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Using Slow Sand Filtration System with Activated Charcoal Layer to Treat Salon Waste Water in a Selected Community in Cape Coast, Ghana

Isaac Mbir Bryant* and Roberta Tetteh-Narh

Department of Environmental Sciences, University of Cape Coast, Ghana

Abstract

Discharge of untreated salon waste water into the surrounding environment in Ghana remains so probably because of poor knowledge of Ghanaians about treated waste water and its reuse as well as ignorance of waste water to ground water pollution. In Ghana, there is little or no knowledge on waste water treatment technology for salon waste water. In addition, a greater proportion of Ghanaians have no knowledge regarding reusability potentials of treated waste water. Thus, this study assessed the efficiency of a simple slow sand filtration system integrated with activated charcoal layer for salon waste water treatment. The study also assessed the perception of some selected Ghanaians in Cape Coast on reuse of treated salon waste water. For sixteen weeks, salon waste water collected from five different beauty salons in Amamoma was homogenized and treated. Selected parameters of both influent and effluent were analyzed. The percentage removals of some selected heavy metals present in the treated waste water (Effluent) show Copper 32.836 ± 7.013%, Cadmium 59.259 ± 8.006%, Zinc 83.333 ± 6.881%, Iron 38.095 ± 2.002%, Lead 100.000 ± 12.939% and Arsenic 100.000 ± 11.573%. pH 9.877 ± 1.107%, Conductivity 6.250 ± 0.819%, Total Dissolved Solids 5.810 ± 0.629%, Biological Oxygen Demand 21.780 ± 1.578%, Turbidity 93.798 ± 6.073%, Nitrates-nitrogen 67.727 ± 5.759%, Phosphate-phosphorus 67.614 ± 3.264%, Ammonia-Nitrogen 79.249 ± 8.311%, Total Suspended Solids 94.043 ± 0.948% and Chemical Oxygen Demand 84.487 ± 2.823%. All effluent parameters conformed to EPA Ghana standards for effluent discharge except turbidity, $N\text{-}NO_3$, conductivity, TSS, COD and $N\text{-}NH_3$. The results proved that treatment of salon waste water using an integration of slow sand filtration system and activated charcoal layer could be adopted as domestic waste water treatment technology especially in developing countries like Ghana since the percentage removal for four of the treated heavy metals (Cadmium, Zinc, Iron and Arsenic) were around 60% and above except for Iron and Copper which were below 40%.

Keywords: Slow sand filtration system; Activated charcoal layer; Salon waste water

Introduction

With the rising population in recent times, many countries worldwide battle with the issue of waste management, especially the efficient treatment of waste water as well as its disposal. This has given rise to various forms of pollution. Waste water can be described as water that is not whole to be used as a result of influence by humans [1]. This includes liquid waste discharges from domestic residences, commercial properties, small-scale industries and institutions. This study centers on salon waste water. To satisfy the demands of the increasing population of people who patronize salon services, proliferation of salons is on the ascendancy and the result is that too much waste is generated in providing more of the beauty care services. Salons offer a wide range of services such as hair styling and treatment, make-up application and the like. The waste water contains lots of organic and inorganic compounds. These components usually end up in the sanitary sewer system, where it can affect environmental health adversely [1].

In view of the issues associated with waste water and the increasing demand in water and environmental needs, efforts have been made to treat waste water for the sake of environmental health and conservation. Water treatment plays a greater role in the water supply chain. It helps in the sustainable management of vital water resources alongside water conservation and efficiency. This project therefore aims to determine the efficiency of slow sand filtration system with activated charcoal layer in pollutant removal. The slow sand filtration system is composed of shallow layers of stones and gravels beneath a deep layer of sand, and schmutzdecke on the topmost layer of the system where most of the removal and biologic activity occurs [2]. Apart from desalination and reverse osmosis, the slow sand filtration is said to the most effective single treatment for drinking water purification. It is used for water supply to large cities, small villages and even for use in individual households [3]. Activated charcoal refers to a form of processed carbon with very high porosity and a very large surface area for adsorption. It can effectively reduce certain organic and inorganic compounds such as micro pollutants, lead, chlorine, fluorine, dissolved radon, dissolved oxygen, color, harmless taste and odor causing compounds, which may not be removed in slow sand filtration [4-6]. In Ghana, there is little or no knowledge on waste water treatment technology for salon wastewater. In addition, a greater proportion of Ghanaians have no knowledge regarding reusability potentials of treated wastewater. Thus, this study assessed the efficiency of a simple slow sand filtration system integrated with activated charcoal layer for salon waste water treatment. The study also assessed the perception of some selected Ghanaians on reuse of treated salon wastewater.

