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ANALYSIS AND CHARACTERIZATION OF UNTREATED GREYWATER OBTAINED FROM ENUGU METROPOLIS.

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ABSTRACT

Greywater is a wastewater discharge originating from kitchen sinks, showers, baths, washing machines and dishwashers. The composition of greywater varies greatly according to its origin (*i.e.*, bathroom, laundry or kitchen greywater) and is influenced by the water quality of the locality. In the current study, the physicochemical and microbial characteristics of greywater obtained from Enugu metropolis were assessed. The greywater samples were collected from different households and mixed together to get a representative sample of the location. The samples were analyzed for: pH, temperature, turbidity, total suspended solid (TSS), chloride, phosphate, sulfate, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammonia, total bacterial count, total fungal count and total coliform using standard procedures. The results showed that the pH, temperature, turbidity, total suspended solid (TSS), chloride, phosphate, sulfate, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammonia had values of 7.1, 30 (◦C), 527.5 (NTU), 831.5 (mg/L), 708.7 (mgCl/L), 3.5 (ppm), 17.5 (mg/L), 705.2 (mg/L), 14.0 (mg/L), and 5.6 (µg/L), respectively. Total bacterial count, total fungal count and total coliform had values of 3.2×10^4, 1.6×10^4, and 1.1×10^4, respectively. Most of the physicochemical parameters such as pH, temperature, BOD_5, phosphate, sulphate, ammonia fall within the permissible limits allowed for wastewater discharge by WHO and FEPA standard while turbidity, total suspended solid (TSS), chloride, and chemical oxygen demand (COD) were above the maximum permissible levels. The presence of microbial load in the greywater could be as a result of mixing children diapers with other clothes during cleaning. The presence of these compounds showed that the greywater samples were contaminated and could harm ecosystems if not properly treated and therefore should be treated before reuse or disposed.

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Keywords:
Greywater, chemical oxygen demand, biochemical oxygen demand, physicochemical and microbial characteristics.

Introduction

The environmental pollution caused by the indiscriminate discharge of the untreated greywater into the environment or water bodies has become a menace and source of concern to the general public. Greywater contaminants are likely to cause waterborne illnesses like diarrhoea, typhoid, cholera and poliomyelitis (Ingrao *et al*., 2020). At the same time, its compounds lead to alteration of taste, colour and odour of the wastewater effluent-dominated rivers.

Greywater is wastewater discharged from showers, baths, kitchen and washing basins which represents an attractive alternative water source for non-potable uses (De Gisi *et al*., 2016). Greywater can also be defined as wastewater without any input from toilets, which means that it corresponds to wastewater produced in bath tubs, showers, hand basins, laundry machines and kitchen sinks in household, offices, buildings, school etc. The composition of greywater varies greatly according to its origin (*i.e.*, bathroom, laundry or kitchen greywater) and is influenced by the water quality of the locality. Greywater is usually divided into light greywater, which come from showers, baths, hand basins laundry machines and dark greywater which includes laundry facilities, dishwasher machines, and in some studies also kitchen sinks (Ghaitidak and Yadav, 2013).While dark greywater may contain high concentrations of pollutants, light greywater has a low concentration (Allen *et al*., 2010). Greywater generation could be up to 75 % of the water volume used by households (Ghaitidak and Yadav 2013).

The characteristic of greywater differs, and it is largely a reflection of the lifestyle, the type and choice of chemicals used for laundry, cleaning and bathing. The quality of the water supply and the type of distribution network also affect the characteristics of greywater. The composition may also be affected by chemical and biological degradations of some compounds within the transportation and storage network. (Boyjoo *et al.*, 2013) reported that greywater with high nutrient concentrations is a result of a high fraction of kitchen and laundry effluents in the greywater. Generally, greywater contains high concentrations of easily biodegradable organic materials and some basic constituents which are largely generated from households.

