The Use of Natural Filter Media Added with Peat Soil for Household Greywater Treatment

Radin Maya Saphira Radin Mohamed (Author)
Department of Water and Environmental Engineering,
Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
maya@uthm.edu.my

Chee-Ming Chan (Co-Author)
Department of Water and Environmental Engineering,
Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
chan@uthm.edu.my

Anwaruddin Ahmed Wurochekke (Co-Author)
Department of Water and Environmental Engineering,
Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
yadembo02@yahoo.com

Amir Hashim bin Mohd. Kassim (Co-Author)
Department of Water and Environmental Engineering,
Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
amir@uthm.edu.my

Abstract— **Greywater is wastewater that produces 50-80% of overall water consumption in a house. In many village houses of Malaysia, the household greywater that comes from kitchen, laundry, bathroom and sinks is usually untreated and discharged directly into streams or rivers. This phenomenon escalates the pollution among Malaysian rivers. This study examines the effects of household greywater treated with locally available peat soil. This study was performed by using a two-stage filter media (i) pre-treatment (gravel + sand) (ii) peat based (peat + charcoal + gravel). Effects of filtration on the peat soil were examined via the one-dimensional consolidation test and X-Ray Fluorescence Test (XRF). Removal efficiency of the greywater effluent was found to be TSS- 81%, BOD- 54%, COD – 52% and AN - 87%. pH of the greywater was improved from acidic (4.6) to neutral (6.9). Quality of the treated greywater complied with the limits of the Malaysian Standard (Standard B) for wastewater effluent discharge. The consolidation test was affected and became slower. XRF test indicates that peat soil has an increased amount of the inorganic content of Silicon Dioxide (SiO_2) and Aluminium Oxide (Al_2O_3) associated with the absorption of certain elements in greywater. The peat based filter resulted in a substantial removal of pollutants. Further study is needed to look in depth the mechanism of adsorption and its applicability in a large scale processes.**

Keywords- *g*reywater, peat soil, filter media, sand, gravel, charcoal

I. INTRODUCTION

In many rural and sub-urban residential with decentralized system, a significant portion of greywater always ends up into stream without treatment. Problems of direct discharge of household greywater that comes from kitchen, laundry, baths and sinks have caused environmental concern in recent years. For many, especially in developing countries, the environmental outlook is gloomy. Furthermore, contamination the earth's surface, such as euthrophication of water bodies is more serious and more obvious and generates public environmental action. To solve these environmental problems, certain treatment procedures are necessary. Sustainable development has to be the main agenda regulated by federal, regional and municipal governments to limit environmental damage and to protect the environment for the benefit of future generations [1]. In this context, greywater should be well treated prior final discharge to the nearest river to protect public health and environmental pollution.

Greywater traditionally receives the least attention compared to other aspects of environmental sanitation, such as toilet wastewater or solid waste. Greywater contains suspended particles and some familiar organism such as pathogens, nutrients, and chemicals. For example, in studies on Swedish household wastewater, greywater is reported to contain 25% of the phosphorus and 10% of the nitrogen [2]. Previous data revealed that BOD levels indicate a high organic fraction was derived mostly from kitchen and bathing [2] [3]. High TSS which includes small amounts of oil, grease, soap residue, and organic materials may potentially clog the greywater treatment. The direct discharge of greywater to the drains and through the sewerage systems leads to oxygen depletion, increased turbidity, eutrophication as well as microbial and chemical contamination of the water resource system [3]. Tang et al., (2007) [4] stated that the unsustainable means of greywater discharge from residential affecting most of Malaysia's fresh water supply. Therefore, greywater treatment is necessary to ensure the greywater is released to comply with water quality standards.

Peat soil is classified as highly organic and representative material of soft soils [5]. According to Leong and Chin (1997) [6], peat soil is defined as a naturally occurring, highly organic substance derived primarily from plant materials (ASTM D4427-92, 1997). Peat is distinguished from other organic soil

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materials by its lower ash content (less than 25% ash by dry weight) and from other phytogenic material of higher rank (i.e., lignite coal) by its lower calorific value on a water-saturated basis [7]. The application of peat as a filter or natural sponge for cleaning up domestic wastewater and oily contaminated water has been studied for several years and the results suggest that peat is efficient in removing contaminants from water (([3], [8], [9], [10], [11], [12], & [13]). However, there is an absence data of the feasibility peat soil to enhance the removal of pollutants in household greywater.

