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Using a Peat Media for Laundry Greywater Filtration: Geochemical and Water Quality Check

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Abstract: Worldwide depletion and pollution of natural water resources have made the recycling of used water a necessity. The level of awareness and sense of urgency to reuse household greywater is relatively high in developed countries with potential water shortage problems, compared to developing nations like Malaysia which enjoys year-round rain and mild droughts. One of the obstacles to the recycling of greywater is the cost for filter installation to treat the discharge prior to reuse. If an effective yet affordable filter is available, the reuse rate would probably increase. The present study introduces peat as a filter media and synthetic greywater prepared from a powder and liquid detergent respectively. The study was conceived with the double-aim of (1) treating the mildly contaminated laundry greywater for non-potable water usage and (2) enhancing stiffness of the peat soil for possible reuse as a sound geo-material. It was postulated that greywater chemistry would alter the geochemical properties of the originally weak, soft peat to form a stronger and stiffer matrix for load-bearing, while the porous peat media would help entrap and cleanse the greywater for safer reuse. The experiments were conducted in an in-house designed reactor, with measurements taken at intervals of 1, 3, 7, 14 and 28 days. The water quality parameters examined for the greywater pre and post-treatment through the peat filter include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), Turbidity and pH. The geochemical properties of the peat filter monitored using XRF analysis and 1-dimensional compressibility test. Overall, the results indicate that time plays an important role in the effectiveness of the filtration process, where an aged filter cleanse the greywater better than a newly installed one. The peat soil showed improved compressibility post-treatment, though the effect was considered slight and insufficient to cater for load-bearing purposes.

Key words: Greywater · Laundry · Peat · Filter · Geotechnical · Chemical

INTRODUCTION

Water is the most important natural resource for the sustenance of human life, animals and plants. Nearly three-fourths of the earth is covered by sea and 75% of a human body consists of water. The main function of water in a human body is as a regulator of temperature, i.e. the temperature would remain at 36.9°C despite the changes in surrounding temperature [1]. In addition, water helps remove toxic substances from the human body via the excretion processes. Water is also needed to improve blood circulation, help the digestive system function and reduce friction between human joints.

The major natural water resources are the seas, rivers, lakes, ponds and rain water. In Malaysia, 97% of the raw water supply comes from the rivers, with the remaining 3% extracted from sub-ground acquifers [2]. River is a source of water supply for domestic and agriculture activities as well as a source of protein. At the same time, river functions as means of transport and communication,

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especially in rural areas. With such important roles to play, needless to say rivers should be protected and preserved and one such measures is to recycle used water with low levels of contamination like greywater.

River pollution in Malaysia is an increasingly worrying environmental problem. There are two main sources of river pollution, i.e. point sources of pollution and non-point sources of pollution. Point sources include discharge outlets for sewage, underground mines, oil wells, agricultural plots and industrial plants, at specific locations through pipelines or sewers into the surface water. Unlike point sources which are traceable to a single site of discharge, non-point sources are difficult to trace and control, such as traffic pollution and propagation of pollutants in groundwater into bodies of water [3].

Greywater is one of the major point sources of pollution which is discharged from residential and commercial areas into rivers without any treatment. Considering the lightly contaminated nature of greywater, an incentive to encourage its reuse would be a simple and economical treatment system. The reuse of greywater for toilet flushing has been reported to reduce water usage by 30% [4]. Other applications include irrigation, wetland preservation and fire protection [5-7]. The treatment system could be physical filtration, chemical or biological processes, but cost remains the main selection factor.

The present study examines the possibilities of using a natural peat media abundant in the local area for filtration of domestic laundry greywater, with potential reuse in non-potable applications. The post-filter peat was tested for changed compressibility too.

