Biosand Filtration as a Green Approach to Septic Tank Effluent Management in a Tertiary Institution in Ghana

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Abstract

Sewage and household effluents at some institutions in Ghana have been discharged into the ocean for years. This degrades environmental media and is detrimental to ecological systems. The Three Local Plastic Barrel-Biosand Filter (TLPB-BSF) is an innovation on the slow sand filter that has been used to prevent discharge of raw sewage into the environment. The study aimed to test the performance of a modified BSF on sewage tank effluent and assess suitability of the filtrate for non-drinking purposes at a tertiary institution renamed KOTU to maintain confidentiality. **Method:** A filtration system made of three modified interconnected BSF was constructed on-site, with last filter connected to a storage tank. The modification was the provision of an additional media (charcoal) in the second barrel. Two sample collections were made from the system one week apart. The pre-filtrate samples were raw septic tank effluent (STE) and the samples obtained after running system was Biosand filter effluent (BSFE). Samples were analysed for physical and microbiological parameters at designated laboratories. Measured values of the parameters in pre-filtrate and filtrate samples were compared with EPA (Ghana) reference values. The removal efficiency of a parameter was computed as the difference between pre-filtrate and filtrate values expressed as a percentage of the pre-filtrate value. **Results:** Most of the effluent parameters from the BSF were within the EPA standards, while others were unacceptable. Removal efficiencies obtained for the parameters were: Ni trogen (83.3%), Phosphorus (89.5%), Total Suspended Solids (71.3%), Total Dissolved Solids (66.2%), Total coliform (99.9%), Faecal coliform (99.7%) and E. coli (97.6%). **Conclusion:** BSF is effective for upgrading physical and microbial quality of sewage at household and institutional level, prior to discharge in the environment. It produced a filtrate that met most of EPA standards for irrigation of non-edible crops.

Introduction

The timeframe for the Millennium Development Goals (MDG) elapsed without global achievement of the Goal 7 by 2015 (targets 2 and 4) (UNEP, 2015). This was partly attributed to inadequate wastewater management resulting in 80% of the world's wastewater being discharged untreated (UNESCO, 2012). The failure in attaining MDG 7 was recognized in the post-2015 development agenda and led to the creation of the Sustainable Development Goal (SDG) 6. This was accompanied by the realisation that the focus on drinking-water and sanitation without due attention being paid to the end products of water and sanitation provision (i.e. wastewater) may have contributed to failure to attain the goal. Wastewater includes industrial effluent, storm water and sewage which should be managed in systems that reduce or remove the impurities, discharging a relatively innocuous effluent into the environment.

Effluent discharged from septic tanks contain human pathogens such as bacteria, viruses and parasites. Additionally, large amounts of dissolved solids, nutrients (nitrogen, phosphorus), urea, heavy metals, and other particles have been found in the sewage (Gomes and Ebrary, 2009). The presence of excessive nutrients in water bodies, often referred to as eutrophication, promotes algal blooms and plant growth in streams, ponds, lakes, reservoirs and estuaries, and along shorelines (Tettey-Lowor, 2008; Venkatesh et al., 2015; Volterra, 2002). Eutrophication also creates environmental conditions that favour

the growth of toxin-producing cyanobacteria (Gomes and Ebrary, 2009) Recreational water users and individuals coming into contact with the infected water are at risk (Sanborn & Takaro, 2013). Pollutants can also seep down and affect groundwater deposits. They enter groundwater, rivers, and other water bodies. Some pathogens found in sewage such as *Salmonella spp,* and *Escherichia coli* are known to affect human health adversely by causing diarrhoeal diseases (Kahlown, et al., 2006). This results from the consumption of contaminated food and water. Contaminated water is a vehicle for several waterborne diseases, such as cholera, typhoid fever, shigellosis, salmonellosis, campylobacteriosis, giardiasis, cryptosporidiosis and Hepatitis A (WHO, 2006a). Chronic exposure to toxins produced by these organisms has been associated with gastroenteritis, liver damage, nervous system impairment, skin irritation and liver cancer in animals (WHO, 2006b).

To prevent pollution from the discharge of raw sewage into water bodies, the Biosand Filter developed by Dr. David Manz at the University of Calgary, Canada in the 1990s was modified to achieve the aim of the research (Mwabi et al., 2012). The BSF was an innovation on the slow sand water filter which had been used for community water treatment (CAWST, 2009). The filter can be assembled locally using materials that are always available. A BSF consists of a simple container with a lid and vertical layers of sand and gravel, which physically trap sediments, pathogens and other impurities from the water. The filter container can be made of concrete, plastic or any other water-proof, rust-proof and non-toxic material. The filter media consist of layers of sieved and washed sand and gravel (CAWST, 2009). The filter media allows the formation of a biofilm as a shallow layer just above it and contributes to the elimination of pathogens. There is a standing water height of 5 cm above the sand layer, which is maintained by adjusting the height of the outlet pipe (CAWST, 2009; Lantagne et al., 2006). The filtered water can be collected via a connected conduit to a container. The storage container should be placed on a block or stand, so that the container opens just under the outlet, minimising the risk for recontamination (CAWST, 2009).

