Sustainable Filter Media for Physiochemical Treatment of Greywater in Single Village House

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***Abstract*—Diverse contaminations occurred such as water pollution. The developing nations experienced increase water pollution problems in these recent times. The discharge of untreated greywater in an uncontrolled manner to the main rivers is a key issue which pollutes the surroundings and causes unpleasant odours. Commonly, in village areas they discharge from the houses into the drains without any treatment. It represents water that can potentially be intercepted at the household level for reuse. The purpose of this study is to establish a sustainable greywater treatment system in village house. The treatment system is aimed to provide simple and less maintenance for village household. Therefore, greywater was collected at the outlet pipe from the kitchen and bathroom using buckets with grabbing method at individual house Parit Hj. Rais. The treatment system consisting of sand, gravel and limestone in layer one; clamshell and ceramic in layer two and sand in layer three. The effluent was evaluated every week by using HRT 1 to HRT 4 day in 30 day treatment process. Besides, analyses of samples were collected from the outlet tank. The efficiency of greywater treatment achieves high percentage removal of BOD 98.04%, COD 97%, SS 99.24% and pH 6.60. The quality greywater parameters were accepted compared to previous study and standard of effluent discharge. Therefore, contaminant will be resolved by this treatment to avoid infectious diseases and pollution flowing into the drains. By increasing public awareness and upgrading the laws necessary to control the discharge of greywater in order to protect river systems from further degradation, exploitation and contamination is recommended.**

Keywords—Greywater; Drains; Pollution; Treatment

I. INTRODUCTION

On a global scale, the decreasing availability of conventional water sources has increased the demand for high quality freshwater. This forces everybody independently to think the alternative and sustainable solutions to manage this valuable resource [1]. In India, about 25 billion liters of untreated wastewater discharged into the water bodies every day. The untreated wastewater will lead the environment as stake and well being/health of the people at risk by increase infectious disease [2]. Past several years, the rapid development and industrialization in Malaysia affected the water resources in rural community [3]. However, these development and industrialization decrease quality of water in many rivers producing major water contamination contributing to the water problem in Malaysia. Water Quality Report (2012) stated that out of 473 rivers monitored, 161 (34%) were found to be slightly polluted and 34 (7%) polluted [4]. They are becoming serious and need to solve before it becomes the critical pollutant issue in Malaysia.

However, the sources of water problem keep rising, and among of them are called greywater. In the reality, the greywater discharge is a varied significantly with time of day and day of the week and affluence of the household. The major source of greywater is the laundry and it generates about 25% of a household daily water use [5]. The laundry outlet is the one of the greywater pollutant that affected the soil in a ditch. The laundry water containing high salt and phosphorus concentrations can lead to salt accumulations in the soil and stunting of plants with low phosphorus tolerance [6]. Furthermore, greywater is also a wastewater derived from the kitchen, bathroom (i.e., discharge from the hand basin, shower, and bath) and laundry water. However, greywater does not include wastewater that is discharge from the toilet use but hence considered as black water [7]. Besides, greywater is generated in different quantities between households within one community and depend on different factor such as lifestyle and household activities [8, 9].

Besides, the sources of greywater represent the largest potential source of water saving in domestic residences,

accounting for as much as 50-80% of the total water uses [10]. Greywater was sourced from laundries, hand basins, bathrooms and kitchen. In Seward, it is illegal to use kitchen greywater for irrigation as it contains a high pollutant load of oil and grease and organic content [11]. The characteristic of greywater varies greatly upon factors such as the quality of the source water and the activities of household occupants [12]. There are three factors significantly that affect greywater compositions. There is water supply quality, the system that treated greywater and activities in the house. The greywater may contain disease causing organisms from nappies and soiled clothing. Furthermore, chemicals from soaps, shampoos, dyes, mouthwash, toothpaste, detergents, bleaches and disinfectants may be moderately saline and have a high pH when discharge in to drains [13]. Yet, many communities in Malaysia mainly the villagers discharged the greywater directly into the nearest ditch.

From previous studies, the simple greywater management treatment system allows direct utilization of the water. It can use natural gravity by a hybrid treatment process with the use of natural filter materials. The natural materials were used as filter beds in filtration unit such as fine particles (equal size) sand bed, course size bricks bedded, charcoal bed, wooden saw dust bed and bed of coconut shell cover. It will facilitate the breakdown of organic compounds and recovery of nutrients [14]. Based on the aforementioned criteria, low cost on-site treatment option is septic tank followed by an intermittent sand filter, septic tank followed by wetlands and UASB-hybrid reactor [15]; Therefore, use of filter of the combination of sand, gravel, limestone, clam shell and ceramic designed in layer was proposed for the simple greywater treatment system. Preferably greywater should be treated anaerobically because of lower treatment costs and the possibility of recovering energy [9].