The physicochemical parameters of relevance to greywater are temperature, colour, turbidity suspended solids, pH, electrical conductivity, biological and chemical oxygen demand (BOD_5), (COD), nutrient content (nitrogen, phosphorous). Greywater also contains microorganisms such as bacteria, fungi, protozoa and helminths which are introduced into it by body contact. Inappropriate food handling in the kitchen and direct handling of contaminated food have been identified as sources of enteric pathogenic bacteria such as *Salmonella* and *Campylobacter* into greywater (Maimon *et al*., 2014).

Faecal contamination of greywater typically depends on the age distribution of household members, i.e. the higher faecal contamination of greywater is typically experienced where babies and young children are present in a household. (A. A. Ilemobed, 2012). Faecal contamination is also common in greywater and is largely associated with poor personal hygiene and disposal of greywater which contains washed nappies. The most common indicators used to assess faecal contamination are coliform bacteria and *Esherichia coli*.

Greywater reuse is a promising alternative water source, which could be exploited on a continuous basis and treated for non-potable uses (Chong *et al*., 2015). Increasingly, greywater reuse is seen as an essential component of local and national efforts to adapt to climate change, enhance food security, extend potable water supply, and reduce pollutants in the environment (Drechsel *et al*., 2015). The use of greywater for urinal and toilet flushing is one of the possibilities since the water that is used in many countries today is of drinking water quality. In other words, potential savings of fresh water can be achieved from greywater recycling (Fowdar *et al*., 2017). According to the World Health Organization (WHO), greywater with a low pathogenic content can be used for crop irrigation. It is therefore necessary that when planning for the reuse of greywater to properly analyze the water with respect to physical, chemical and microbial qualities.

The study was designed to analyze and characterize the physicochemical and microbiological characteristics of greywater obtained within Enugu metropolis with a view to getting it treated for non-potable reuse.

Materials and Methods

Study Area

The study was carried out at Enugu metropolis. Enugu Metropolis is the administrative capital of Enugu State, which is one of the five States in South-East geo-political zone in Nigeria. Enugu metropolis is made up of the more developed areas in the State and they are located mainly in the capital city. The geographical coordinates of the study area lies approximately between latitude 6° 21′N 6° 30′N and between longitude 7° 26′E and 7° 30′E. It has a density approximate of 6,400/km^2.The metropolis is made up of three local government areas namely Enugu North, Enugu South and Enugu East local government areas. It is bounded in the West by Udi Local Government Area, in the North by Igbo-Etiti and Isiuzo Local Government Area and in the South by Nkanu West Local Government Area. Some areas in the metropolis include: Achara Layout, Obiagu, Uwani, New Layout, Ogui, New Market, GRA, Iva Valley, New Haven and Independence Layout. Its population according to the 2006 National population census was 722,664 people.

Greywater sampling

Greywater samples from different sources (laundry, kitchen and bathroom) were collected at the discharge pipe of the selected households within Enugu metropolis and mixed together to form a representative greywater of the location. The samples were collected using sterilized 1litre plastic containers; washed with liquid soap, rinsed with distilled in accordance with standard procedures as reported by APHA (2012). The samples were appropriately fixed in the field and transported on ice parked cooler to the laboratory where analysis such as physical, chemical and microbiological tests commenced upon arrival.

Physicochemical analysis

Physico-chemical analyses of the greywater collected were determined for the selected parameters: pH, temperature, turbidity, total suspended solids, chorides, phosphate**,** sulfate, chemical oxygen demand (COD), and biological oxygen demand (BOD). All analyses were carried out using Standard Methods for the Examination of Water and Wastewater (APHA 2012). pH, temperature , and turbidity were measured using Pocket – sized pH meter (HANNA instruments), mercury thermometer and turbidometer instrument respectively. Chloride was obtained using Argentometric titration method and as described by Adelowo (2016)**.** The amount of phosphate was determined using molybdenum blue phosphorous method in conjunction with UV-Visible spectrophotometer according to APHA (2012) and as described by Oladeji, *et al*., (2016). The amount of biological oxygen demand was determined using Winkler's method according to the description of APHA (2012). A phenate method was adopted for ammoniacal nitrogen determination according to the standard method of APHA (2012). Total suspended solid (TSS) determination was determined according to the method of singh, *et al* 2017; 100 mL of the sample was centrifuged at 2000 rpm for 10 minute. The supernatant was removed and the residue was washed three times by resuspending it in distilled water and recollecting by centrifug ation. The residue was finally transferred quantitatively to pre_ weighted dish (X1g). The dish was weighed again after drying (X2g) to a constant weight at 105 °C. The sulphate concentration was determined according to the standard method of APHA (2012) and as described by Sharma and Kaur (2016).