It has been reported that out of the 44 wastewater treatment plants in Ghana, only 20% are working, most of them below design standard (IWMI, 2012). Consequently, sewage and household effluents are discharged into the ocean. The scale of damage to the environment from sewage overflow typically depends on the volume and duration of discharge, as well as the characteristics of the receiving environment (Rangwala, 2011). Currently one of the tertiary institutions in the country's capital empties sewage from its sewerage system directly into the ocean. Furthermore, the institution lacks adequate water for irrigation of non-edible crops grown in the premises. As a proposed strategy to recycle wastewater in the institution to meet this need, the authors undertook an experimental study to assess the performance of a BSF on sewage tank effluent at the institution. The objectives were to assess its capacity to remove physical and microbiological parameters (removal efficiency) and determine its suitability for non-drinking purposes.

Materials and methods

Study Area

The study was carried out in a tertiary institution that for the purpose of anonymity

will be referred to as KOTU. The premises is divided into two areas: the Area A and Area B. The research was undertaken at Area B. Area B consists of a block of flats namely Flats 1, 2, 3, 4, some bungalows and a Lodge. These various premises have sewerage systems linking the wastewater and excrement all to one septic tank, west of flat '4'. The study was conducted at the final storage site where all sewers from the various blocks of residence converge and empty into the septic tank. Area A has a student population of about thirteen thousand nine hundred, about five hundred staff, including lecturers, administrative and other staff. Area B accommodates a population of 300, including all flats, the bungalows and the Lodge.

Study design

The study adopted an experimental design in which a series of three interconnected Biosand filters (BSFs) were introduced in an institutional sewage system as an intervention. To assess the ability of the BSFs to improve effluent quality, three types of samples were assessed for physical and microbial parameters as prescribed by the Standard Methods for the Examination of Water and Wastewater (APHA/AWWA/WEF, 2012; APHA, 1998). The samples were (i) raw septic tank effluent (STE 1A and STE 1B) obtained directly from the institutional sewage system, (ii) filtrate (BSFE 1A and BSFE 1B) obtained from passing the effluent through the BSFs, and (iii) field blanks (Control 1A, Control 1B) obtained after passing the distilled water through the BSFs.

Construction of the Biosand Filter

The media (fine sand, course sand gravels and charcoal) were sieved and washed thoroughly with clean pipe borne water until clarity of drained filtrate from the media was obtained. The diffuser basin was prepared by punching several holes in a local plastic basin to simulate a sieve and control flow rate of influent to the Biosand filter system. Three plastic barrels were connected in series by plastic (polyvinyl chloride) pipes secured with stop-corks.

The filtration media were gently introduced into each barrel containing the following: a combination of gravel, course sand and fine sand called 'biosand' (barrel 1); a combination of biosand and charcoal called 'biocharsand' (barrel 2); and the storage tank (barrel 3) respectively. This formed a filter system which was then connected to the wastewater source using similar pipes and reducers. Clean pipe borne water was poured into the first barrel to help wash through the entire system. The stages in the construction are shown in Figure 1 and a cross section of a typical biosand filter can be found in the diagrams that follow (Figures 1 and 2).

To maintain the biosand filter, periodic maintenance was required. This was done by pouring clean, pipe borne water through the filter system to wash backlog and avoid clogging the media. The storage tank was washed thoroughly with pipe borne water and a chlorine solution and rinsed with pipe borne water thoroughly again between each sample collection. Laboratory analysis was conducted to ascertain the quality of water produced.

Assessment of physical parameters

To measure temperature, a thermometer was immersed in six samples (STE1A, STE1B; BSFE 1A, BSFE 1B; Control 1A and Control 1B) for two minutes respectively. The height of mercury was read from the meniscus and recorded. Prior to each immersion, the

