidity value for the original grey water sample is 60.4NTU. The turbidity values for Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples are 11.7NTU, 12.9NTU, 12.5NTU, and 9.5NTU respectively. From the result, it is denoted the Eleyele water sample comes closest to the W.H.O. standard turbidity value (5NTU) with a turbidity value of 9.5NTU. This further proves that the Eleye soil sample, through which filtration occurred is capable of most efficiently removing particles suspended or dissolved in water, thereby providing a clearer effluent.

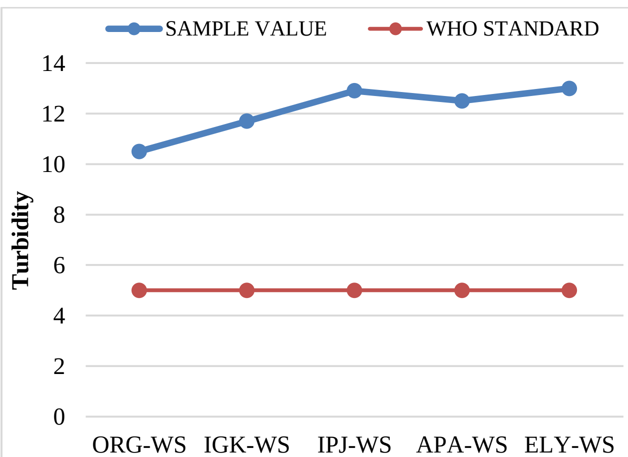

Figure 3. Turbidity Values

pH. Also the pH values reduced after filtration through the soil samples. The pH of the original grey water sample is 7.5 and reduces to values of 6.97, 6.5, 6.5, 6 for Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples respectively As shown in figure 4. All values fall within the range of 6.5-8.5 for W.H.O. standard. This implies that soil samples through which grey water was filtered through provide water portable for drinking and able to support aquatic life.

Biological Oxygen Demand. As shown in figure 5, BOD values also decreased considerably after filtration through the soil samples. The original grey waters sample has a BOD value of 73.86 mg/L. The value is high as a result of high organic pollution leading to greater amount of organic matter or food available for oxygen consuming bacteria. The result therefore shows depletion in the BOD values for all water effluents. The depletion in BOD values after filtration through sand media signifies increase in water quality. The Igbokoda sample comes closest to the BOD value for sustaining aquatic life (3 mg/L).

Chemical Oxygen Demand (COD): COD values for all effluent water samples are well lower than that of the original grey water sample. The original grey water value for COD was gotten to be 120.4 mg/L. Post- filtration COD values for effluents are 66mg/L, 40.2mg/L, 66mg/L, 37.4mg/L for the Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples respectively As shown in figure 6. A noticeable pattern of lower COD values can be observed for all effluents after filtration through their respective individual soil samples. This shows that the amount of oxidizable pollutants have been reduced. COD value for the Eleyele water sample of 37.4 mg/L comes close to the WHO standard limit of 20mg/L. Total suspended solids for all effluents obtained from the filtration process previously undergone. The original grey water sample has a TSS value of 281mg/L, while proceeding values of effluent are 29mg/L, 30.1mg/L, 29.4mg/L, 24.9mg/L for the Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples respectively. The result shows that the Eleye water sample has the least concentration of bacteria, nutrients, pesticides and metals in water, though still above the Fisheries and Aquatic life standard (25 mg/L) with a value of 24.9 mg/L.

Total Dissolved Solid. As shown in figure 7, TDS values also reduced after filtration through soil samples. The original grey waters sample has a TDS value of 174 mg/L. The high value does not necessary mean that the water sample will cause any health hazard but it does lend the water a bitter, salty or brackish taste. The water quality is therefore low. The TDS values for the Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples are 17.2mg/L, 12.57mg/L, 11.69mg/L and 13.1mg/L respectively. All water sample in this case are well below the required WHO standard of 1000mg/L. The depletion in TDS values after filtration through sand media signifies increase in water quality as the samples may now be tasteless. Alkalinity increased for all four effluent samples. The original grey water sample has a value of 33.33Mg/L while Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples have values of 50Mg/L, 283.33Mg/L, 275Mg/L and 303Mg/L. This goes on to depict high presence of carbonate, bicarbonate or hydroxide compounds in the soil samples through which all water samples were filtered. All values are still below the limit for the BIS 10500-2012 standard (600mg/L).