This paper presents the capacity of the peat filled filter media in removing contaminants from household greywater in the village house case study. This includes an effectiveness of peat and other pre-treatment (sand and gravel) with the charcoal based filter that may be provide an extensive greywater treatment by filtering or absorbing impurities.

II. MATERIALS AND METHOD

A. *Greywater Sampling*

Greywater samples were collected at the effluent pipes of a single house in Kg. Parit Haji Rasipan. This location was chosen because the greywater was directly discharge into drain by surface runoff. Sampling of greywater was done by composite method during during peak hours in the morning, lunch and night in 24 hours intervals. Sampling container preparation and preservation was done according to the Standard Method for Examination of Water and Wastewater [14].

Raw greywater was collected and analysed for the following parameters: total suspended solids (TSS) by the gravimetric method; biological oxygen demand (BOD_5) by five-day test; chemical oxygen demand (COD) by using COD reflux method, ammonium nitrogen (AN) by the Nesslerization method. All were measured by spectrometer using the HACH 2010, an USEPA-approved method. In situ measurements of pH and Electroconductivity (EC) were obtained with an AQUA meter (TPS, Australia).

B. *Filter media Establishment*

Four model of filters were prepared to evaluate the replicacy settings. Control model was prepared to simulate the irrigation with tap water. The filter was using a container sized 410mm x 300 mm x 255 mm and it can store about 20 liter of water. The filter was designed based on the gravity concept.

Filter consist two parts; (i) pre treatment process and (ii) peat + charcoal filter process. Pre treatment process contained gravel and sand layer. Pre treatment was a screening process where gravel was function to remove the particles and suspended solids from raw greywater. The second layer was filling up by sand. Sand was known as an effective filter media because of its ability to hold back coagulum or precipitates containing impurities. Sand filter are beds of granular material, drained from underneath so that greywater can be treated.

Peat filter consist three layer which are peat soil, charcoal and gravel. The peat soil filling up to 3 inch, charcoal 2 inch and gravel up to 2 inch. Charcoals were applied to remove the color and odor of greywater. According to Hernández-Leal et al, (2011) [15], charcoal filter can remove even micropollutants of greywater. Gravel was used as a base to support the overall filter system. The peat filter is filling in loose condition in order to allow greywater pass through the filter. Mosquito net and wire mesh were used to separate layer and to avoid the peat soil taken down during filtration process. Figure 1 shows the schematic diagram of filter media.

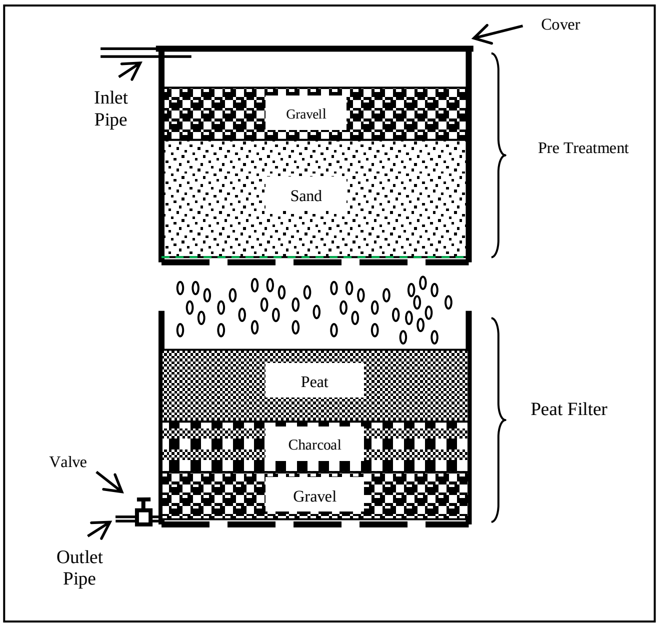

Figure 1. Schematic diagram of filter media

C. *Peat Soil Sampling*

Disturbed sampling was used for peat soils collected at the Kampung Parit Nipah, located about 10 kilometres from Universiti Tun Hussein Onn (UTHM). Samples were kept in plastic bag and tied up tightly in order to prevent any changing in the moisture content. Samples were then taken about 0.305 metre depth (1foot). All the samples were taken to geotechnical and RECESS (Research Centre for Soft Soils) laboratory and all soil tests were conducted in accordance with the British Standard BS1377: 1990.