Materials and Methods

Study area

Amamoma is a community in the Cape Coast Metropolis located in the Central Region of Ghana (Figure 1). Cape Coast is located South to the Gulf of Guinea (5° 6' 0" North, 1° 15' 0" West).

The major rainy season occurs between May to July and minor rainy

***Corresponding author:** Isaac Mbir Bryant, Department of Environmental Sciences, University of Cape Coast, Ghana, Tel: 233242076335; E-mail: ibryant@ucc.edu.gh

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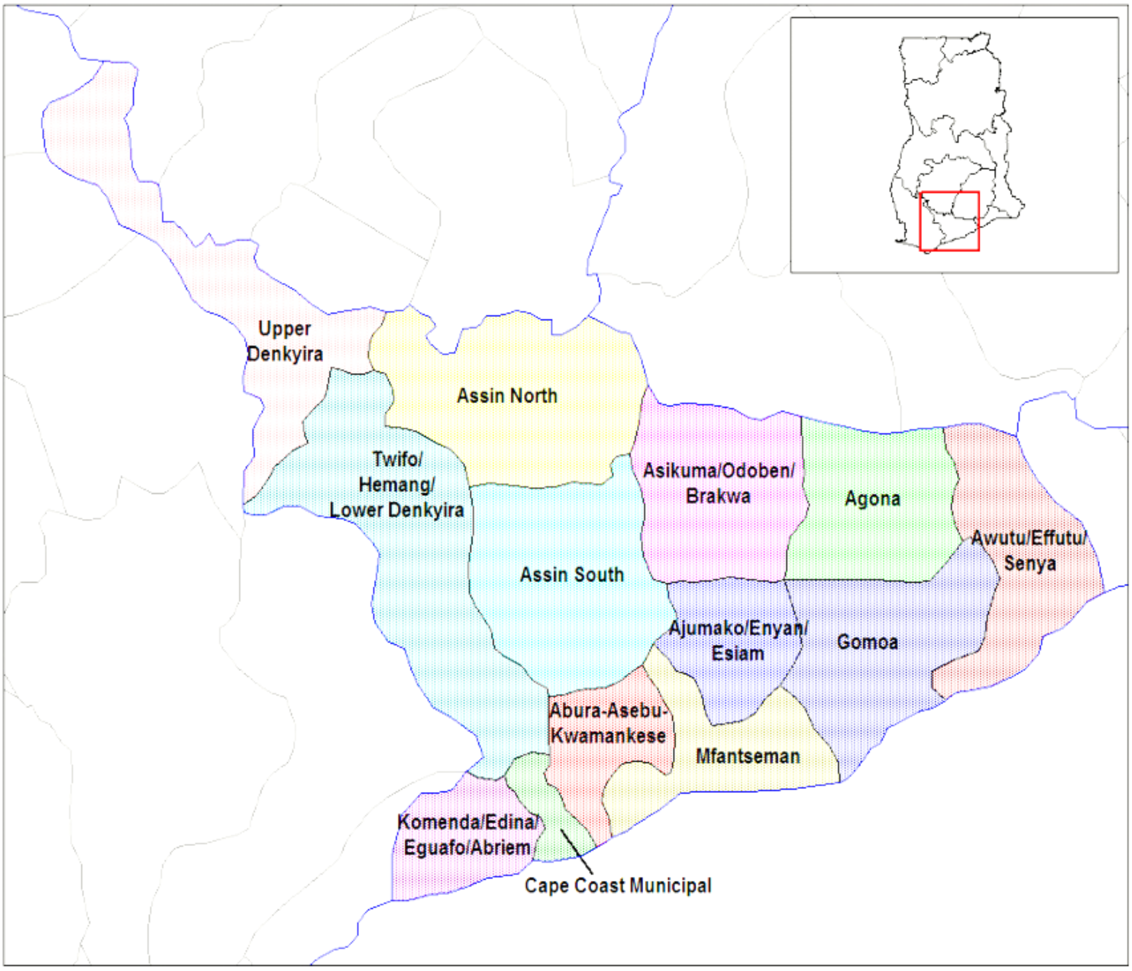

Figure 1: Geographical location of the Central Region showing Cape Coast Municipal.

season falls within November to January [7]. The majority of students of the university are also found there and this has made salon services a booming business in Amamoma. Ground water is the primary water source due to irregular supply of tap water, especially during the dry season. During this season, supply of potable water through pipes reduces thus attention is shifted to underground water.

Sample collection and preparation

A total of about 800 L of waste water was collected from five selected salons in Amamoma, via random sampling. The collection was carried out for sixteen weeks, between the period of January and April, 2015. About 10 L of waste water was collected from each salon once a week during this period. Prior to treatment, the waste water from all five salons was homogenized. A disinfected 750 ml water bottle was filled with the homogenized waste water and kept in a refrigerator at a temperature of 0-4°C, before transportation to the laboratory for analysis. The rest of the waste water was introduced into the slow sand filtration system.

