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EFFECTS OF FILTRATION USING SOIL AND FIBRE MEDIUMS IN IMPROVING THE QUALITY OF STORMWATER

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ABSTRAK

Water shortage problems occurred when insufficient quantities or only poor quality of water available for consumption . In some places, while fresh water is abundantly available for domestic use, high demand at industrial site and agricultural area requires the need to investigated alternative method of treatment for non-domestic water supply. In this study, effects of treatment unit using Odec and Sulaman soils, fibre and fibre-soil combinations were investigated towards their ability to filtrate and improve the quality of stormwaters collected from SST Lake, Likas River and Odec Sea. For comparison, treatment was also conducted for soy bean water. Stormwater quality tested include the chemical oxygen demand (COD), pH, turbidity and suspended solid. It was found that Sulaman soil medium yielded 100 % removal rate of suspended solid compared to ODEC and fibre medium while fibre medium showed the least effective filter. The removal rate of COD of all medium was low. All the medium failed to filter soya water due to the high concentration of chemical compound. The study concluded that when the parameters measured is chemically-related such as COD and pH, the soil medium filter less effectively. The effectiveness in filtering non-chemical parameter such s suspended solid is affected by the grain size and distribution, texture and the structure of the mediums.

Kata kunci : Soil Treatment Unit, COD, Turbidity, Suspended Solid

1. PENDAHULUAN

Shortage of water supply occurred due unavailability in sufficient quantities or quality of water fit for usage at locations of high water demands such as city, industrial site and agricultural area. In Malaysia, the city of Kuala Lumpur, petrochemical complexes in Melaka, Kertih in Terengganu and the Muda agricultural area reported shortage problem. The water shortage problems surface more often during extended dry weather periods. Thus the search for new water sources, including reuse of wastewater.

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When untreated wastewater reaches, water used as a drinking water source for the community, there can be significant health risks. Occurrence of micro pollutants in the aquatic environment have been frequently associated with a number of negative effects, including short term and long term toxicity, endocrine disrupting effects and antibiotic resistance of microorganism (Luo et al., 2014). According to Bolong et al (2009), the effect of endocrine disrupting chemicals exposure on human health includes a decrease in male sperm count, an increase in testicular, prostate, ovarian and breast cancer and reproductive malfunction. Thus, a proper design of wastewater treatment unit is required to overcome this problem.

The effectiveness of water treatment can be reduced when water is heavily contaminated with waste. To ensure safe drinking water, communities need both effective water and wastewater treatment. In addition, communities need to make sure that untreated wastes are not disposed of improperly on land where people can come in direct contact with it can attract disease carrying insects or animals. For agriculture and industrial use, lower level of water quality is needed hence treatment of stormwater can become a good alternative.

Most treatment methods include a preliminary step in which the solid materials are filtered out or allowed to settle and separate from the rest of the wastewater. Soil and other filtrating materials can be used to help treat wastewater.

Previous study by Kesraoui-Ouki et al. (1994) uses different filter mediums such as calcium silicate rock (*opoka*), zeolite and peat in reducing the level of heavy metals in water. The experiments found that high metal-reduction efficiency is observed for low hydraulic loads through the filter substrates, and lower metal-reduction efficiency is observed with higher hydraulic loads. The combination of *opoka* and zeolite seemed to be the most suitable compositions with regard to reduction efficiency and clogging properties. Additionally, combination of ozonation with the membrane filtration process was used by Chen et al (2015) in mitigating membrane fouling in treating surface water. They found that Ti-Mn/TiO_2/Al_2O_3 and TiO_2/Al_2O_3 catalytic membranes were effective in antifouling and removal of total ammonia nitrogen.

An soil profile can be conceptualized as a wastewater treatment unit operation that is designed to hydraulically process and purify the effluent within the soil profile to the extent needed to protect public health and water quality. The major processes can have categorized to include effluent infiltration into soil pore networks, effluent water movement within a soil profile and effluent pollutant and pathogen removal reaction. According to Janzen et al (2009), the removal efficiency micro pollutants in soil profile can be very high with low hydraulic load.

A study conducted by Zhu et al (2013) emphasized on the importance of the empty bed contact time to the removal of chemical. The longer the contact time between the pollutants and medium, the better the removal efficiency. Therefore, low hydraulic load and longer contact time can yield better outcome. Therefore, effectiveness of these soil mediums are effected greatly by their porosities.