D. *Peat Soil Analysis*

The physical and some selected mechanical properties of the peat soil sample from Kampung Parit Nipah, Batu Pahat Johor were determined. The tests were conducted by following the prescribed method in BS 1377 Method of test for Soil for civil engineering purposed:

i. Part 2: Classification test
ii. Part 3: Chemical and electro-chemical test

iii. Part 5: Compressibility, Permeability and Durability tests
iv. Part 6: Consolidation and Permeability tests in hydraulic cells and with pore pressure measurement
v. Part 7: Shear strength tests (total stress)

Peat soil analysis had been done to investigate the peat soil engineering properties of the post filtration. The tests one-dimensional consolidation and X-ray fluorescence (XRF) test to determine any changes in their properties due to the reaction between peat soils with greywater. The properties of peat soil used in this study were shown in Table 1.

TABLE I. PROPERTIES OF PEAT SOIL IN KG. NIPAH, BATU PAHAT, JOHOR

Parameters	Results
Natural moisture content (%)	371
Specific Gravity (Gs)	1.25
Acidity (pH)	2.94
Organic content (%)	49.72
Sieve analysis	60 % Medium sand, 20 % Fine Sand
Ash content (%)	50.3
Liquid Limit (%)	83

III. RESULTS AND DISCUSSION

A. *Greywater Quality Before and After Treatment*

Summary data of the quality of greywater effluent after being treated with greywater were obtained and are shown in Table 2. It is observed that pH concentrations were acidic in raw greywater but were improved to neutral after being treated with peat soil. pH concentration in greywater is generally acidic (5.9-7.4) mostly contributed from organics compound in foods such as citrus fruits, pickles and sauces [16]. The pH of the treated greywater gradually increased from 4.6 to 6.9 with increasing duration of time possibly due to decomposition of organic materials into peat soil. Furthermore, peat is mainly a positively charged. Negatively charged particles in the greywater effluent are highly attracted to peat and will adhere to the peat. As the greywater flows through the peat, particles are absorbed by the peat and removed from the flow. Treated greywater also have shown better quality during the period of treatment by the reduction of BOD, COD, AN, TSS and turbidity concentrations.

TABLE II. SUMMARY OF GREYWATER QUALITY BEFORE AND AFTER TREATED WITH NATURAL FILTER MEDIA WITH PEAT SOIL (NO. OF SAMPLES, N=3; MEAN ± STANDARD DEVIATION)

Parameter	Greywater concentration (mg/L)							
	Day 1		Day 7		Day 14		Day 28	
	I	*E*	*I*	*E*	*I*	*E*	*I*	*E*
pH	4.6	6.9 ± 0.2	4.2	6.6 ± 0.1	4.71	6.8 ± 0.2	4.4	6.9 ± 0.2
BOD (mg/L)	75	61 ± 4	72	48 ± 5	67	37 ± 2	69	32 ± 2
COD (mg/L)	149	122 ± 7.55	143	98 ± 15.63	128	73 ± 5.03	135	66 ± 4.04
AN (mg/L)	12.83	8.28 ± 0.27	15.30	4.32 ± 0.21	12.74	1.54 ± 0.17	13.30	1.73 ± 0.07
TSS (mg/L)	312	205 ± 16	296	176 ± 8	234	53 ± 6	212	40 ± 3
Turbidity (NTU)	298	193.3 ± 16.26	267	164.3 ± 7.37	210.0	43.7 ± 5.03	198	31.7 ± 3.50

Note: I=Influent, E= Effluent

The removal percentage of TSS on 14th day and 28th day was increased up to 77 % and 81% (Figure 2). Research conducted by [17] had shown peat acts as a very effective filter for removing TSS from wastewater. However, the sorptive mechanism of the TSS with peat soil has not been detailed. The other reason may cause by the pre-treatment using a sand filter which is designed to trap suspended solids for raw greywater during the filtration process.