MATERIALS AND METHODS

Materials

Greywater: Greywater is defined as the wastewater from bathrooms, rainwater pipes, hand washing basins, laundry processing units and kitchen sinks, excluding toilet waste (which is categorized as ‘black water’ or wastewater). Greywater derives from homes in residential areas, schools, office buildings and human dwellings. The characteristics of greywater produced by any household varies according to the dynamics of the household, the number and age distribution of occupants, their lifestyle characteristics and water usage patterns. Greywater is generally less polluted than domestic or industrial wastewater, but it may still contain high levels of pathogenic microorganisms, suspended solid and substance such as oil, fat, soap, detergents and other household chemicals.

It was reported that the amount of water used for (and hence greywater generated) washing basins, bathrooms and laundry sources accounts for 32% of the total water usage in a single domestic household [8]. Referring to the same authors, exterior water consumption for watering of lawns and gardens accounts for 54% of the total use. Judging from this, if greywater from a single household is retrieved and put back into circulation for exterior usage, over 50% of water savings can be achieved!

Peat: Peat is also known as swamps, bogs, moors, muskegs, mires and fens and it generally refers to natural materials with high compressibility and very deformable low strength type of soil with high organic contents [9]. It is partially or totally decomposed of dead hygrophytes, which have accumulated under water for tens to thousands of year. Peat commonly occurs as extremely soft, wet, unconsolidated deposits found at surfaces which are integral parts of a larger wetland system. Usually peat has a dark brown to black colour, depending on the stage of decay it is in; a spongy consistency without exhibiting distinct plasticity and a texture ranging from fibrous to amorphous. Peat is commonly characterized by physical properties like decomposition degree, water retention properties, specific gravity and bulk density [10]. The chemical properties of peat are greatly affected by the chemical composition of the peat components, the environment where it is deposited and the extent of its decomposition [11].

Peat is usually acidic with low values of pH ranging from 3.0-4.5. The acidic condition is attributed to the humic acids formed in the peat resulting in increased acidity of the pore water. However it has been observed that the acidity of peat decreases with depth. The organic carbon of peat increases with depth of the peat deposit profile, with values ranging from 30-40%.

The peat used in the present study was collected as bulk samples from a local site. The relevant properties are summarized in Table 1.

Methods: The reactor for housing the simulated greywater filter system was developed in-house (Fig. 1). The reactor’s diameter is 15 cm and the total height is approximately 28 cm. ‘hw’ indicates the greywater level in the reactor, while ‘hs’ represents the peat media height. The peat layer was supported at the bottom by a fine-mesh mosquito netting overlying a wire mesh. Suitable intervals were marked on the see-through external wall of the reactor to enable easier measurements to be

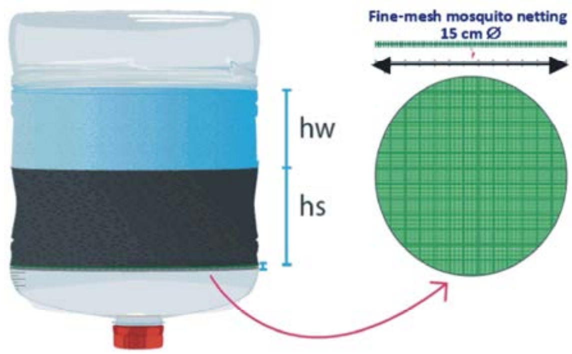

Fig. 1: Greywater reactor with peat filter.

Table 1: Summary physical and chemical properties of peat.

Parameters	Results
Natural moisture content (%)	371
Specific gravity (G_s)	1.25
pH	2.94
Organic content (%)	49.72
Particle size distribution (% wt.) xx	60% medium sand + 20% fine sand
Ash content (% wt.)	50.3
Liquid limit (%)	83

taken. A removable cap at the reactor's outlet allows controlled outflow of the filtered greywater for flow rate monitoring, prolonged water retention as well as water sample collection. Note that 3 reactors were set up so that triplicate samples could be obtained for analysis.