Design of the slow sand filtration system

The slow sand filtration system was designed, using a 100 L plastic container. A white thread socket covered with a mesh was fitted through a hole created at the base of the container. The mesh was used to prevent particles (e.g., fine sand) from clogging the effluent outlet. Connected to the socket was a PVC tube which served as effluent outlet. The lid of the container was perforated to serve as diffusion plate. This is to enable even distribution of the influent into the filter bed and to trap large solid materials in the influent such as hair strands. The filter bed was made of a bottom layer of stones (average of 6 cm in diameter) to a depth of 8 cm, followed by 11 cm depth of gravels (average of 3 cm in diameter). The strata were covered with a mesh to prevent mixing of the gravels and the coarse sand (which occupied the next stratum). The coarse sand with 2 mm diameter and depth of 8.5 cm occupied the next layer. This layer was followed by fine sand of about 0.125 mm diameter to a depth of 31 cm. The high depth of fine sand was so to increase retention time in order to ensure efficient treatment. The final layer of the filter bed was activated charcoal (from Zeal Technology-Takoradi, Ghana) of a depth of about 5 cm. The activated charcoal has the following properties: 0.5 mm square surface area, moisture content=5.0% w/w, ash content=6% w/w, adjustable pH value (7), bulk density=0.5 g/cm^3, hardness number=90, density=21 g/cm^3, appearance=black and insoluble matter=3% w/w. In effect, the whole filter bed occupied 63.5 cm of the plastic container. The perforated lid was used to cover the set-up during treatment to prevent foreign particles from dropping into the treatment system.

The detailed layers of the slow sand filtration bed used in this study are shown in the Figures 2-5.

Figure 2a: Picture of stones (Average 6 cm in diameter) used in slow sand filtration system design (8 cm depth).

Figure 2b: Picture of gravels (Average 3 cm in diameter) used in slow sand filtration system design (11 cm depth).

Figure 3a: Picture of coarse sand (2 mm in diameter) used in slow sand filtration system design (8.5 cm depth).

Figure 3b: Picture of fine sand (0.125 mm in diameter) used in slow sand filtration system design (31cm depth).

The flow rate for the effluent was calculated by recording the volume of effluent collected and the difference in the time the effluent started flowing out of the system and the time it stopped flowing in drops. After filtration, a disinfected 750 ml water bottle was also filled with the treated water for analysis. On a weekly basis, two well labeled samples were kept in a cooler containing ice blocks and transported immediately to the Ecology Laboratory of the University of Ghana in Accra.

Heavy metals analysis

The heavy metals that were determined included Cadmium, Lead, Copper, Zinc, Iron and Arsenic. These were analyzed using the Graphite Furnace Atomic Absorption Spectrophotometer 900T (GFAAS 900T) by Perkin Elmer with model pinAAcle 900T. The GFAAS 900T measured the heavy metals based on the following wavelengths and slit respectively: Cadmium (326.1 nm, 0.7), Lead (405.8 nm, 0.2), Copper (324.7 nm, 0.7), Zinc (213.8 nm, 0.2), Iron (372.0 nm, 0.2) and Arsenic (235 nm, 0.2). The GFAAS is a technique which employs the use of a graphite- coated furnace to vaporize and it is capable of producing very high temperatures as 3000°C. It measures samples in parts per billion hence detects even very minimal concentrations of heavy metals in samples. The set-up was warmed up and calibrated three times after which an aliquot was introduced into the heated graphite tube. The samples were acidified with Nitric acid (a drop) and deposited in the graphite-coated tube to heat, vaporize, ash and atomize the samples. The results measured for a sample is the average of triplicate analysis. This process was repeated for both samples of the influent and effluent for each heavy metal.

Laboratory analysis of physico-chemical parameters

The methods outlined in the Standard Methods for the Examination of Water and Waste water [8] and HACH Company Ltd. (1996) DR/2010 Spectrophotometer Procedure Manual was followed for the analyses of all the physico-chemical parameters. The process was repeated for both samples of the influent and effluent for each physicochemical parameter.

Figure 4a: Picture of the overall set-up of the slow-sand filtration system used for the treatment of salon waste water in Cape Coast.

Figure 4b: Picture of Activated Charcoal layer used for the treatment of salon waste water in Cape Coast.

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Results

Table 1 shows mean values obtained from heavy metals analysis of the homogenized salon water before and after treatment over sixteen weeks. Lead and Arsenic were Below Detectable Limits (BDL). Iron recorded the highest value both in the treated (0.039 mg/L) and untreated water (0.06). Highest percentage removal of heavy metals was recorded in Cadmium (80.135 ± 32.024%) while copper recorded the least (31.876 ± 108.052%). All the parameters were within the acceptable limits of EPA Ghana.