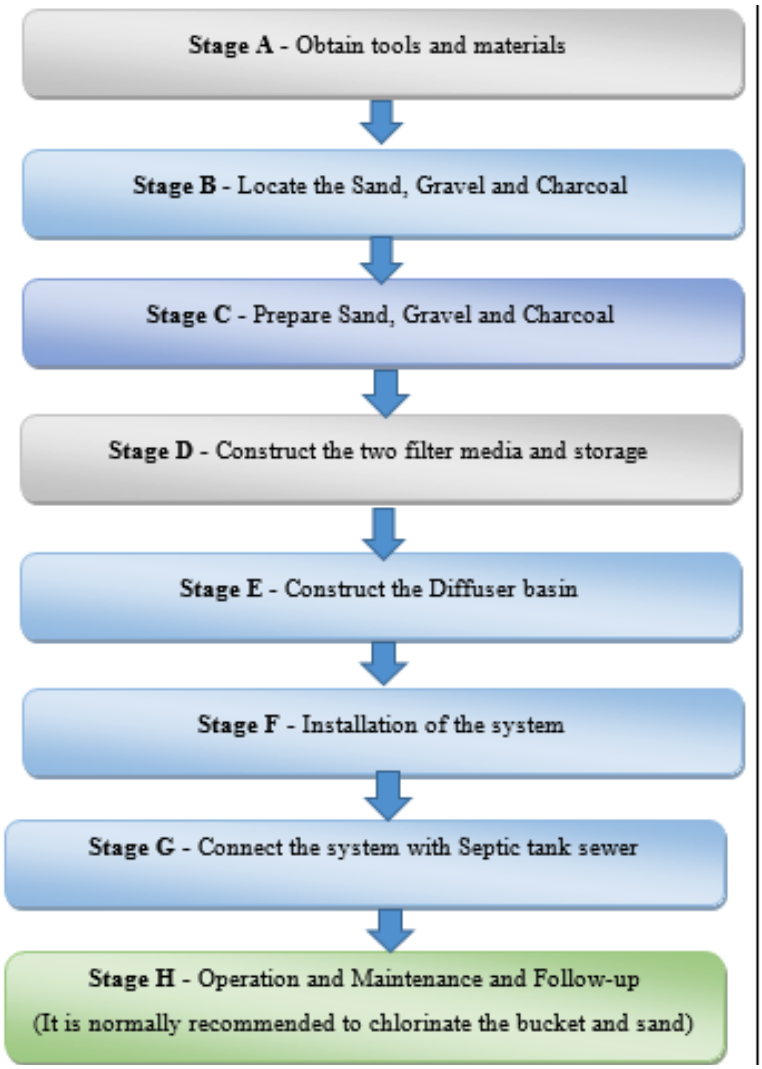


Figure 1. Steps in the construction of a Biosand Filter (Source: Field, 2017)

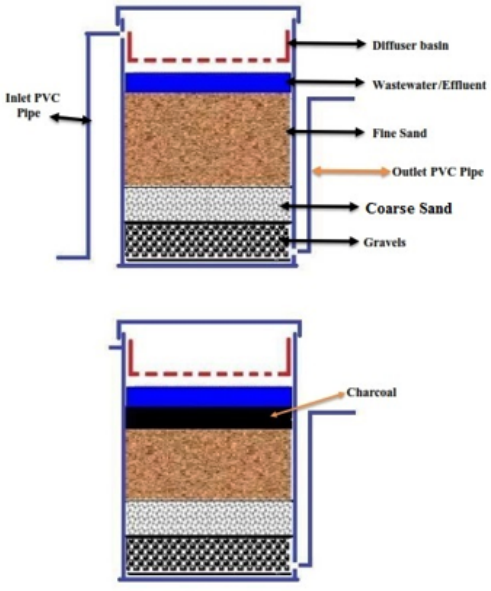


Figure 2. A cross section of a biosand filter (Source: Mensah, 2017)

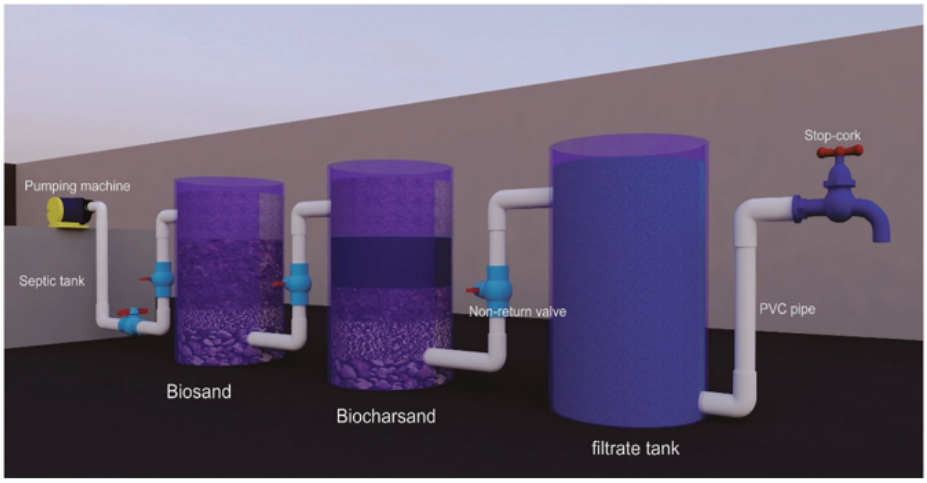


Figure 3. Graphic representation of the Biosand filtration system (Source: Mensah, 2017)

thermometer was rinsed with deionized water. The process of determining the temperature level was done twice for each sample. The temperature is an important determinant of bacteria action within the samples. Samples were ice-packed when transported to the laboratory for analysis within 24 hours, to avoid increases in the rate of chemical and biological reactions.