Nitrate (NO_3^-) concentration is shown in figure 8 the standard limit of 50mg/L for WHO except Ipetu ijesa and Eleyele samples. Ipetu ijesa and Eleyele samples have concentration values of 50.54mg/L and 51.44mg/L respectively as shown in figure 8. Values higher than the permissible limit of 50mg/L can be harmful to heath especially for pregnant women and infants. Consuming too much Nitrate can affect how blood carries oxygen and cause methemoglobinemia (also known as blue baby syndrome). The original, Igbokoda and Apapa water samples have NO_3^- concentrations of 28.1mg/L 26.58mg/L and 18.74mg/L respectively. They can support plant and aquatic life and can be portable for drinking. Nitrite depletes after filtration through soil samples.

Nitrite (NO_2^-)**.** As shown in figure 9, The original water sample has a concentration of 0.95Mg/L of NO_2^-. Concentration. Nitrite NO_2^- concentration values of Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples are 0.55Mg/L, 0.37Mg/L, 0.61Mg/L and 0.35Mg/L respectively. Nitrites are a salt or ester anion of nitrous acid, which can be naturally or artificially occurring in groundwater. Nitrites come from fertilizers through run-off water, sewage, and mineral deposits unfortunately it can also stimulate the growth of bacteria when introduced in high levels into a body of water, causing eutrophication. All water samples are below the provisional limit of 3mg/L for nitrite concentrations. This signifies that the water effluent samples will not cause any harmful health effects to infants or affect aquatic life.