Table 2 shows mean results obtained from analysis of physicochemical parameters in the homogenized salon waste water before and after treatment over sixteen weeks. pH, nitrates, BOD and COD were within the limits of EPA Ghana while turbidity, $N-NO_3$, conductivity, TSS, COD and $N-NH_3$ exceeded the limits.

Figures 6 to 11 show the relationship between percentage removal and flow rate, as well as percentage removal and HRT for the heavy metals. The graphs reveal an inverse relationship between flow rate and HRT and percentage removal.

Perception of some residents of Cape Coast on reuse of treated salon wastewater

A total of 50 individuals were randomly selected and issued with the questionnaire to find out their perception on the reuse of treated salon waste water. The results were compiled into the Figures 12-23.

Discussion

Turbidity, electrical conductivity and pH

Turbidity values exceeded EPA Ghana standard limit of 75 mg/L. This could be because of the high levels of the suspended and dissolved particles in the homogenized salon waste water as a result of high variability in the salon waste water characteristics from each salon such as source of water used in washing of hair, products used in the various salons (detergents, shampoos, soaps, dyes, etc.). Raw water turbidity recorded in this study was high compared to the study by ref. [9] which recorded a raw water turbidity value of 950 NTU. This is probably because the sampling was from a particular salon, unlike the homogenized samples from five salons for this study. Conductivity however, was beyond EPA's acceptable limit of 1500 µS/m (Table 2). The high level of conductivity in the influent could be attributed to the high concentration of dissolved ions present the wastewater. On the other hand, the conformity of the mean pH value to Ghana Environmental Protection Agency's acceptable limits of 6.5-9 could be attributed to the large surface area of both the activated charcoal and the fine sand. In treating salon waste water using activated charcoal only, Egbon et al. [9] recorded pH of 7.10 ± 0.10. The results of this study (pH of 7.0), however, is contrary to the findings of Egbon et al. [9]. This may be due to the integration of slow sand filtration with activated charcoal in the study. The alkalinity may also be traced to input from the chemical composition of the hair products used at the salons.

Phosphate, nitrates-nitrogen and ammonia-nitrogen

Phosphate concentrations of 0.1-5.6 µ/l over a long period of time are enough to cause eutrophication in a water body, according to Browman et al. [10]. In this study however, the levels of phosphate were 2.4 mg/L and 0.8 mg/L for untreated and treated waste water respectively (Table 2). Phosphate concentration conformed to the guidelines of the Environmental Protection Agency's permissible limit of 2 mg/L (Table 2). The level is not enough to cause much eutrophication to cause adverse effects in water bodies if discharged into any, except over a long period of time, as asserted by Browman et al. [10]. The Nitrate concentration from this study conformed to the Ghana EPA acceptable limit of 50 mg/L (Table 2). This may be due to the fact that less organic matter was broken down to Oxides and Nitrate [11] Egbon et al. [9], recorded 0.05 mg/L Nitrate. The difference between the two studies may be attributed to the homogenized effect of nitrates from the five salons unlike from a single salon in the case of Egbon et al. [9]. The ammonia nitrogen concentration (2.885 mg/L)

Figure 5a: Picture of untreated salon waste water.

Figure 5b: Picture of the treated salon waste water.

Parameter	Influent	Effluent	% Removal STD	EPA GHANA
Cu (mg/L)	0.067 ± 0.045	0.045 ± 0.022	2.836 ± 27.013	0
Cd (mg/L)	0.027 ± 0.004	0.011 ± 0.005	59.259 ± 8.006	0.1
Zn (mg/L)	0.054 ± 0.009	0.009 ± 0.003	83.333 ± 6.8805	0.5
Fe (mg/L)	0.063 ± 0.010	0.039 ± 0.022	38.095 ± 2.002	0.3
Pb (mg/L)	0.010 ± 0.004	0.000 ± 0.000	100.000 ± 12.939	0.1
As (mg/L)	0.002 ± 0.000	0.000 ± 0.000	100.000 ± 11.573	0.1

Table 1: Mean results for analyzed heavy metals of homogenized Salon waste water samples collected for sixteen weeks.