The bulk samples were collected in 500ml sterilized plastic bottles. They were transferred to narrow-necked BOD or incubation bottles of 280ml capacity. To determine dissolved oxygen, two milliliters (2 mls) of Manganese (II) sulphate ($MnSO_4$) solution or "Winkler (I)" was added using a pipette, discharging it below the surface. The bottle was inverted several times in order to distribute the precipitate uniformly. When the precipitate settled leaving the supernatant clear, it was agitated again. Similarly 2 mls of concentrated H_2SO_4 was added to dissolve the precipitate (which turned an intense yellow colour) and mixed until the precipitate dissolved. Using a measuring cylinder, 100ml of the acidified sample was measured into 500ml conical flask. Using starch as an indicator, it was titrated against 0.050M $Na_2S_2O_3.5H_2O$. The titration

$$\text{DO (mg/l)} = \frac{\text{Titre (average)}}{\text{Sample Volume}} \times 101.2 \quad \text{(APHA, 1998)}$$

was repeated for 2 other 100ml aliquots of both the filtered sewage and septic tank effluent sample and the results were tabulated. A colour change from blue to colourless gave the endpoint. The Dissolved Oxygen (DO) was computed using the expression below:

$$BOD_5\,(\text{mg/l}) = \frac{D1-D2}{P}$$

Biological oxygen demand followed a similar procedure. The difference in DO and a dilution factor was used to calculate BOD_5 as indicated below:

Where:

D1 = DO of effluent sample immediately after preparation, mg/l

D2 =DO of effluent sample after a 5-day incubation at 20°C, mg/l

P = Decimal volumetric fraction of sample used (APHA, 1998).

To determine phosphate, an aliquot of 100 mls of sample was decolorized by strong acid (H_2SO_4), diluted with 100 mls of distilled water, and 0.05 ml (one drop) of phenolphthalein indicator added. Next, 4 mls of Molybdate

Reagent I and 0.5 ml (10 drops) of Stannous Chloride reagent I (prepared from dissolving 2.5 g of fresh $SnCl_2.H_2O$ in 100 ml glycerol) were added, while thoroughly mixing after each addition. The absorbance was measured after 10 -12 minutes at a wavelength of 690 nm using a spectrophotometer-UV/VIS T 60 by PG Instruments. The spectrophotometer was standardized with a blank solution. The readings were recorded and the process repeated for the other effluent samples. Nitrate was determined by the hydrazine reduction method. Ten (10) ml each sample was introduced into a test tube with the aid of a pipette. Next, 1.0 ml containing 0.3M NaOH was added and mixed gently. A reducing mixture was prepared by adding 20 ml of Copper Sulphate ($CuSO_4$) working solution and 16 ml Hydrazine Sulphate to 20 ml of 0.3M NaOH. One milliliter of the mixture was added and mixed gently. The mixture was heated in a water bath at 60^{o}C for 10 minutes and cooled to room temperature. Thereafter, 1ml of colour developing reagent was added and shaken to mix. Absorbance was read at 520 nm and the readings recorded.

The pH of each 100 ml sample in a beaker was determined with a Wissenschaftlich-Technische Werkstatten (WTW) digital pH meter. The pH meter was calibrated with 4.0, 7.0 and 10.0 pH buffers. The pH of the raw sample was determined on site and that of the filtered sample immediately after filtration. Total Dissolved Solids (TDS) and conductivity was measured using the WPA CMD510 Conductivity meter. The electrode for measurement of TDS was rinsed with distilled water and blotted dry. The samples were swirled and the electrode placed in the sample, ensuring that the entire sensing edge was submerged. The TDS and Conductivity modes were selected. The values displayed on the screen were recorded in ppm for TDS and µS/m for the Conductivity. To estimate Total Suspended Solids (TSS), a filtration apparatus was assembled and the filter paper moistened with 10ml of deionized water. Sample bottles were vigorously shaken and 100ml of a sample was transferred using a funnel. The filter was washed with three successive 10ml volumes of distilled water for complete filtration. The filtrate was carefully removed from the holder, transferred onto a weighing dish and

$$\frac{A - B}{\text{Sample Volume (ml)}} \times 1000000 \text{ (a constant factor)}$$

was dried at 105^{o}C for one hour. The cycle was repeated until weight loss of less than 1.0g was obtained. The analytical procedure was repeated using 500ml of control standard. TSS was computed with the equation (APHA, 1998):