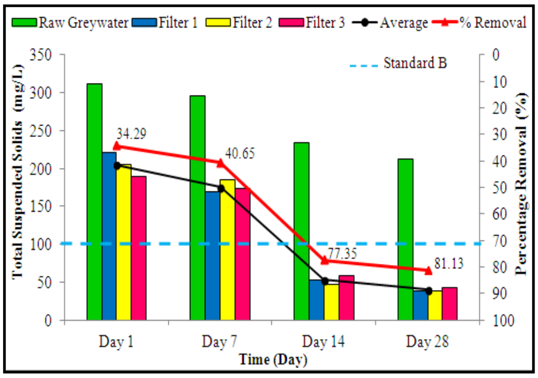

Figure 2. Concentration of TSS and its percentage removal during the treatment period

Figure 3 shows regression plot was used in order to determine if there was a correlation between TSS and BOD in the treatment of raw greywater using peat soil filter. The regression line (R^2 = 0.92) in the plot showed that there was a positive correlation between the TSS and the BOD. This finding suggests that a significant fraction of the TSS was organic and degradable. Figure 4 shows the graph of the BOD concentration. BOD for treated greywater indicates downward trend from the 1st day until 28th day with the higher percent BOD concentration up to 54%. The high BOD_5 is attributed to the kitchen and bath effluents that had high activities occurred in the house.

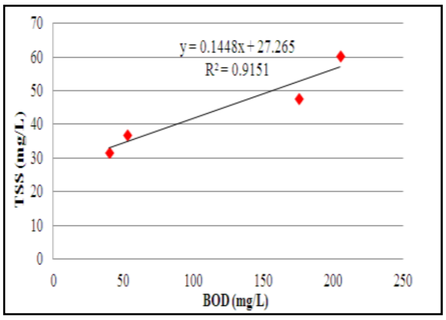

Figure 3. The regression analysis between TSS and BOD

The COD concentration for pre-filtration raw greywater was slightly removed from the 1st day until 28th day. From the graph, the values of COD are decreased throughout the time. COD concentration against time (Figure 5) for 7th day followed by 14th day and 28th day was 98 mg/L, 73 mg/L and 66 mg/L, respectively indicate the removal process had done gradually. The result shows the overall weak performance of 51.36%. The results shows that peat filters are not very effective on the removal of COD. This is agreed by [17] through their research showed that two types of peat, namely *sapric* (most decomposed) and *fibric* (least decomposed) peat performed equally well in removing the SS but performed unsatisfactorily in removing BOD and COD. On the other hand, [18] reported BOD and COD removal rates by *sapric* and *fibirc* peat were as 96% and 84% respectively.

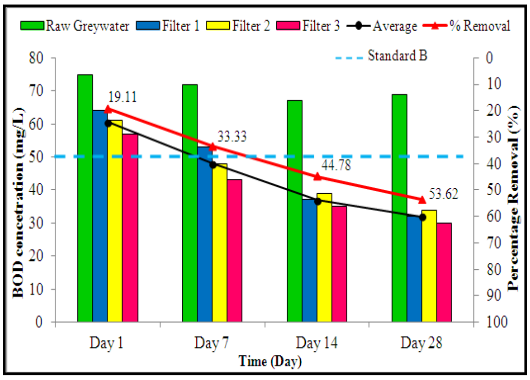

Figure 4. Concentration of BOD and its percentage removal during the treatment period

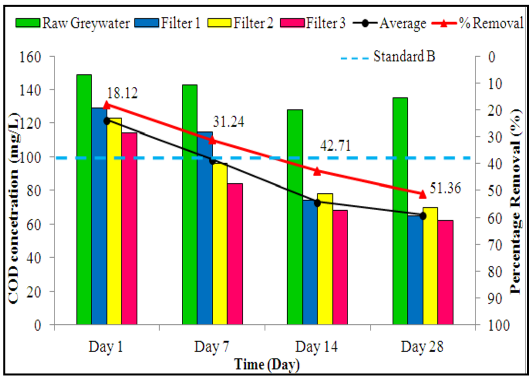

Figure 5. Concentration of COD and its percentage removal during the treatment period

For treated greywater using peat soil as filter media the value of Ammoniacal Nitrogen (AN) has concentration in the range of 1.5mg/L and 8.3 mg/L (Figure 6). It shows that the value of AN was decreased to 87% after the filtration process. The decreased of AN value may be due cause of using charcoal as addition material on the filter system. Charcoal can be quite effective at removing some tastes, odors, and color of the water infiltration process [3]. The lowest concentration of AN recorded at 28th day was 1.73 mg/L and comply with the permitted value for standard B. The maximum value of standard B for AN before discharge for irrigation was 5.0 mg/L. It shows that the treated greywater by using peat soil filtration are suitable to discharge for irrigation according to Environmental Quality (sewage) Regulation (DOE, 2009).