Conceptually, greywater should have a much lower concentration of various potential pollutants than the wastewater. Therefore, through this study, a lab scale project was conducted in individual village in Parit Hj. Rais, Parit Raja, Batu Pahat, Johor, Malaysia with the objectives to quantify wastewater production in village households, characterize important water quality parameters, and design simple treatment systems. It is hypothesized that the results show a high degree of variability of greywater production and its quality from individual households. A simple design treatment system is expected to protect public health and environmental pollution prior final discharge to the nearest river.

II. METHODOLOGY

A. Greywater Sampling and Filtration System

Greywater was collected at the outlet pipe from the kitchen and bathroom using buckets with grabbing method at individual house Parit Hj. Rais at peak period of morning and evening. Figure 1 shows the design of filter media. Three plastic tanks were used as inlet, treatment system and outlet tank accordingly at different height to have gravitational flow for household greywater treatment system in this study. At inlet tank, stocking filter is used to remove large particles like hair, to prevent clogging. This can be as simple as waterproof box and a stocking attached with the tap. Secondly, three layers were created in waterproof box as a tank according to the filter design. The design of greywater filter in first layer comprises mixed of sand, gravel and limestone as filter media to remove large particles, clarify the water and stabilization of pH. The second layer comprise mixed of clamshell and ceramic. With this combination, the pollution can be reduced and reuse it beneficially for gardening. The last layer was fine particles of sand used for microbiological treatment. Then it goes down to outlet tank finally.

The application of clam shell and ceramic will give sufficient microorganism for degrading organic pollutant in the greywater. Microbes in the clamshell and ceramic break down organic matter in the water. The basic structure was a waterproof box filled with coarse sand laid below a mixed (sand, gravel and limestone) bed. The design of greywater percolation was done vertically through the media. The treated greywater can be reused for gardening as an optional function. The treated water was compared with untreated water to get their efficiency of the treatment.

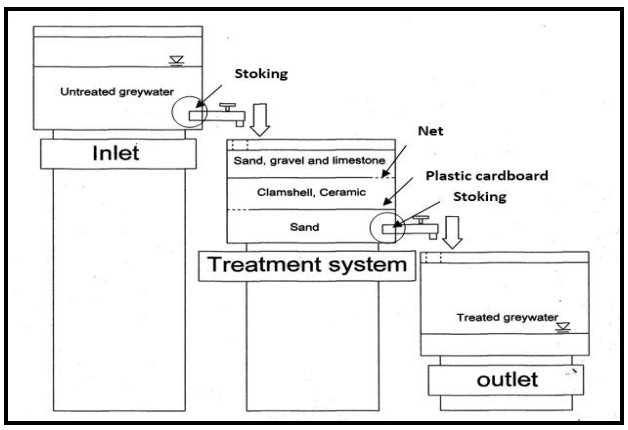

Fig. 1: Greywater filtration Treatment system

The tank volume has been calculated about 24557.5 cm^3 in order to calculate the tank soil mass for each material. By calculation, the materials were filled in the tank according to their weight from a layer created respectively. The tank materials mass for each layer in the tank can be seen in Table 1.

TABLE 1: SUMMARY SOIL FILLING MATERIAL FOR TREATMENT SYSTEM TANK

Materials	**Tank Soil Mass (kg)**
Layer 1	

Sand	13.02
Layer 2	
Clamshell	2.46
Ceramic	7.16
Layer 3	
Sand	4.34
Gravel	4.09
Limestone	3.82

By the volume of tank 0.0025 m³, the hydraulic retention time (HRT) and flow rate (Q) has been calculated. The HRT result were 1st day, 2nd day, 3rd day and 4th day respectively while the flow rate Q was 17.36 ml/min for HRT 1st day, 8.68 ml/min for HRT 2nd day, 5.90 ml/min for HRT 3rd day and 4.69 ml/min for HRT 4th day respectively. The inlet greywater has been controlled using the flow rate from each HRT and be retained for 1 day, 2 day, 3 day and 4 day to get the pattern of removal of greywater. The samples taken on site after treatment were tested in the laboratory for analysis.