Where

A = weight of residue + dish in grams

B = weight of dish in grams

Assessment of microbiological parameters

Estimation of total coliforms (TC) was done using the Most Probable Number (MPN) test, which applies serial dilutions method in multiple test tubes for the dilution and analyses. The ten dilution with three test tubes was pipetted at initial stages and inoculated dilutions were done at the latter stage. Each sample was apportioned three test tubes each. Serial dilution of 10^{-1}to10^{-12} were prepared by filling 12 test tubes with 9 ml of brilliant green bile broth labelled 10^{-1} to 10^{-12} to start processing for total coliforms. A 1 ml aliquot of effluent samples were pipetted to the first test tube labelled 10^{-1}. The dilution in the first test tube was mixed thoroughly by turning the content upside down and up repeatedly. Next,

1 ml from the first test tube was transferred to the second test tube labelled 10^{-2} with aid of a fresh pipette. The second dilution was treated in like manner to the first and 1ml transferred to the third test tube labelled 10^{-3}. The process was repeated for all samples. To assess for *Escherichia coli (E. coli)*, a similar process was repeated on another dilution set. This time, the medium filled in the test tubes was lactose broth, with inverted Durham tubes. The dilutions were incubated at 48oC for 24 hours. Test tubes showing high fermentation, colour change and gas formation after 24 hours gave an indication of probable positive bacteria coliforms. These were counted with reference to the MPN table for multiple tubes. Next, the dilutions containing the lactose broth were transferred to the *E. coli* (E-C) medium and incubated for 24 hours under 48^{o}C. A 1ml aliquot of each dilution from the lactose broth was transferred to three test tubes each containing Tryptone water and left for 24 hours. Thereafter, two drops of Kovac's reagent were added and the formation of a pink ring at the surface in tubes confirmed the presence of *E. coli*. Faecal coliforms were assessed following the same procedure for the total coliforms. The clear signs of fermentation, gas formation in inverted Durham tubes and colour change were indicative of faecal coliforms (FC). The dilutions in test tube that showed positive or negative reactions were counted with reference to the MPN table for multiple tubes method.

Quality control measures

The samples were carefully handled to avoid any external influences that could interfere with the integrity of the sample and hence contaminate it. Triplicate determination of the samples were made and the data were presented as means. Sample collection and analysis were performed twice, one week apart to assess consistency of results. Glassware were properly cleaned, and reagents were of analytical grades. Deionized water was used for dilutions throughout the study. For the spectrophotometric analysis, reagent blank determinations were used to correct instrument readings. For validation of the analytical procedure, repeated analysis of the samples against internationally certified/ standard references (SRM-1570) of National Institute of Standard and Technology, USA were used. With the exception of temperature, multi-probe meters were calibrated together using the same standard and procedures. Electrical conductivity was calibrated against 0.005M, 0.05M and 0.5M standard potassium chloride solution and pH was calibrated with standard buffer at pH of 4 and 9.2. The dissolved oxygen (DO) was calibrated against zero solution of sodium sulphate. Temperature was checked against a standard mercury thermometer for consistency. Appropriate labelling of samples was done with relevant information: location, date and time of sample collection, identification number, and tests required. Water proof markers were used to avoid misclassification of samples due to wearing off of labels from handling.

Statistical Analyses

Measurements of physico-chemical and microbiological parameters in the samples were generated using Microsoft Excel, 2013. The percentage removal efficiency of the Biosand filter was determined by deducting the BSFE value from the STE value for each

$$\text{Step 1: STE1-BSFE1} = D1$$

$$\text{Step 2: } \frac{D1}{STE1} \times 100$$

parameter using the formula indicated below: The removal efficiency was a proxy indicator for performance of the BSF in the study. The data were imported into Stata version 14.1. Significant differences between samples (STE and BSFE) were determined for each parameter using the t-test. Statistical significance was assumed at 95% confidence interval when the p-value < 0.05.

Results

The Biosand filter was constructed within 12 working days including Saturdays and Sundays. The construction included assembling the materials, washing the various media and testing the feasibility of the filter to filter. Effluent from the septic tank, Biosand filter and control samples (field blanks) showed lower concentrations. Figures 4 (samples in week 1) and 5 (samples in week 2) show the physical change in state of the sewage after it has undergone filtration.

Figure 4: Effluent Samples fetched from STE, BSFE and Control in Week 1

Figure 5: Effluent Samples fetched from STE, BSFE and Control in Week 2

presented typical variations in contaminant concentrations with time. High contaminant concentrations were obtained for the sewage samples, whereas the filtrate from the BSF

Figure 6: Assessment for Total Coliforms in brilliant green broth

The multiple test tube in decade dilution (Figure 6) used to determine total coliforms showed foaming (seen in STE samples on the right) which is an indication of the possible presence of coliforms (Refer to Tables 2 and 4 for the MPN counts).