Microbiological analysis

By the method of Nkansah, *et al*. (2016), 10 mL of the greywater samples were aseptically pipetted into a sterile Erlenmeyer flask and diluted tenfold by adding 90 mL of sterile buffered peptone water (BPW) followed by subsequent decimal dilution using the BPW. Total bacterial count for wastewater samples were conducted in triplicate according to the APHA (2005) using standard plate count agar (SPCA) and incubated at 30 °C for 48 h. For total coliforms, 1.0 mL of the diluted sample was poured in sterile Petri dishes and then 20 mL of both mEndo Agar (MA) were added and the media was allowed to solidify. For total fungal count, 0.1 mL of the diluted sample was spread on Potato Dextrose Agar (PDA). The incubation was carried out at 37 °C and 24 h for bacteria and 25 °C and 72 h for fungi. After incubation, colonies were counted and results obtained were CFU/ mL of greywater sample as follow:

CFU/mL = No. of colonies ×Dilution factor ×Volume correction.

Table 1.0: Physicochemical and microbiological characteristics of untreated greywater, in comparison with FEPA and WHO discharge standard.

Parameter	Units	Untreated greywater	FEPA discharge standard limit	WHO discharge standard limit
pH		7.1	6-9	6.5‗ 8.5
Temperature	◦C	30	40	Ambient
BOD_5	mg/L	14.0	30	30
COD	mg/L	705.2	250	80‗ 100
Sulphate	mg/L	17.5	500	500
Chloride	$mgCl^{-1}/L$	708.7	600	250
Turbidity	NTU	527.5	30	5‗ 10
Ammonia	µg/L	5.6	20	50
Phosphate	Ppm	3.5	5	5
TSS	mg/L	276.0	30	30‗ 200
Total bacterial count	Cfu/mL	3.2×10^4	1×10^2	—
Total fungal count	Cfu/mL	1.6×10^4	—	—
Total coliform	Cfu/mL	1.1×10^4	400MPN/100ml	—

Key:WHO = World Health Organization; FEPA = Federal Environmental Protection Agency; ◦C = Degree centigrade;mg/L = Milligram per litre; ppm = Part per million; µg/L = Microgram per litre; NTU = Nephelometric turbidity unit; Colony forming unit per milliliter; TSS = Total suspended solids;BOD_5= Biochemical oxygen demand; COD = Chemical oxygen demand; mgCl = Magnesium chloride;

Results and Discussion

The results of the physicochemical and microbiological characteristics of the untreated greywater are presented in Table 1.0. From the table, pH, temperature, turbidity, total suspended solid (TSS), chloride, phosphate, sulfate, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), and ammonia, had values of 7.1, 30 (◦C), 527.5 (NTU), 831.5 (mg/L), 708.7 (mgCl/L), 3.5 (ppm), 17.5 (mg/L), 705.2 (mg/L), 14.0 (mg/L), and 5.6 (µg/L), respectively. Total bacterial count, total fungal count and total coliform had values of 3.2×10^4, 1.6×10^4, and 1.1×10^4 respectively.

pH is an indicative parameter that define the extent of acidity and alkalinity of greywater. The pH value of 7.1 reported in this study is in conformity with those reported by Saumya, *et al.,* 2015 which ranges from 6.5-8.4. Also, Mohamed, *et al.*, 2018 reported the pH for raw greywater in the range of 6.1–6.4.These differences might be due to the variation of greywater and the type of products utilized by the households. The pH of the greywater is within the discharge requirement set aside by WHO and FEPA.

The greywater temperature value of 30 (◦C) as reported in this study is within the discharge requirement set aside by (FEPA). Greywater temperature is often higher than that of the municipal water supply and within a range of 18-35 ºC. These comparably higher temperatures are attributed to the use of warm water for personal hygiene and/or cooking.