The greywater was prepared using either a powder or liquid laundry detergent of the same manufacturer. The concentration used was as recommended by the manufacturer for normal laundry washing load in a household. The greywater was derived by washing a single soiled garment (with human sweat) in each solution. Water quality check was performed at intervals of 1, 3, 7, 14 and 28 days, while the peat media was extracted for tests and analysis only upon completion of the 28-day test cycle. This was mainly to allow a longer contact and reaction time for the peat properties to evolve.

The water quality tests included Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), Turbidity and pH measurements. The tests conducted for the peat were mainly conducted in accordance with procedures described in BS 1377 [12]. The main geotechnical test conducted was the oedometer test, at 12.5, 25, 50, 100, 200 and 400 kPa load increments. The physico-chemical tests included XRF, XRD and SEM analysis. As for the laundry greywater, the measurements were performed based on recommendations APHA Standard Method for Examination Water and Wastewater [13]. The water quality parameters were checked against maximum levels stipulated in [14], for maximum effluent parameter limit of Standard B.

RESULTS AND DISCUSSIONS

Greywater Quality: Fig. 2 shows the percentage removal of BOD with time. Regardless of the detergent type used, the greywater's BOD was significantly reduced within a day of filtration. It is interesting to note that the greywater made with liquid detergent seemed to have immediately acted upon the biological elements in the water even prior to filtration. Both the post-filter samples show BOD removal to the level required for a Standard B effluent [14].

The COD removal rate is depicted in Fig. 3. It can be observed that the powder detergent sample had a higher COD level at the start, but an abrupt drop upon 1 day of treatment was significant. The COD level remained relatively stable over the following 2 weeks, but rose again after that. The liquid detergent sample, on the other hand, seems to demonstrate more uniform filtration effectiveness over the 28 days. Neither of the samples reached the Standard B effluent limit though [14]. The fact that both samples reached the same COD level at day 28 suggests a possible threshold in the filtration effectiveness of the peat media at the particular thickness or volume in the reactor. This makes a worthy point for further exploration, i.e. the volume ratio of peat to the greywater for COD removal.

Both samples showed remarkable decrease in pH, falling below the lower range of pH permissible for Standard B effluent, i.e. range of 5.5-9 (Fig. 4). This could be attributed to the inherent acidity of the peat (Table 1), which somehow was transferred to the greywater during filtration. The slightly higher pH of the powder detergent greywater corroborates with the trends of BOD and COD (Fig. 2 and Fig. 3), suggesting the powder form to be more potent than the liquid one, where the chemical contents for cleansing are alkaline in nature.

Looking at Fig. 5 and Fig. 6, the change in TSS and Turbidity with time corresponded with one another. The spike on day 1 is suspected to be caused by the first flush of loose organic debris dislodged from the weakly bonded peat filter. As the peat filter was placed with only slight compaction in the reactor, the layer has retained its original fragmented structure, with bits and pieces of organic matter essentially 'floating' in the pore water. As such, the initial high void ratio, combined with the loose solid formation, made the filter susceptible to material loss in the flow of the greywater. Nonetheless the

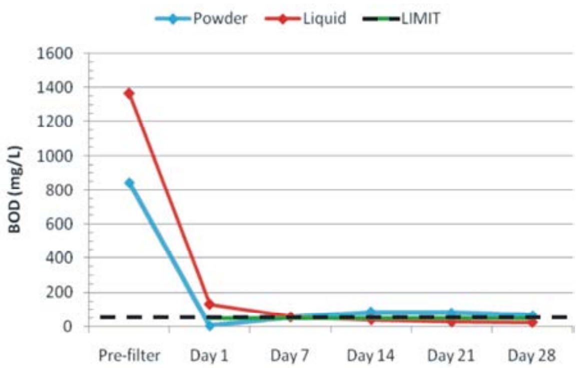

Fig. 2: BOD vs. time plot.