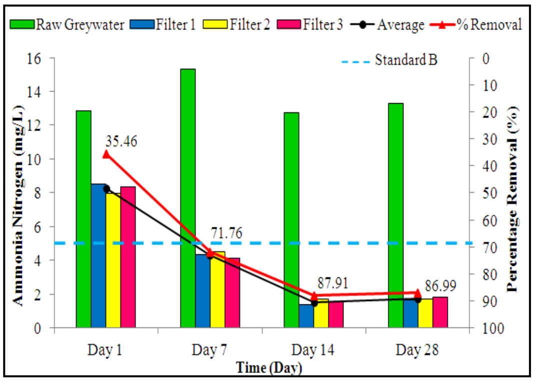

Figure 6. Concentration of COD and its percentage removal during the treatment period

B. *Effects of Peat Soil*

One-Dimensional Consolidation

Consolidation test was conducted to obtain the settlement of the samples when subjected to different loading. Figure 7 shows the relationship between void ratio and applied pressure for both the untreated and treated peat soil sample (i.e. after filtration process by using mixed greywater). It can be observed that both sample showed typical compressive characteristics of a soft material, with excessive settlement taking place with the first loading. It is also apparent that the loading-unloading curves of both samples showed very little difference in pattern, suggesting no change in the micro-fabric with negligible effect from the greywater passing through it. Nonetheless this could also be due to the relatively short retention time designated for the present study.

The initial void ratio was very different though, with the untreated sample containing 20 % more pores or voids compared to the post-filtration sample, possibly caused by entrapment of fine materials during the filtration process. In addition, referring to Figure 2, the suspended solids in the filtered water showed a significant drop over the 28-day test period, suggesting an increase in the material retention rate in the peat media. This implies an increased efficiency of the peat filter media over time, due to the entrapped fines filling up the voids, as well as slime formed in the pores of the peat soil. However, as discussed earlier, this decrease in voids did not contribute to micro-fabric change for enhanced stiffness, resulting in very similar load-settlement responses for the samples, treated and untreated. In short, apart from the initial difference in the void ratio, both samples have undergone the same magnitude compression.

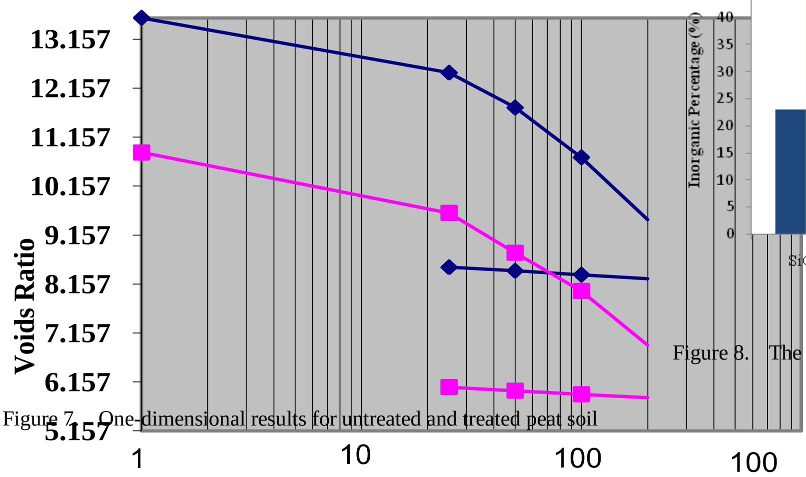

Figure 7. One-dimensional results for untreated and treated peat soil

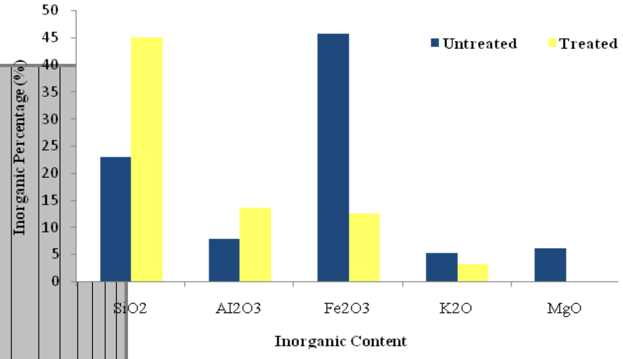

Figure 8. The comparison of inorganic content for untreated and treated peat soil