In this study, the untreated greywater had turbidity value of 527.5 (NTU), which is far above the discharge requirement set aside by (FEPA) and could be attributed to the water use activities in the households. The range of turbidity recorded for greywater is between 19 and 444 NTU and it is mostly influenced by the water use activities (Katukiza *et al.* 2014). Greywater that has most of its sources originating from the kitchen and laundry is expected to become more turbid due to the presence of suspended matter. The color and turbidity of greywater tends to get darker and heavier as the more nutrients gets into the water then finally becomes black water.

Total Suspended Solids reflects the overall deposition of suspended particles in greywater. The TSS content of greywater is largely influenced by the original source of water, along with the use pattern of habitants (Eriksson *et al.,* 2012). In this study, TSS of the raw greywater was found to be 276.0 (mg/L), which is lower than the 355 mg/L value reported by Jamrah, *et al.* (2011) and 996 mg/L reported by Katukiza, *et al.* (2014) in their greywater stream. This unusual spike in TSS can be explained by the source of greywater being heavily concentrated with detergents from sources such as washing machine and dishwasher. The TSS value of the greywater in this study was found to be far above FEPA and WHO discharge standard.

The chloride value of the untreated greywater was 708.7 (mgCl/L). The high level of chloride in the sample may be as a result of the type of detergents or soaps used. It has been shown that most commercially available bathroom/laundry products are currently manufactured using various types and quantities of sodium salts. Also household cleaning products are often sources of sodium, chloride and other salts (Wiel-Shafran *et al.*, 2006). Chloride being a strong disinfectant when its concentration is high, results to less level of infection and vice-versa. The chloride value of the greywater in this study was found to be far above FEPA and WHO discharge standard.

Chemical oxygen demand (COD) is the amount of oxygen required to oxidize the organic material present in a water sample. The measured value of COD is usually higher than that of measured BOD in many waste streams because many organic substances can be oxidized chemically rather than biologically. Chemical oxygen demand is an indication of the polluting strength of the greywater. In this study, the untreated greywater had the COD value of 705.2 (mg/L). The COD value of the raw greywater reported in this study was contrary to the values of 1583 mg/L reported by (Hern´andez, *et al.*, 2010) in a study conducted in Netherlands. This can be validated by the studies done by (Katukiza *et al.*, 2014) who reported a COD of 2861 mg/L in the discharge from a commercial laundry greywater. However, in a balanced discharge with greywater collected from different sources, the COD value of 290-850 mg/L was obtained which conforms to the calculations done by (Hern´andez *et al.*, 2010) for an average value of COD discharged into wastewater stream by a household. The variations are mostly dependent on the source and time of sampling as there may be surge of nutrient/COD discharge if greywater is only collected at certain times of day that coincide with activities such as washing clothes or bathing etc.

Biological oxygen demand (BOD_5) is the measure of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given grey water sample. The BOD_5 values of 14.0 (mg/L) reported in this study, was in the range of BOD_5 values Smith and Melhem (2012) reported which is 5 mg/L to 431 mg/L. Abinaya and Loganath (2015), reported BOD_5 range of 120 mg/L to 350 mg/L. The main contributor to BOD_5 in greywater is the dissolved organics and suspended food particles. The higher BOD_5 value of greywater was due to higher demand of oxygen in water and vice-versa. The transcended value of BOD_5 might be attributed to the increased demand of oxygen for microbial decomposition of suspended solids present in greywater. The sharp differences between the COD and BOD_5 values of the untreated greywater throw light unto the efficiency and population of the microorganisms that are metabolizing the organic matter in the greywater.

In regards to phosphate and sulfate concentration of the untreated geywater, it was observed that the values recorded were 3.5 (ppm) and 17.5 (mg/L) respectively.