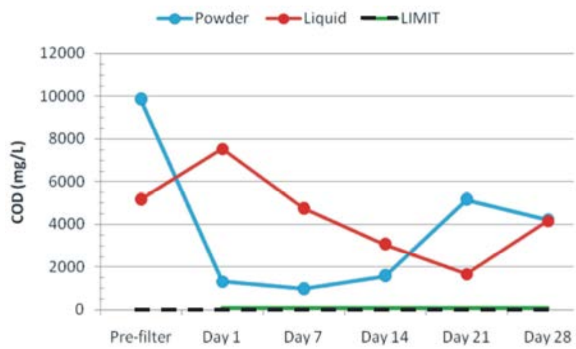

Fig. 3: COD vs. time plot.

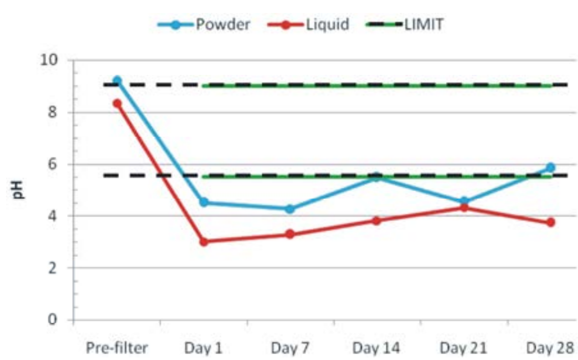

Fig. 4: pH vs. time plot.

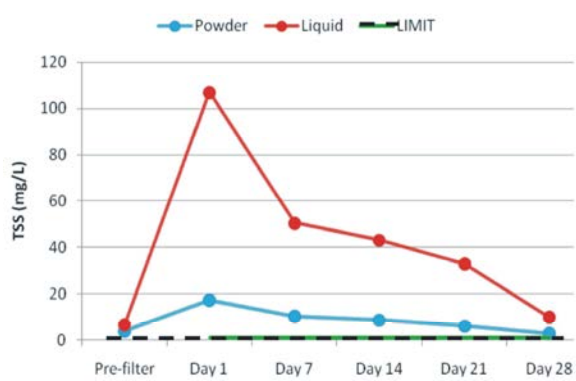

Fig. 5: TSS (Total Suspended Solids) vs. time plot.

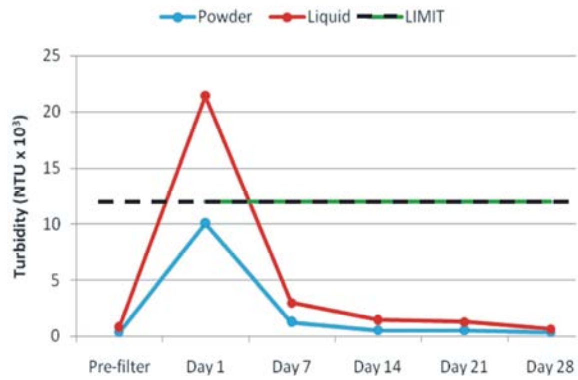

Fig. 6: Turbidity vs. time plot.

Table 2: Chemical composition of peat.

Elements / Compounds (%)	Pre-filtration (%)	Post-filtration (%)
Ferum	42.4	17.5
Silica	24.8	33.7
Aluminium	9.4	10.8
Calsium	6.2	18.4
Sulphides	5.4	5.8
Zinc	4.6	6.6
Potassium	4.2	2.9
Chlorides	0.9	1.3
Phosphorus	0.7	0.4
Magnesium	0.6	0.4
Titanium	0.4	1.4
Bromine	0.2	0.6
Manganese	0.1	-
Carbonate	0.1	0.2

murkiness improved with time, where both TSS and Turbidity reached the limits of Standard B effluent [14] by day 28 and day 7 respectively. This is suggestive of some pre-treatment necessary for the peat media prior to being put in the reactor.