Therefore, sample container, preparation and preservation was done according to the Standard Method for Examination of Water and Wastewater (2005). Untreated greywater was collected and analyses for the following parameters: pH by pH meter (HACH, HQ440d); biological oxygen demand (BOD_5) by five-day incubation test; chemical oxygen demand (COD) by using COD reflux method (method 8000); suspended solids (SS) by the photometric method (method 430); turbidity by the attenuated radiation method (method 3750); phosphorous by the ascorbic acid method (method 3025); oil and grease by the partition gravimetric method (method 5520B).

III. RESULT AND DISCUSSION

A. Household Activity

From the survey and interview session, information about the house occupants at the study site on household activities was recorded. There were 5 people at the study site consisting of 2 adults, 2 house wifes and 1 child. The people in the house usually take bath 2 or 3 times a day. Because of the weather in Malaysia with temperature around 24º and 39º compare to other temperate countries caused people to bath more than 1 time per day. The analysis also showed that the occupants regularly cook two times in a day morning, afternoon and night. They wash (laundry) everyday in the morning.

B. Water Consumption Survey

Based on survey data, they were five family members among them a child. Figure 2 shows the total percentages of greywater consumption for the household. The activities of the occupants include cooking, cleaning, laundry and shower which generate 50-140 liters daily. There are three main sources of greywater which involves bathroom, kitchen and laundry. Based on the pie chart, bathing activity contributes the highest percentage of greywater producing 41 % of total greywater from the household. The increase percentage is because the occupants bath 2 or 3 times daily. Furthermore, the bathroom and laundry greywater release together from the same pipe. Otherwise, laundry greywater contributes about 28% of the greywater volume. The occupants in the house do their laundry work every day in the morning. The quantity of kitchen greywater contributes about 31% of total greywater volumes because they use the kitchen 2 times to cook for their family.

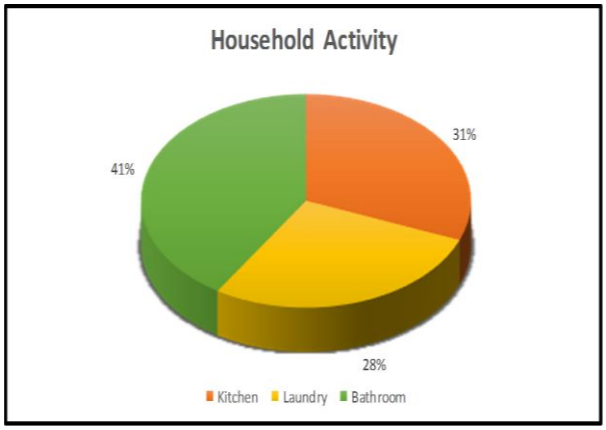

Fig. 2: Percentage of Greywater Consumption from Household

C. Characteristics of Filter media

According to table 2, XRF analysis, three highest concentration percentage in clamshell were contains of calcium oxide (CaO), silicon dioxide (SiO_2) and ferric oxide (Fe_2O_3) about 90.40%, 3.41% and 2.34% respectively. Ceramic contains silicon oxide (SiO_2), aluminium oxide (Al_2O_3), and potassium dioxide (K_2O) with 65.40%, 21.90%, and 3.31% respectively. In addition, limestone has similar concentration percentage with clamshell which contains calcium oxide (CaO) about 96.40% and silicon dioxide (SiO_2) about 1.29%. It also has magnesium oxide (MgO) contain about 1.60%. Furthermore, gravel also has similar concentration percentage with limestone with calcium oxide (CaO), magnesium oxide (MgO) and silicon dioxide (SiO_2) about 97.10%, 1.03% and 0.90% respectively. In other hand, sand generally use the for filter system contains silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and titanium dioxide (TiO_2) about 95.60%, 3.28% and 0.34% respectively.