Phosphate is one of the important ingredients to plant blooms and eutrophication of lakes and streams. The greywater phosphate studied, had concentration below the ideal value of 5 ppm recommended by FEPA and WHO as a permissible discharge limit. This low amount may be due to the life style of people in the households which includes usage of high amounts of soaps, detergents and cleaning agents when carrying out activities. The lower value might also be attributed to the light of quantity-intensity factor of phosphate which is as result of the presence of suspended solid leading to increase the adsorption (quantity) at the cost of decrease in solution phosphate (intensity) (Edwin *et al.*, 2014). Sulphate naturally occurs in water bodies by the dissolution of sulphides such as pyrite from the interstratified materials by percolating water producing sulphate ions (Braga *et al.,* 2014). This study revealed a low sulphate value which was within the FEPA and WHO stipulated limits of 500 mg/L. The low concentration of sulphate could be due to the absence of anthropogenic activities that influence the concentration in water bodies. Also, the lower value of sulphate might be due to low level of sodium lauryl sulphate used commonly as surfactant for cleaning products, cosmetic and personal care product (Braga *et al.,* 2014).

Ammoniacal nitrogen (NH_3) is a common pollutant in freshwater ecosystem that is associated with organic compound or sometimes from industrial effluents (Magdalena *et al*., 2015). Ammoniacal nitrogen indicates nutrient status, organic enrichment and health of waterbodies (Abdel-Raouf 2012). Higher NH_3 value can be toxic to fish, but in small concentrations, it could serve as nutrients for excessive growth of algae (Al-Badaii *et al*., 2013). The maximum threshold level of ammonia according to FEPA and WHO are 20 μg/L and 50 μg/L, respectively. The 5.6 μg/L value of ammoniacal nitrogen obtained from this study was within the permissible discharge range for wastewater according to FEPA and WHO. The relatively low NH_3 content in the untreated greywater could be attributed to the lifestyles of the households.

The relatively high number of microorganisms in the untreated greywater sample is as indicator of possible contamination with faecal materials and could be as a result of some households mixing children diapers with other clothes during cleaning. It may also be due to poor sanitary condition. The factors that may contribute to the variation in the microbial counts were differences in hygiene conditions, variation in water economy that is some household recycle cleaning water more than others, variation in the period of in which the items being cleaned had been left soaking in the cleaning water. Food remains and possibly overnight soaking of used utensils may have contributed to high counts in dish greywater. The significant difference in the microbial counts in the greywater samples shows that the level of hygiene in the residential areas is different (Birks *et al.*, 2017). The total bacteria counts recorded in this study were above WHO permissible limit for wastewater discharge. This study agrees with the report of Harsha, *et al*. (2013) that extremely high total bacterial load in waterbodies suggested that the water has been contaminated by potentially dangerous microorganism. The major diseases that could arise from bacteriological contamination of the greywater include typhoid, diarrhea and cholera. The coliforms are the primary bacterial indicator for faecal pollution in water and they are most abundant bacteria in water responsible for waterborne diseases such as typhoid, dysentery, diarrhea and also been implicated in mortality across the world (WHO 2011). The coliforms represent the faecal contamination in the water. Weinberg, *et al*. (2014) reported that the fecal contamination of greywater is a common occurrence, creating the risk of a range of fecally transmitted pathogens. Coliform populations of 3×10^3 to 2.4×10^7 CFU per 100 ml was reported by Eriksson, *et al*. (2012). The presence of *E. coli* was seen as indicator of possible contamination with fecal materials.

CONTRIBUTION TO KNOWLEDGE

From the findings, it can be established that the efficiency and population of microorganisms in the greywater are affected by the chemical inorganic matter that are present. In other words, it is imperative to find out the chemical composition of greywater prior to treatment in order to achieve high success rate in the treatment process.

CONCLUSIONS

In this study, the physicochemical and microbiological characteristics of untreated greywater obtained within Enugu metropolis were analyzed. The results of the characterization showed a varying degree of contamination and therefore indicate the necessity and importance of treatment prior to disposal into the environment or for reuse purposes (including non-potable reuse). The nature of the greywater is a very important factor prior to treatment. This study therefore recommends that appropriate treatment methods should be developed to treat the greywater generated from this metropolis in order to reduce the menace of environmental pollution and preserve scarce freshwater.

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