Parameter	Influent	Effluent	% Removal	EPA STD
pH	7.776 ± 0.497	7.008 ± 0.166	9.877 ± 1.107	6.0-9.0
EC (µs/m)	1780.125 ± 178.274	1668.875 ± 111.286	6.25 ± 0.819	1500
TDS (mg/L)	891.375 ± 88.868	839.625 ± 55.659	5.81 ± 0.629	1500
DO (mg/L)	3.725 ± 0.394	4.038 ± 0.551	n.a.	1000
BOD (mg/L)	29.325 ± 5.224	22.938 ± 5.294	21.780 ± 1.578	50
Turbidity (NTU)	1556.675 ± 253.136	96.538 ± 36.466	93.798 ± 6.073	75
$N-NO_3$ (mg/L)	24.025 ± 7.710	7.863 ± 2.471	67.727 ± 5.759	50
PO_4(mg/L)	2.393 ± 0.939	0.775 ± 0.324	67.614 ± 3.264	2
$N-NH_3$(mg/L)	13.903 ± 1.503	2.885 ± 0.79125	79.249 ± 8.311	1
TSS (mg/L)	1662.000 ± 273.257	99.000 ± 27.310	94.043 ± 0.948	50
COD (mg/L)	2925.000 ± 300.223	453.750 ± 50.959	84.487 ± 2.823	250

Table 2: Mean results for analyzed physico-chemical parameters of homogenized Salon waste water samples collected for sixteen weeks.

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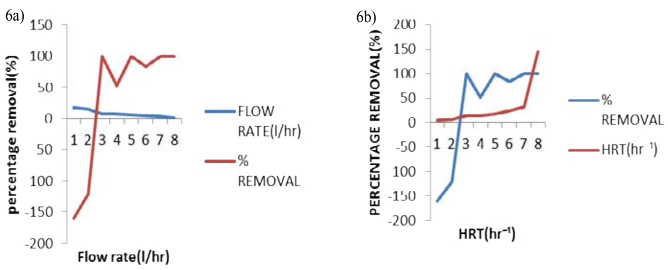

Figure 6: Relationship between copper removal, flow rate and HRT.

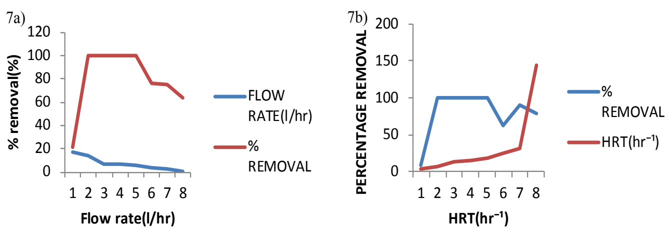

Figure 7a and 7b: Relationship between cadmium removal, flow rate and HRT.

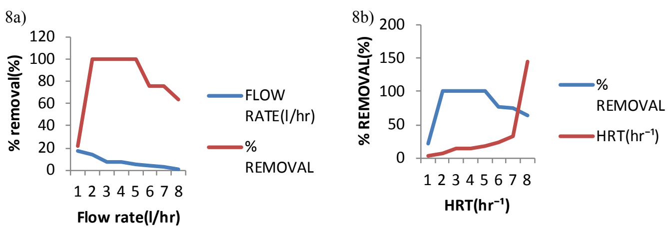

Figure 8a and 8b: Relationship between zinc removal, flow rate and HRT.

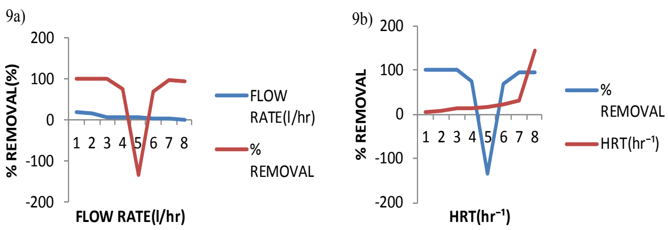

Figure 9a and 9b: Relationship between iron removal, flow rate and HRT.

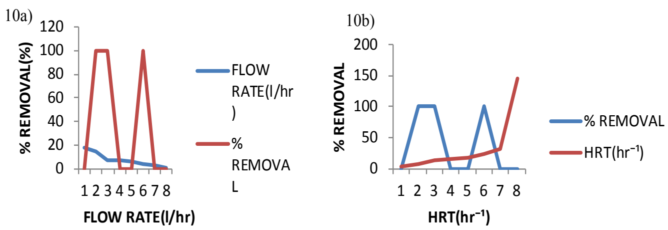

Figure 10a and 10b: Relationship between lead, flow rate and HRT.

however, did not conform to Ghana EPA permissible limit of 1.0 mg/L (Table 2). This could be attributed to the high levels of Nitrogen present in the wastewater. However, it recorded a percentage removal of 79.2%, which is appreciable. This high removal is attributed to the low effluent flow rates.