Figure 7: Showing results of Faecal Coliforms in test tubes with Lactose broth

Figure 7 below show the reaction of the faecal coliforms to the lactose broth after 24 hours at 48^{o}C.The colour change from amber to pale amber as displayed, is indicative of faecal coliforms (Refer to Tables 2 and 4 for the

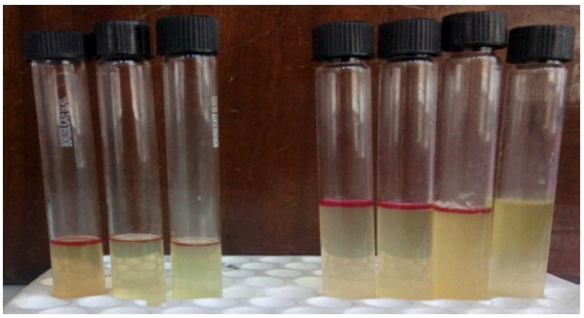


Figure 8: Showing the laboratory analysis for E. coli in STE (right) and BSFE (left)

TABLE 1
Laboratory analyses values for physico-chemical parameters, before and after filtration

SAMPLES	STE 1	STE 2	MEAN STE	BSFE 1	BSFE 2	MEAN BSFE	D1 = STE-BSFE	% R.E. = D1/STE × 100	P. VALUE (T-TEST)
Temperature (ºC)	28.2	27.8	28	26.4	26.2	26.3	1.7	6.1	0.0169
pH	8.5	8.9	8.7	7.7	7.7	7.7	1	11.5	0.0377
TSS (mg/100ml)	250	258	254	70	76	73	181	71.3	0.0008
TDS (ppm)	443	447	445	143	158	150.5	294.5	66.2	0.0007
Conductivity(µS/cm)	887	894	890.5	683	574	628.5	262	29.4	0.0408
Colour (TCU)	85	87	86	11	14	12.5	73.5	85.5	0.0006
*DO (mg/l)	0	2	1	2.23	5	3.615	-2.615	-261.5	0.2655
*BOD (mg/l)	0	179	89.5	0.18	12	6.09	83.41	93.2	0.4506
Nitrogen (mg/l)	142.8	167	154.9	22.8	29	25.9	129	83.3	0.0092
Phosphorus(mg/l)	62.44	63.81	63.125	6.38	6.84	6.61	56.515	89.5	0.0002

TSS = total suspended solids, TDS = total dissolved solids, DO = Dissolved oxygen, BOD^5 = Biological oxygen demand, %R.E. = Percentage Removal Efficiency
** The DO and BOD in STE 1 were recorded zero (0) because, there was delay in laboratory set-up which lasted a whole day before analyses.*

TABLE 2
Laboratory analyses values for physico-chemical parameters, before and after filtration

SAMPLES	STE 1	STE 2	MEAN STE	BSFE 1	BSFE 2	MEAN BSFE	D1 = STE-BSFE	% R.E. = D1/STE × 100	P. VALUE (T-TEST)
Total Coliform (MPN/100ml)	920000	920000	920000	900	1700	1300	918700	99.9	0.0000
Faecal Coliform (MPN/100ml)	350000	300000	325000	600	1200	900	324100	99.7	0.0059
E-Coli (MPN/100ml)	1400	1100	1250	20	39	29.5	1220.5	97.6	0.0148

MPN = most probable number

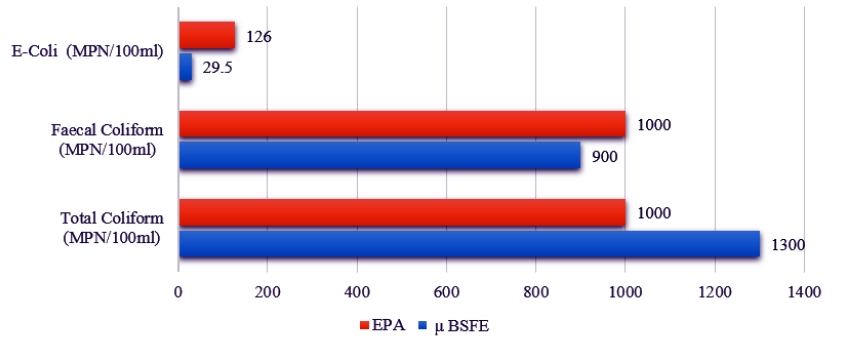
MPN counts).

After sample incubation in Tryptone water for 24 hours, followed by addition of a drop of Kovac's reagent, E.coli was indicated by the presence of a pink ring formed on the surface of the dilution in the test tube (Figure 8).