X-Ray Fluorescence Test (XRF) Analysis

X-Ray Fluorescence (XRF) was conducted to identify and measuring the element or composition of inorganic content in peat soil. The sample of peat soil before and after filtration process has been tested by using XRF and the data was recorded into table and bar histogram. As shown in Figure 8, an inorganic matter that had been defined from the XRF test was Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3), Ferum Oxide (Fe_2O_3), Potassium Oxide (k_2O) and Magnesium Oxide (MgO).

From the result, inorganic content of Ferum Oxide (Fe_2O_3) for untreated sample obtained the highest percentage with 45.80% compared to treated sample was 12.60%. It shows that the Ferum Oxide (Fe_2O_3) was reduced during the filtration process. This probably because of reaction between mixed greywater and peat soil can reduce the Ferum Oxide (Fe_2O_3). Another percentage of inorganic content was found on untreated sample was Silicon Dioxide (SiO_2) with 22.30%, Aluminium Oxide (Al_2O_3) with 7.88%, Potassium Oxide (k_2O) with 5.15% and Magnesium Oxide (MgO) was 0.30%. From the Figure 9, some of the inorganic content was increase after the filtration process which was Silicon Dioxide (SiO_2) and Aluminium Oxide (Al_2O_3).

The various household activities contribute the wide arrays of chemical content in greywater. According to [14] chemicals elements was present in many of our ordinary household chemicals, e.g. shampoos, perfumes, preservatives, dyes and cleaners. The efficiency of adsorption process will involves the groups present on the surface of the adsorbent materials and the pollutants chemisorption process. The basic chemisorptions involve the sharing of electrons between the pollutants and the surface of the adsorbent resulting into a chemical bond [9].

IV. CONCLUSION

Utilization of pre-treatment and peat based filter media for the treatment of greywater is greatly affects the removal of pollutants. The removal of total Suspended Solid (TSS) efficiency removed up to 81.13%, Ammonia Nitrogen (AN) was removal percentage of 86.99%, Chemical Oxygen Demand (COD) concentration was decreased by 51.36% and affiances to remove Biological Oxygen Demand (BOD) concentration was 81.13%. The treatment process was gradually effective by time during 28th day of treatment most probably due to the oxidation process. The entire samples that undergo treatment of raw greywater were archived value of standard B, which is permitted by Environmental Quality (Industrial Effluent) Regulation 2009.

Analysis of the one-dimensional compressibility test results showed negligible effect of the greywater chemistry on the inherent stiffness, but this could be attributed to the rather short retention period preventing further chemical reactions or micro-structuring. From the result of XRF test, peat soil contains an increased amount of the inorganic content of Silicon Dioxide (SiO_2) and Aluminium Oxide (Al_2O_3). These findings had given initial hyphothesis that the chemical pollutants particles are absorbed by the peat and removed from the flow. The future research on the peat soil mechanism and their sorptive characteristics will answer those questions.

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Dr. Radin Maya Saphira Radin Mohamed is a senior lecturer at Dept. of Water & Environmental Engineering, Faculty of Civil & Environmental Engineering, Universiti Tun Hussein Onn Malaysia. She did her PhD in Environmental Engineering (Greywater Recycling/Reuse for Irrigation), at Murdoch University, Perth, Australia. MEng (Research) in Civil Engineering (Environmental) with thesis titled 'River Modelling for Water quality in Bekok River' from College University Tun Hussein Onn Malaysia and BSc (Hons) in Industrial Chemistry, University Technology of Malaysia.

Dr. Radin Maya Saphira's research involves issues related to grey water management and soil qualities as well as their impact on the environment, and the search for practices to improve environmental quality related to contamination by greywater. In the last few years she has extended her research interest on the low-cost and sustainable technology to alleviate the greywater discharge pollution in the house villages. The use of natural sources and local soil are the most resources she interested for and she and her team of research have been conducted several research to fill the gap of research.