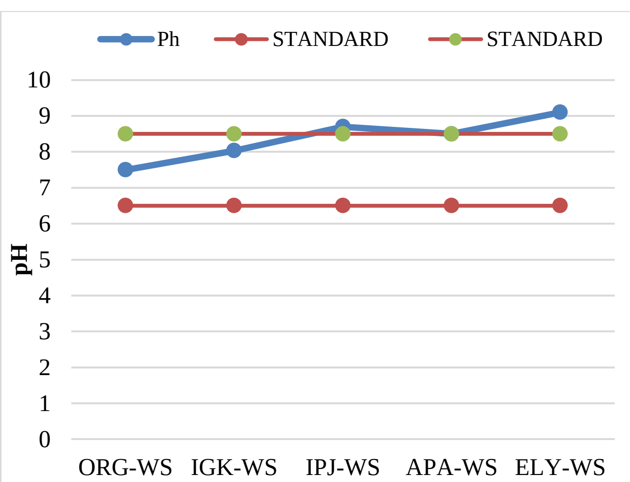

Figure 4. pH alues

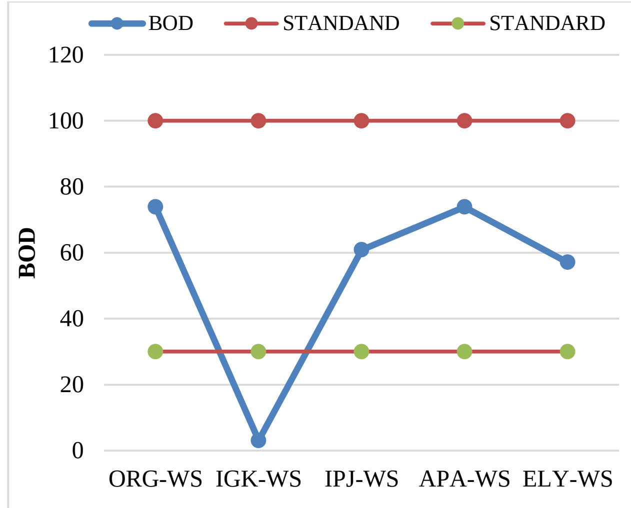

Figure 5. Biological Oxygen Demand Values Comparison

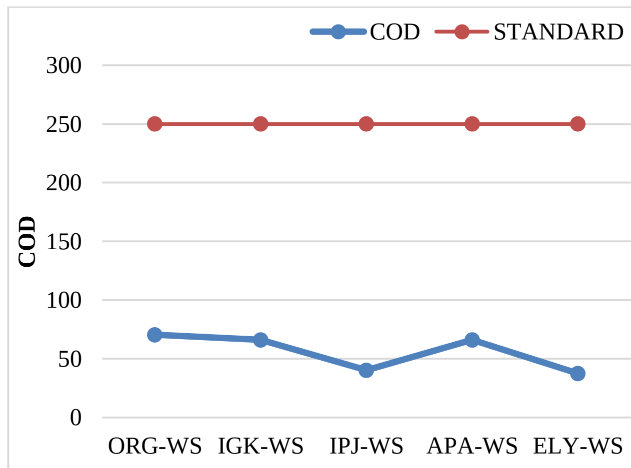

Figure 6. Chemical Oxygen Demand Values

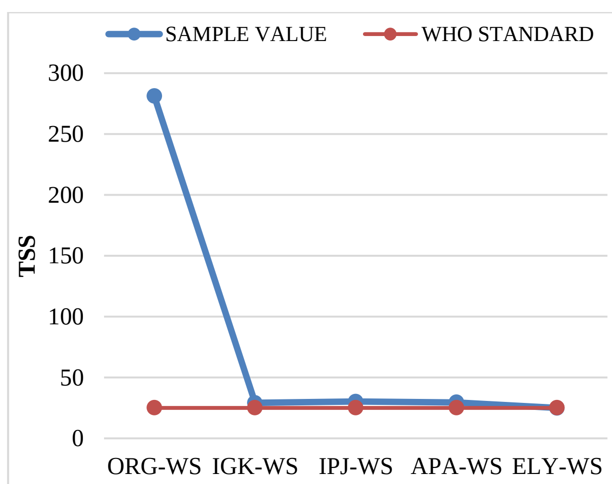

Figure 7. Total Suspended Solids Values

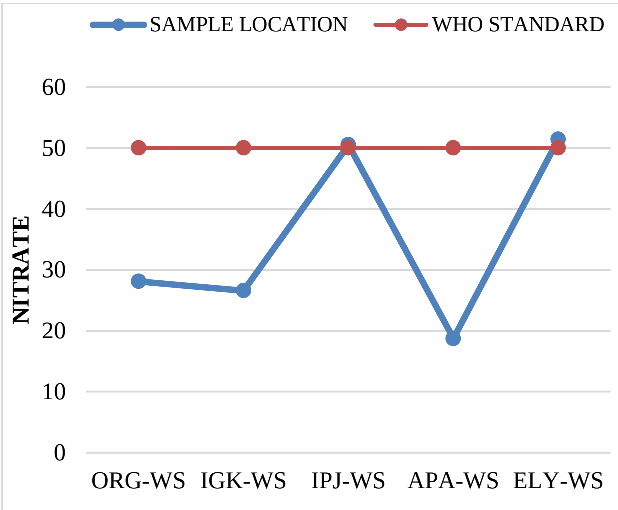

Figure 8. Nitrite Values

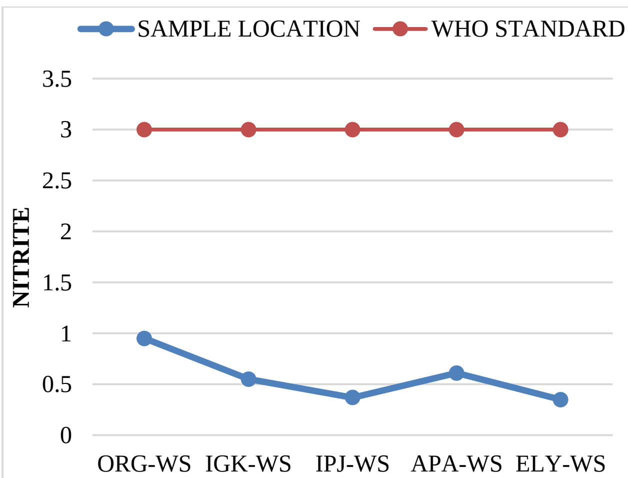

Figure 9. Nitrate Values

Figure 10. Sulphate values

Sulphate. As shown in figure 10, Sulphate concentrations for the original, Igbokoda, Ipetu ijesa, Apapa and Eleyele water samples are 978.26mg/L, 466.75mg/L, 4312.05mg/L, 1918.16mg/L and 4303.07mg/L respectively. These values indicate high levels of sulphates for all water samples and therefore decrease water quality. The presence of high level of sulphates well above the standard limit of 250mg/L may make water taste bitter or like medicine. It also corrodes plumbing, particularly copper piping.