As the porosity of the filter medium increases, the hydraulic conductivity also increases. However, the efficiency of the filtration will be decreased due to empty bed contact time is low. The pollutants do not contact with filter media at the longer period. It is known that the porosity of soils varies depends on soil type, shape and degree of compaction. According to Cherry and Freeze (1979), the reported total porosities for peat vary between 60% and

95%, for sand between 20 % and 35 % and for gravel between 15 % and 40 %. Values for effective porosity range in the literature from 0 % to 5 % for peat, from 10 % to 35% for sand and from 12 % to 35 % for gravel.

Therefore, this study aims to determine the effectiveness of different type of mediums (soil / fibre) and porosities in filtrating stormwater. It aims to determine the physical and chemical changes of effluent water after filtration and to discuss how the quality of water is affected by the filtration materials.

2. RESEARCH METHODOLOGY

2.1. Filtration Materials

Four filter medium were constructed with Sulaman soil, ODEC sand, fibre and the mixed of the three material medium. Sulaman soil was taken near the KFC Sulaman, while ODEC sand was taken from the ODEC beach UMS. The fibre (coconut coir) was taken from geotechnical lab. Figure 1 shows the location of the samples taken. Four lab tests such as pH of the soil, sieve analysis, Atterberg limits and porosity test were carried out for soil classification.

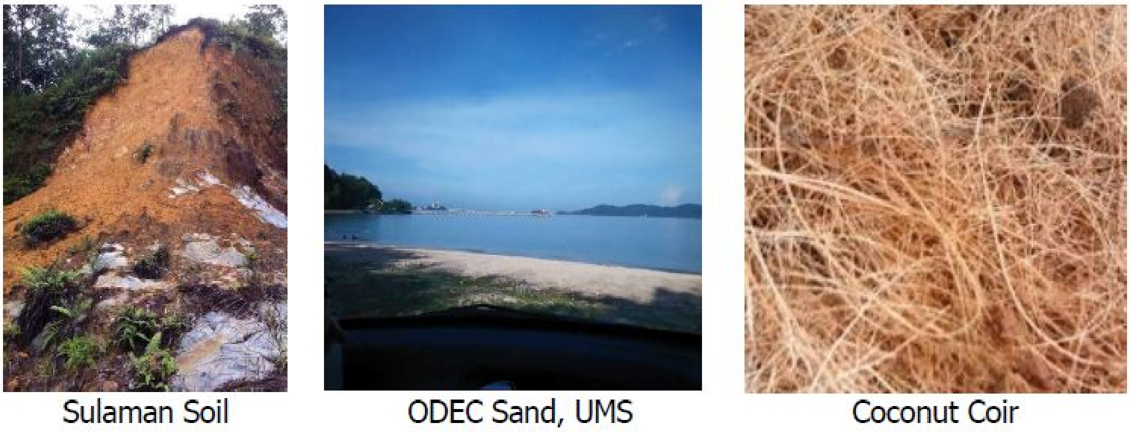

Figure 1. Filtration Materials

2.2. Filtration Unit

The filtration unit was built using constant head permeability head mould (shown in **Figure 1**) with estimated internal diameter of 75mm and effective height of 260 mm. The testing apparatus comes with adjustable reservoir for water supply. A porous stone was used to support the medium from runoff. The filtration mediums (ODEC, coir fibre and Sulaman), specimen were compacted inside the mould layer by layer according to the required soil porosity at 40-50%. For multilayer, specimen was prepared in order of Sulaman, Odec and fibre at 3 layers of equal thickness and porosity of 40-50%. A fixed amount of stormwater (1100ml) is used for every specimen, passing through the inlet and collected at the outlet for testing.