TABLE 2: RANGE OF COMPOSITION ELEMENTS OF XRF DATA FOR EACH MATERIAL

SS (mg/L)	263.89 ± 7.78	14.67±0.58	13.67±0.58	9.67±0.58	2.00±0.58

Avg±StDev= Average and Standard deviation

Filter media	Concentration (%)
Clam shell	CaO – 90.40%, SiO_2 – 3.41%, Fe_2O_3 – 2.34%
Ceramic	SiO_2 – 65.40%, Al_2O_3 –1.90%, K_2O – 3.31%
Limestone	CaO – 96.40%, MgO – 1.60%, SiO_2 – 1.29%
Gravel	CaO – 97.10%, MgO – 1.03%, SiO_2 – 0.90%
Sand	SiO_2 – 95.60%, Al_2O_3 – 3.28%, TiO_2 – 0.34%

Summary data of the quality of untreated and treated greywater is shown in Table 3. The pH, BOD, COD and SS results of untreated greywater showed a good compatibility with all data reported in literature [16, 17]. Concerning turbidity, COD, and BOD values some of them were lower than the maximum referenced in literature. It should be underlined that households where high organic fraction and soaps were used led to higher SS, COD, and BOD values. As all of these parameters characterize pollution, the efficiency of any treatment would much depend on frequency of bath, cooking style and dishwashing products used rather than on the family composition.

The analysis of greywater treatment system shows that the pH concentrations were improved from acidic to neutral. pH concentration in untreated greywater was generally acidic (5.28) mostly contributed from organics compound in foods such as fruits, pickles and sauces. The pH of the treated greywater gradually increased from 5.28 to 6.9 with increasing duration of time possibly due to decomposition of organic materials into the materials of treatment system. As the greywater flows through the treatment system, particles were absorbed by the materials in the filter media and removed from the flow. Treated greywater also has shown better quality during the period of treatment by the reduction of BOD, COD and SS concentrations.

TABLE 3: OVERALL RESULT PARAMETER FROM GREYWATER TREATMENT SYSTEM

Parameters	Avg ± StDev of untreated greywater	Treated Greywater (Avg±StDev)			
		HRT 1 Day	*HRT 2 Day*	*HRT 3 Day*	*HRT 4 Day*
pH	5.28 ±0.07	8.24±0.01	8.24±0.02	7.84±0.01	6.60±0.21
BOD (mg/L)	108.07± 8.69	19.30±3.03	13.70±4.13	3.31±0.64	2.06±0.05
COD (mg/L)	262.56 ± 22.05	147.67±0.58	56.67±0.58	48.67±0.58	8.67±0.58

D. Physiochemical Pollutant Removal

Figure 3 shows the BOD concentration for untreated and treated greywater. The application of sand, gravel and clamshell was considered to give sufficient microorganism for degrading organic pollutant in the greywater because of the XRF result shows the high calcium oxide content about more than 90% concentration. Therefore, these fluctuations in BOD value indicate the variation in organic matter which is coming in the water through kitchen. Low COD removal indicated that greywater contain slowly-biodegradable organics, which will affect BOD values also [18]. The concentration of BOD for untreated greywater was 108.07 mg/L. After filtered with filter media, the BOD concentration was decreased gradually to 19.69 mg/L, 15.50 mg/L, 3.95 mg/L and 2.11 mg/L on the HRT 1, HRT 2, HRT 3 and HRT 4 day of treatment. The percentages of removals were 81.78%, 85.66%, 96.35% and 98.04% respectively. It was proved from the previous study conducted by [17] using sand and gravel respectively as a filter about 85.68% removal was attained by sedimentation, [19] pretreatment with sand and gravel then with peat based filter also removed BOD about 81.13% and conducted by [20] using a clamshell as a filter 89.3% removal of BOD concentration was achieve.

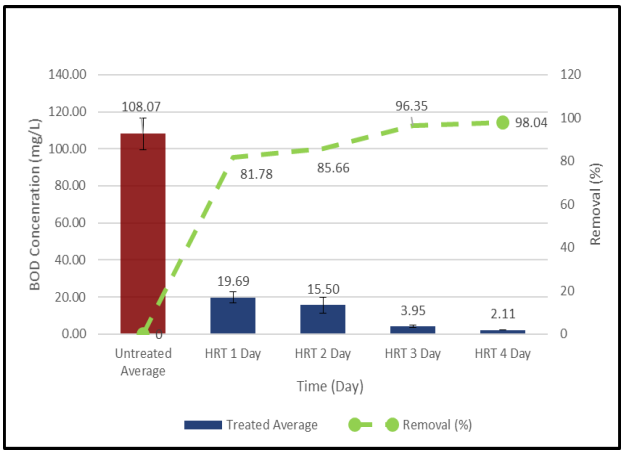

Fig. 3: Removal efficiency of BOD

From Figure 4 below, removal efficiency of COD for untreated and treated greywater is shown. The concentration of COD for untreated greywater was 262.56 mg/L. According to [15] COD was generally higher than BOD measured in a given sample by the amount of refractory organics in the sample. The COD was remove through the time detained and to be absorbed by the natural adsorbents used in filtration. This can be attributed to the facts that greywater pollutants were slowly biodegradable [14, 21]. Based on the XRF data, because gravel and clamshell have high calcium oxide content more than 90% concentration it makes micro-organism attach

to them. After filtered through the media, COD concentration decreased gradually to 147.67 mg/L, 56.67 mg/L, 48.67 mg/L and 8.67 mg/L on the HRT 1, HRT 2, HRT 3 and HRT 4 day of treatment. The percentages of removal were 44%, 78%, 81% and 97% respectively.