Percentage removal efficiency of the Biosand Filter

The percentage removal efficiency of the BSF indicates the proportion of material in the septic tank effluent (as measured by the parameters) that is removed after passing septic tank effluent through the biosand filter. It is expressed as a percentage. The counts

The bar chart below shows the comparison of BSFE with EPA/WHO standard for water for non-edible crop for coliform conformity



and removal efficiencies of the physical parameters (Tables 1) and microbiological parameters (Tables 2) are presented below. The tables are based on measurements of samples tested in the first (pre-filtrate STE1, filtrate BSFE 1) and second weeks of data collection (pre-filtrate STE2, filtrate BSFE 2). It shows the measurements, the mean value of the samples and their test statistic at 95% confidence level. Heavy organic pollution in septic tank effluent resulted in an undetectable concentration of dissolved oxygen (Table 1). Removal efficiencies were highest for phosphorus (89.5%), colour (87.1%), nitrogen (83.3%), TSS (71.3%) and TDS (66.2%).

Removal efficiency was high for all microbiological parameters (Table 2). When the filtrate values were compared to EPA guideline values, Faecal coliforms (FC) and E.coli were below guideline values, while Total coliforms (TC) exceeded guideline values, though none of the values was significantly different (TC = 0.5903, FC = 0.7952 and E. coli = 0.0625) (Figure 9).

Comparison of the filtrate and EPA Guidelines

Tables 3 compares the mean filtrate sample values with EPA guideline values for physico-chemical and microbiological parameters. Temperature, pH and TSS in the filtrate exceeded guideline values. The mean filtrate values were significantly different from EPA guideline values for total dissolved solids (TDS), conductivity, colour, dissolved oxygen and nitrogen.

TABLE 3

Mean Physico-chemical values for BSFE samples compared with EPA (USA/ Ghana) and WHO standards for wastewater for non-edible crop irrigation

SAMPLES	μ BSFE	EPA	D2 = μBSFE-EPA	Pr(|T| > |t|) (P-Value)
Temperature (ºC)	26.3	25	1.3	0.0489
pH	7.7	7.5	0.2	.
TSS (mg/100ml)	73	50	23	0.0826
TDS (ppm)	150.5	1000	-849.5	0.0056
Conductivity (μS/cm)	628.5	1500	-871.5	0.0398
Colour (TCU)	12.5	200	-187.5	0.0051
DO (mg/l)	3.615	50	-46.385	0.0190
BOD (mg/l)	6.09	50	-43.91	0.0852
Nitrogen (mg/l)	25.9	75	-49.1	0.0401
Phosphorus (mg/l)	6.61	7	-0.39	0.3392

Discussion

The performance of the Biosand filter in reducing pollutants in raw sewage effluent was assessed using physico-chemical and microbiological parameters. Physico-chemical parameters were: pH, total suspended solids (TSS), total dissolved solid (TDS), Nutrient (consisting nitrogen and phosphorus), Biochemical Oxygen Demand (BOD). Microbiological parameters were: Total coliforms, Faecal coliforms and *Escherichia coli.* Overall, BSF was efficient in removal of nutrients, microbiological parameters, as well as total dissolved solids and colour. Below we discuss the implications of our findings.

Physical Parameters

One of the most significant impacts of pH in water is the effect that it has on substance solubility and thus bioavailability (WHO,

2006a). For instance, a reduction of coliforms in final effluent was reported in an earlier study when pH exceeded 10.7, Hodgson and Larmee (1998). However, pH values above the recommended guidelines result in alkalinity. Alkalinity in waste waters is often due to the presence of bicarbonates and hydroxides of calcium, magnesium, sodium and potassium. These cause hardness of water and affects chemical treatment of the water. The pH of filtered effluent in the present study was within the recommended range of 6 to 9, and indicates that pH of the effluent should not have adverse effects on non-edible crops.

Suspended solids occur naturally in septic tanks. The effluents often have a high level of suspended solids composed mostly of algal cells, grey water solids and human excrement. Its highly organic content contributes significantly to the oxygen demand (Rao and Kumar, 2007). The breakdown of organic matter in the sewage stream, erosion and the transport of material from the bottom of the septic tank contribute significant quantities. Effluents from KOTU and the municipal contribute to a long-term continuous input of suspended solids to the urban circle. Although removal efficiency of TSS by BSF was high (71.3% average for the two weeks), BSFE values exceeded the EPA guideline value of 50 mg/L, similar to a previous study conducted in Ghana (Agyemang, et al., 2013). Accumulation of sludge is a major contributing factor to changes in TSS. Suspended solids can cause a number of direct and indirect environmental effects, including reduced sunlight penetration, restricting of spawning grounds and physical harm to fish (Volterra, et al., 2002). As reductions in TSS values were observed after the effluent biosand filtration, the quality of effluent is improved and can be recycled for non-edible purposes or prior to discharge to water bodies (Steinmann, et al., 2003).