Biochemical oxygen demand (BOD), Dissolved oxygen (DO) and Chemical oxygen demand (COD)

BOD is the most important variable in water pollution control since it indicates the actual level of biodegradable pollutants in the water [12]. The level of BOD_5 in the effluent (22.9 mg/L) was within the acceptable limit (50 mg/L) of EPA Ghana. This suggests that it will cause no harm to aquatic life since the oxygen content is not high enough to cause anaerobic conditions. From the study of Egbon et al. [9], BOD of the effluent was 5.19 mg/L and removal was 74%. In contrast, several inconsistencies were recorded in the BOD removal over the sixteen weeks in this study. This could be attributed to the fact that the suspected increase in BOD is due to input from the activated charcoal since it is also organic. The inconsistency is also suspected to be due to the fact that the schmutzdecke may not be fully developed in the initial stages to remove the BOD. The non-conformity of dissolved oxygen (Table 2) could be due to lower levels of suspended and dissolved solids in the water. The degree and extent of DO increase depends on the BOD of the effluent in that, the lower the BOD, the higher the DO and vice versa. The overly high concentration of COD (Table 2) is possibly due to the high levels of dissolved and suspended solids which were not efficiently removed. The study however, recorded satisfactory average removal percentage of 84.5 over the sixteen weeks. Egbon et al. [9], recorded COD removal of 60.5% which was lesser compared

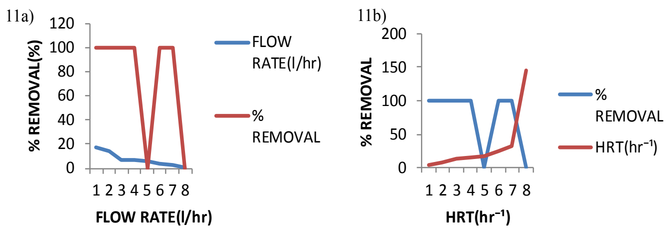

Figure 11a and 11b: Relationship between arsenic removal, flow rate and HRT.

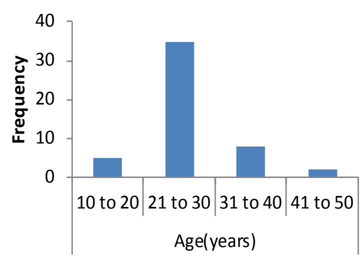

Figure 12: Graph of respondents' age.

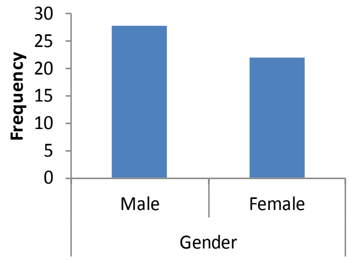

Figure 13: Graph of respondents' gender.

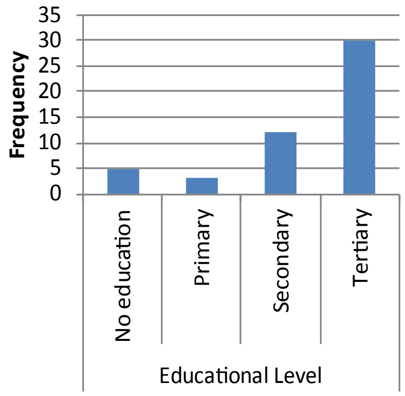

Figure 14: Graph of respondents' educational level.

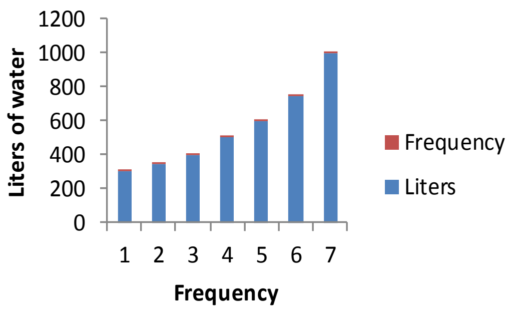

Figure 15: Graph of liters of water used by the salons.

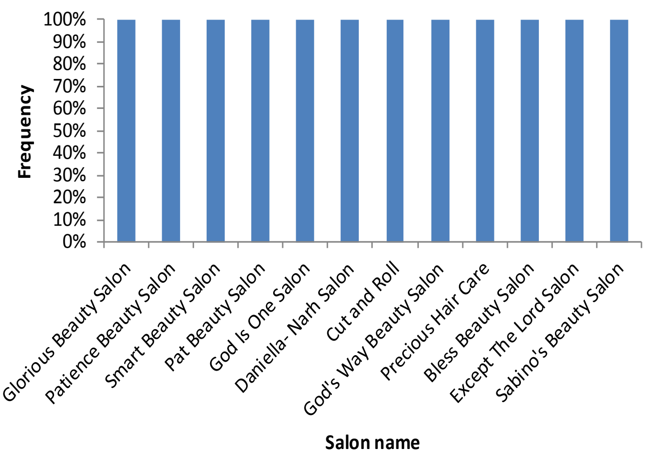

Figure 16: Graph of names of hairdressers salons.

to the percentage removal recorded by this study which employed slow sand filtration system and activated charcoal.