However, according to studies from [22 00] Liu, et al., (2010) using clamshell as a filter, about 85.1% of percentage removal was attained. Another study conducted by [14] using fine sand as a filter, 90.8% removal was achieved and also conducted by [23] using gravel as a filter, 65% removal of COD concentrations was achieved. It shows that the ability of filter media to remove COD. In terms of the parameters for HRT 4 day, the untreated greywater filtered with treatment system was the best among others because it gave lowest COD value.

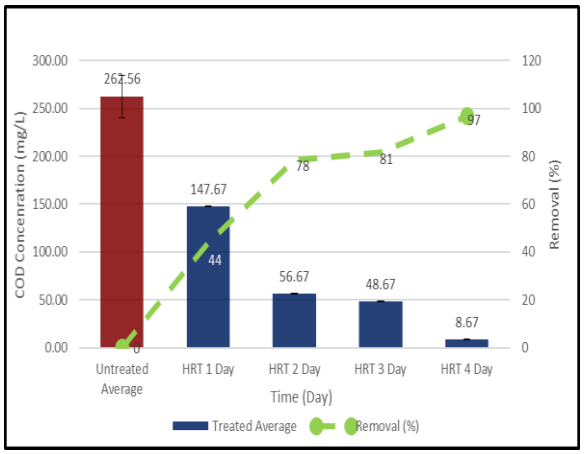

Fig. 4: Removal efficiency of COD

Figure 5 shows the graph of suspended solid (SS) against time for untreated and treated greywater. The concentration of SS before treatment was 263.89 mg/L. After treatment process, SS decreased dramatically by following HRT from 14.67 mg/L to 2.00 mg/L. The removal efficiency percentage was from 94.00% to 99.04%. The larger treating volume available in these beds, the steady hydraulic characteristics of the substrate and the variety in pores' sizes resulted in creating a substantial filtering media able to remove large amounts of solids [24]. However, according to studies from [23, 14, 24] using clamshell, fine sand and gravel respectively as a filter about 89.9%, 89.9% and 84% removal.

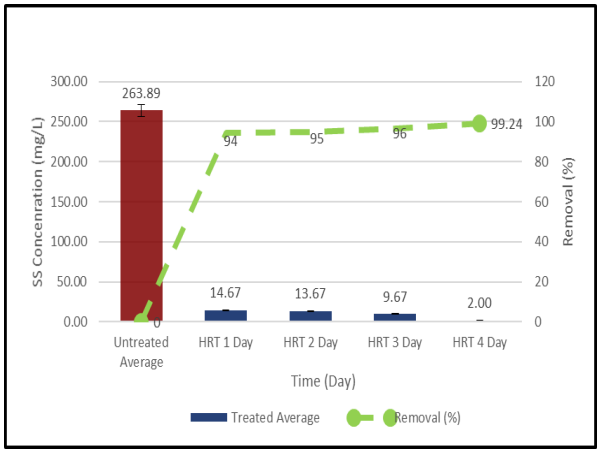

Fig. 5: Removal efficiency of SS

IV. CONCLUSION

Installation of simple greywater treatment system is one of the potential alternatives and can be added to the treatment of greywater system because it is low cost, requires no skill personnel and easy maintenance. From the result gathered, the efficiency of the treatment system was excellent. The performance within proved by the result the highest value of percentage removal for pH was neutral about 6.60, BOD 98.04%, COD 97.00% and suspended solid 99.24%. The overall result of the parameters was 95.09% removal and proved this treatment system was very efficient to treat greywater and more effective if making product and installation of the treatment system created properly at the factory than by hand within low-skilled worker. Therefore, the treatment system can be used in village house without problem arising during the treatment process. Therefore, it suggests to deepen the study more about the materials and treat greywater by using combined material or with different sizes and also do more study about the suitable sizes of the treatment system so that can be placed at anyway around the houses without problems.

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