Total dissolved solids have dimensions smaller than 10-6mm and occur as molecules and ions in solution (Rao and Kumar, 2007). A high concentration of dissolved solids increases the density of dissolving water, reduces the solubility of oxygen gas thereby affecting survival of aquatic life (Kahlown, et al., 2006). High TDS also reduces water clarity, hinders photosynthesis, and leads to increased water temperatures (Volterra, et al., 2002). In the present study, total dissolved solid concentrations were significantly reduced by the BSF. Additionally, BSF effluent concentrations were below the Ghana EPA effluent guideline of 1000mg/L. This suggests that effluent from the BSF is less likely to pose similar threats to aquatic life if released into the environment. The septic chamber in KOTU acts mostly as a primary treatment chamber, with accumulation of sludge containing bacteria. Bacterial decomposition of organic matter in the chamber would place a high demand on oxygen. This may have accounted for the zero levels obtained in STE in the first week. The BSF effluent concentrations for BOD did not meet the required EPA standard of 50 mg/L, therefore prior to application in non-edible crops irrigation, it should be aerated by exposing the BSFE to air.

Specific nutrients, such as nitrogen and phosphorus, are necessary for plant production in various ecosystems. Nonetheless, an oversupply of nutrients can lead to the growth of large algal blooms and extensive weed beds resulting in eutrophication (Akpor, 2011). Furthermore, the addition of nutrients in water

bodies leads to excessive enrichment, and can result in deoxygenation of the receiving water (Palanaippan, et al., 2010). Therefore, the discharge of raw sewage rich in nutrients into water bodies has a negative impact on the marine ecosystem (Volterra, et al., 2002). Reduction of nitrogen in effluent for non-edible crops irrigation is essential to reduce ammonia toxicity, reduce the oxygen demand in receiving water bodies, prevent acidification of ground water aquifers from nitrification in the soil and reduce the potential for surface water eutrophication (Gomes and Ebrary, 2009). In the septic tank, high concentrations of nitrogen are significantly affected by increased sludge deposition. It was evident that there were high levels of nitrogen in the septic tank effluent, however a large reduction was achieved after passage through the BSF (83.3% average for two weeks). Biosand filter effluent nitrogen concentrations were less than a third of the EPA standard of 75 mg/L, an indication that Biosand filtered effluent presents a less significant risk of polluting the receiving non-edible crops, soil, underground water and other environmental hazards.

Phosphorus is an essential macronutrient that is a limiting factor to plant growth. It triggers eutrophic conditions which include the prolific growth of algae and other aquatic plants. Algal growths can have detrimental impacts on aquatic life and at high concentrations, can be lethal (Mishra, et al., 2010). Phosphorus was high in septic tank effluent samples but concentrations were significantly reduced after passage through the Biosand filters. The percentage reduction of phosphorus from STE to BSFE was 89.5% (the average for the two weeks), with values below the reference level of EPA (7 mg/L) in each case. This supports the effectiveness of BSF in producing effluent safe for non-edible crop irrigation.

Microbiological Parameters

As reported elsewhere, BSF demonstrated a high removal efficiency (97.6 % to 99.9%) of coliform bacteria (Kikkawa, 2008). Although high septic tank effluent counts for coliforms were recorded for faecal and total coliforms and E.coli, reductions in filtrate values were evident. Phenomena that contribute to the reduction in microbes are solar radiation, high concentrations of dissolved O_2, presence of predators and retention time of BSF (Mwabi et al., 2012; Wendt, et al., 2015). The BSF effluent counts were within WHO recommended guideline of 1000 MPN/100ml of effluent for irrigation for non-edible crops in the first week, but the guideline values were exceeded in the second week. Possible retention and growth of coliforms from previous filtration efforts may be a potential explanation. This might indicate that the maintenance of the filter is critical to its function. Washing of the filter media periodically may be required.

Conclusion and Recommendations

The quantities in the septic tank effluent were higher than recommended levels across the parameters, while they were lower in the biosand filter effluent. Filtering with the BSF showed optimum percentage removal of total suspended solids, total dissolved solids, faecal coliform, total coliform, E. coli and to some extent phosphate and nitrogen levels. The change in pH and colour recorded an impressive improvement as the turbid sewage became much clearer after passage through the BSF system. Assessment for conformity with WHO and EPA standards in Ghana indicate that the majority of parameters in the filtrate

effluent were either lower than or within range of the guidelines. Based on the results, it is recommended that in the absence of a central sewage treatment facility, BSF can be used to upgrade physical and microbial quality of sewage effluent at household and institutional level, prior to discharge in the environment. It offers potential benefits of recycling waste water for irrigation of non-edible crops as a green approach and can be applied in settings with contextual similarity. Periodic laboratory analysis is required to ascertain that water quality conforms to standards and BSF effluent would require aeration to improve oxygen content before release into aquatic environment. Maintenance of the filter system by periodic washing of the filter media should be undertaken by competent staff. As the present study did not examine the effect of the charcoal on septic tank effluent treatment, the removal efficiencies of pharmaceuticals and heavy metals, this should be the subject of future research.

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