Heavy metals

The values recorded for the heavy metals were within acceptable limits of effluent discharge of the Ghana EPA. This could be attributed to the large porosity and surface area of the activated charcoal and fine sand which was able to remove the metals onto its surface. Even in trace amounts heavy metals pose threats to the human body if exposed to the body continuously. This implies that there may be no safe level of exposure to lead [13]. For instance, cadmium exposure even in lower amounts could cause detrimental health problems [14]. Beyond the recommended limits, zinc exposure could result in significant bioaccumulation with possible toxic effects for aquatic organisms. Lead exposure could be said to be a less significant issue when it comes to salon waste water. This may be because the chemical composition of products used at the five salons contained little or no Lead. However, heavy metals are very toxic components in the shampoos and other cosmetic products used at the salon even at low levels. The large surface area of the sand and the activated charcoal which was able to remove all the Arsenic in the waste water although the Arsenic composition may be insignificant in the hair products used in the salons. However, the continued use of products contaminated with Arsenic, may cause slow release into the human body and cause adverse effects [15].

Discussion of Results

Although majority of the respondents were aware of waste water reuse, the idea of practicing it is not accepted by most. One participant (tertiary student) made an input that the mother who owned a salon always supplied raw salon waste water to many households in Kumasi in the Ashanti Region of Ghana for flushing toilet and that the use of raw waste water was very common in Kumasi. This indicates that the concept of waste water reuse (even in the untreated form) was accepted and employed in Kumasi but not in Amamoma. The reason for the difference could be that the people of Amamoma are not enlightened on

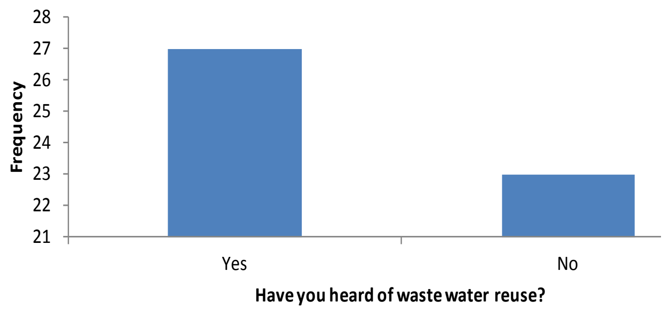

Figure 17: Graph of respondents' knowledge on waste water reuse.

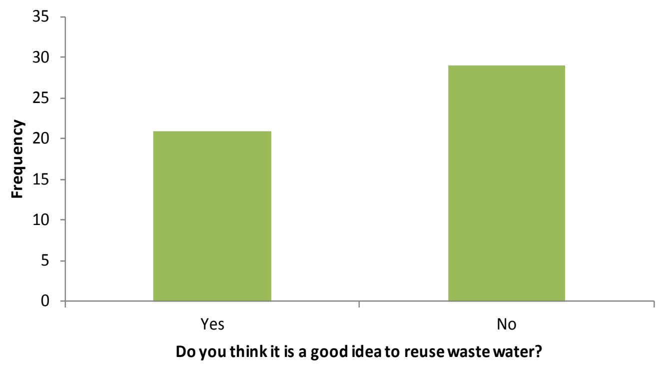

Figure 18: Graph of respondents' views on waste water reuse.

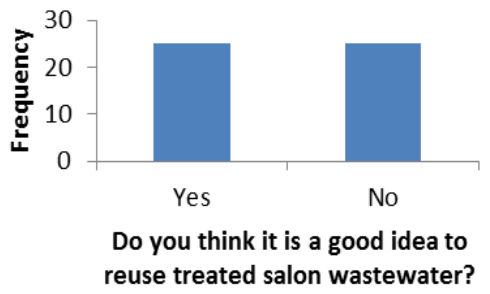

Figure 19: Graph of respondents' views on treated salon waste water reuse.

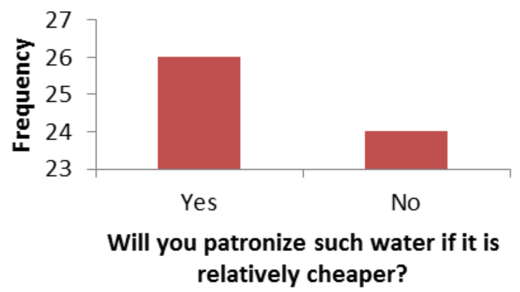

Figure 20: Graph showing willingness of respondents to buying cheap treated waste water.