Properties of Peat Media: The chemical changes of the peat media, pre- and post-filtration were analyzed using the XRF method (Table 2). Most of the chemical elements and compounds remained largely unchanged, apart from Fe, SiO_2 and Ca. Fe reduced by about 60%, pointing to a possible leaching of the element during filtration, resulting in the consequential increase of Fe in the filtered greywater. On the other hand, SiO_2 was found to increase by approximately 35% while Ca rose by an astounding 200%, suggesting effective entrapment of the elements with the peat media.

The microstructure of the peat sample is shown in the SEM micrograph in Fig. 7. Note the large pores where organic fragments of various sizes were seemingly strewn in a random fashion. This inherent porous fabric of the

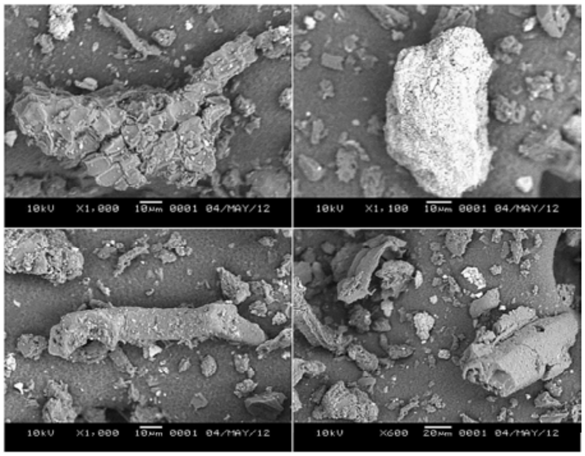

Fig. 7: SEM images of the peat sample.

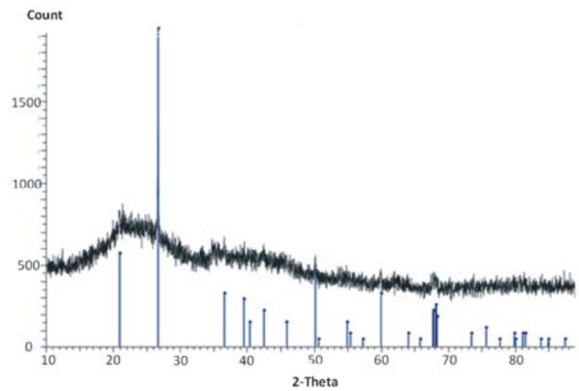

Fig. 8: XRD analysis of the peat sample.

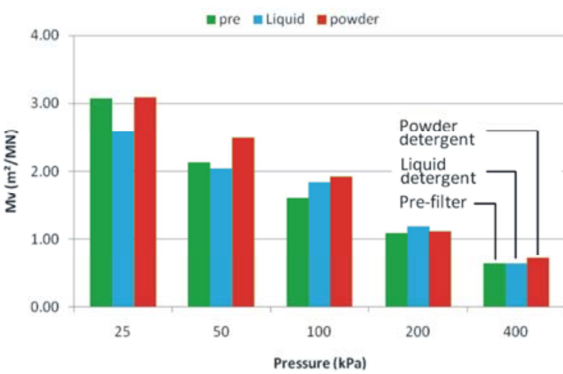

Fig. 9: Coefficient of volume compressibility (mv) evolution with pressure.

peat could bring opposing effects to the filtration process: (1) enhanced permeability and (2) passing of finer particles in the greywater. Moreover, large pores are usually associated with high shrinkage, indicating possible volume change of the peat media over time.

The XRD analysis in Fig. 8 supports the porous and saturated nature of the peat observed earlier, as highlighted by the relatively flat trend of the plot. There were most probably very little crystalline materials in the sample, as commonly reported of such highly organic soils.