CONCLUSION AND RECCOMMENDATION

Sand bed bioreactors are alternate filtration systems for filtration in grey water treatment plants, for micro irrigation systems or even use in household and communities. The advantages of the system stretch from reducing protozoa and bacteria to high flow rate pf up to 0.6 liters per minute.

Assessment of all four samples in this research work shows that the Eleyele soil sample came closest to all physical properties of sand filter media that can be used as sand bed in bioreactors. Eleyele soil sample also most effectively improved water quality than the Igbokoda, Apapa and Ipetu ijesa soil samples. Eleyele soil sample efficiently reduced BOD, COD, turbidity, TSS and TDS of grey water efficiently.

DECLARATIONS

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Authors' contribution

John Famakinwa performed the experiments, analysed the data obtained and wrote the manuscript OM Ojo and CG Williams designed the experimental process and revised the manuscript. Both authors read and approved the final manuscript

Conflict of interest

The authors hereby confirm that there is no conflict of interest whatsoever with any third party.

REFERENCES

Yadu A, Sahariah BP, Anandkumar J. (2016). Studies on biological degradation of 4-bromophenol using anaerobic, anoxic and aerobic bioreactors. J. Modern Chem. Chem. Technol. 7(1): 37-41. Google Scholar

ANSI/AWWA standard No. B100-01 (2001), Standard for granular filter media, American National Standard Institute; American Water Works Association, Denver, Colo.

ASTM C128-15 (2015), Standard Test Method for Relative Density (Specific Gravity) and absorption of fine aggregate America Society for Testing and Materials, West Conshohocken. Google Scholar

ASTM C136 (2019), Standard test method for sieve analysis of fine and coarse aggregate, American Society for Testing and Materials, West Conshohocken. Google Scholar

BS 812-110 (1990), Testing aggregate. Method of determination of aggregate crushing value (ACV), British Standard Institution, London, UK.

BS 812-112 (1990), Testing aggregate. Method of determination of aggregate impact value (AIV), British Standard Institution, London, UK.

Egbinola CN (2017). Trend in access to safe water supply in Nigeria. Journal of Environment and Earth Science. 7(8):89-96. Google Scholar

Nwankwoala HO (2011). An integrated approach to sustainable groundwater development and management in Nigeria. Journal of Geology and Mining Research. 3(5): 123-130. Google Scholar ; DOI:https://doi.org/10.5897/JGMR.9000004

Kang YW, Mancl KM, Tuovinen OH. (2007). Treatment of turkey processing wastewater with sand filtration. Bioresource technology. 98(7):1460-6. DOI: https://doi.org/10.1016/j.biortech.2006.03.006 ; Google Scholar

Nimmo JR. (2005). Porosity and pore size distribution. Encyclopedia of Soils in the Environment. 3(1):295-303. DOI: https://doi.org/10.1016/B0-12-348530-4/00404-5; Google Scholar

Ohio Department Of Natural Resources (1995). Report of Ohio Mineral Industries. Ohio: Division of Geological Survey.

Wolfe ME (2000). Report on Ohio mineral industries: Ohio Division of Geological Survey, 153 p., map. Google Scholar

Gleick PH. (1993). Water in crisis. Pacific Institute for Studies in Dev., Environment & Security. Stockholm Env. Institute, Oxford Univ. Press. 473p. 9:1051-0761. Google Scholar ; Direct Link

Hofkes EH, editor. (1981). Small community water supplies (book). International Reference Centre for Community Water Supply and Sanitation and Wiley. Google Scholar

Rijswljk K (1981). Small Community Water supply. The Hauge, 18. Google Scholar

Sahariah BP, Anandkumar J, Chakraborty S. (2016). Treatment of coke oven wastewater in an anaerobic–anoxic–aerobic moving bed bioreactor system. Desalination and Water Treatment. 57(31):14396-402. DOI: https://doi.org/10.1080/19443994.2015.1065448 ; Google Scholar

Trivedy RK and Goel PK (1986). Chemical and Biological method for water pollution studies. Environmental publication (Karad, India), 6: 10-12. Google Scholar