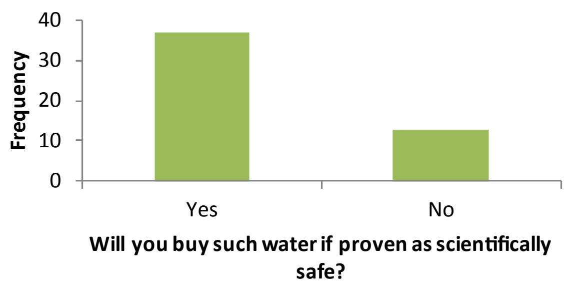

Figure 21: Graph showing respondents' patronization of treated waste water scientifically proven as safe.

water conservation for sustainability. Their belief (people using waste water generated by others for rituals) may also inform their decision.

That notwithstanding, they are very price-sensitive; cheap prices influenced their decision to patronize the treated waste water (although the difference between those who would patronize it due to cheap prices and those who would not patronize at all was 2%). If the people are educated on recycling of waste water, backed by scientific confirmation, they would readily employ it, but only for non-potable domestic use. The amount of water generated daily by the salons averagely, also show that treating the salon waste water for non- potable domestic use or even for washing hair a second time before finally treating it for discharge may be of significant value.

A similar work was done by Robinson and Hawkins (2005) [16], in USA to assess public perception on waste water reuse. The study revealed that the people were against the idea of reusing it for application involving close, personal contact (for instance, laundry) but had no problem using it for firefighting, car washing, lawn irrigation and agricultural uses. The young and highly educated had higher knowledge on waste water reuse than the older and uneducated. Close resemblance of this study to the present study in Amamoma shows that public education is imperative in employing the reuse of treated waste water.

Recommendations

In the reuse of the treated salon waste water, public health is a major consideration. As such, it is recommended that further research should be carried on the microbial parameters of the waste water before and after treatment to assess the risk involved in potential disease transmission. It is again recommended that pre-treatment of the waste water should be carried out in further studies, where all the particles in the waste water are allowed to settle for some time before introducing it into the slow sand filtration system. In addition, it is recommended that

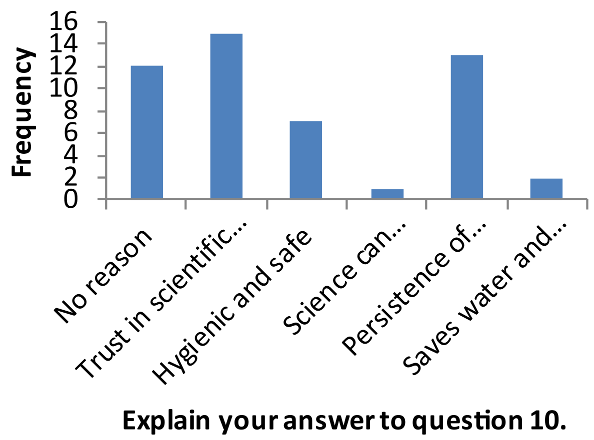

Figure 22: Graph showing respondents' explanation to response to previous question.

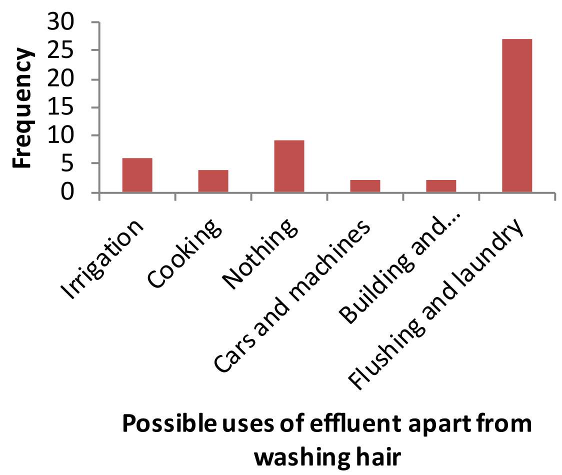

Figure 23: Graph on possible uses of effluents.

this treatment technology is used for the treatment of other waste water such as industrial and sewage. Furthermore, public education should be carried out to enlighten the public on the need to embrace reuse of treated waste water. Finally, utility of the treated water may be further enhanced and maximized with the addition of Chlorine and Alum.

Conclusions

In effect, the slow sand filtration system with the activated charcoal layer could be adopted as domestic waste water treatment technology especially in developing and low-income countries since the percentage removal for four of the treated heavy metals (Cadmium, Zinc, Iron and Arsenic) were around 60% and above except for Iron and Copper which were below 40%. It was established that the flow rate was inversely proportional to the hydraulic retention times and retention time directly proportional to percentage removal. Finally, it was established that it is possible to use the treated waste water for purposes such as non-potable domestic reuse like flushing toilets, cleaning and gardening, irrigation of agricultural areas (for crops that cannot be eaten unwashed), washing vehicles, industrial use for cooling, or discharge into nearby streams, lakes or other water bodies.

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