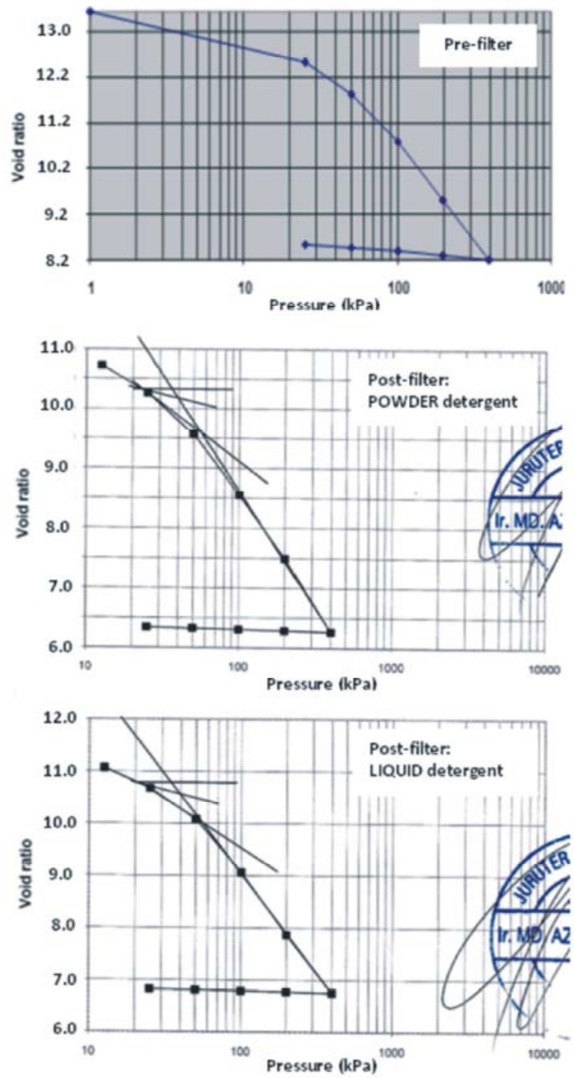

Fig. 10: Compression curves of pre- and post-filtered samples.

Oedometer Test Results: Fig. 9 shows the change of coefficient of volume compressibility (m_v) with the pressure applied. Overall m_v decreased with increased pressure, regardless of pre- or post-filtration, or the type of detergent used. Indeed, the post-filtration sample with powder type detergent showed very similar m_v trend to the pre-filter one. This suggests negligible change to the micro-fabric in terms of cementation or bonding of the particles within. The post-filtration peat sample with greywater of powder detergent origin demonstrated greater compressibility post-filtration, i.e. higher m_v values. Referring to earlier discussions on the possible higher chemical reactivity potential of the powder type detergent, the chemical compounds apparently did not contribute to stiffening of the peat structure.

The void ratio - pressure relationship for the peat samples are presented graphically in Fig. 10. A quick indicator of the compressibility in the normal compression zone (i.e. post-yield) is the compression index (C_c), taken as the gradient of the normal compression line of the plot. The C_c values for the peat sample, pre-filtration, post-filtration with liquid and powder detergent are 4.292, 3.834 and 3.791 MN/m^2 respectively. Clearly the passing of greywater did increase the stiffness of the peat soil, albeit slightly. However, the improved compressibility did not seem to be affected by the detergent type. The total settlement of the individual samples validated this observation, where the sample height reduction for the post-filtration samples was very similar, i.e. 75-76%.

CONCLUSIONS

For the greywater, it was found that the BOD removal rate was good for both types of greywater. The COD removal rate was not as effective, but the results suggested a relationship between mass or volume of the peat media and the greywater loading. pH-wise, the peat appeared to be detrimental to the filtration process by turning the greywater acidic. Some form of pre-treatment may be necessary to avoid this. The TSS and Turbidity results strongly pointed to the need to pre-treat the peat to avoid excessive initial spike in murkiness of the filtered greywater.

For the peat media, the XRF data showed possibilities of effective entrapment of SiO_2 and Ca, but leaching of Fe to the filtered greywater. The SEM images verified a highly porous material, which could improve flowability but allow passing of suspended solids in the greywater. Besides, the compressibility of the peat media is slightly improved by reactions with the passing greywater, irrespective of the detergent type used. A longer retention period is recommended to examine the effective bonding effect by the peat-greywater interaction.

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