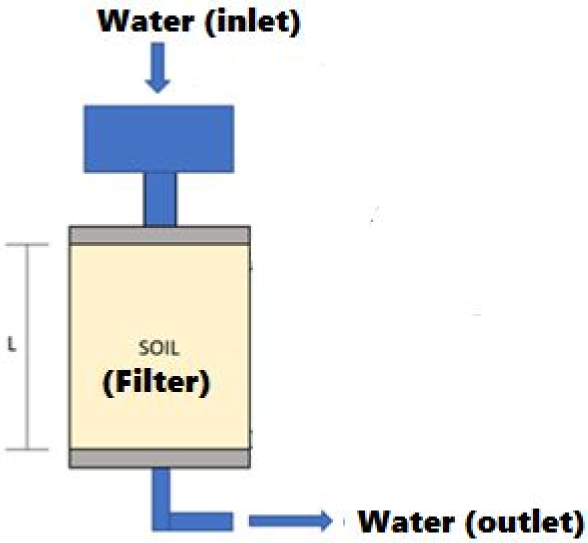

Figure 2. Setup of Filtration Unit

2.3. Water Samples

Four types of water sample were used in this study. Among the four types, three types of the water samples were collected from the area around Universiti Malaysia Sabah such as ODEC sea, Likas River and SST lake respectively. While, soya water was chosen as the forth water sample due to its high concentration of chemical compound for comparison. Figure 3 shows the location of the water samples and soya water.

ODEC sea | Likas River | SST lake | Soya water

Figure 3. Four Types of Water Samples

2.4. Soil Classification

Sieve Analysis was conducted for both ODEC sand and Sulaman soil to plot the grain size distribution curve. Atterberg limit test was conducted only for Sulaman soil, since ODEC sand is cohesionless. In order to determine the liquid limit and the plastic limit of the soil, Fall Cone Method and rolling hand method were conducted respectively. Unified Soil Classification System (USCS) was used to classify the soil. In addition, pH, porosity and permeability were determined for the Sulaman soil and ODEC sand. Based on the grain size distribution curve, Hazen's formula was used to determine the permeability of the soil.

2.5. Water Quality Testing

Parameters such as Chemical Oxygen Demand (COD), pH, turbidity and suspended solid of all water samples were taken before and after the filtration for future comparison. Figure 4 shows the lab work for COD, turbidity, pH and suspended solid test in an environmental lab. D6000 Device was used to determine the suspended solid and COD of the water samples.

COD Reactor   Turbidity Meter   pH Meter   D6000 Device

Figure 4. Water Quality Testing Equipment

3. RESULTS AND DISCUSSION

3.1. Filter Properties

From the grain size distribution curve of ODEC sand (Figure 5(a)), the curve has very steep slope with most of the soil particles being of almost same size, it is called uniformly graded soil. For Sulaman soil (Figure 5(b)), the curve is smooth and is spread evenly with almost constant slope, it is called a well graded soil.

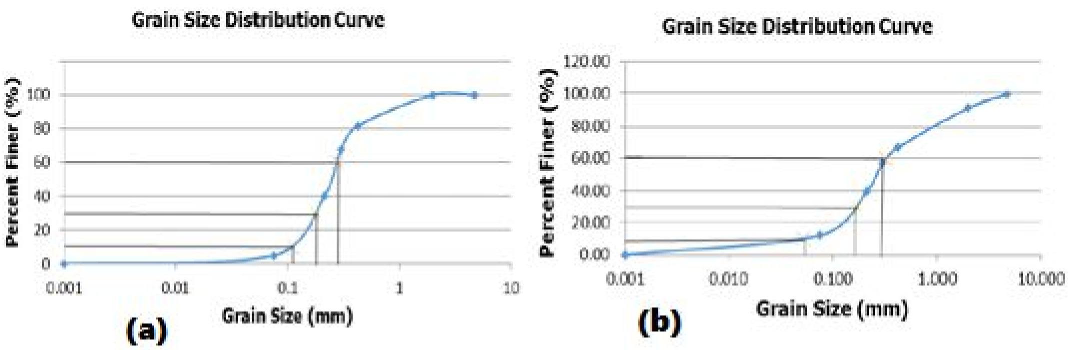

Figure 5. Gradation of a) ODEC Soil and (b) Sulaman Soil

According to the Holtz et al (1981), larger C_u values indicate well graded soils and smaller C_u indicate uniformly graded soils (Onur, 2014). From the sieve analysis result, the C_u of ODEC sand is 2.55 lower than Sulaman soil, 6.15.

Meanwhile, **Table 1** shows the summary of properties between two soils. It can be observed that ODEC sand (50%) is generally more porous than Sulaman soil (43.75%) due to the soil classification and grain size distribution. In addition, ODEC soil is also more permeabile than Sulaman soil.

Table 1. Summary of Properties of ODEC and Sulaman Soil

	ODEC Sand	**Sulaman Soil**
Passing 4.75 mm (No. 4)	100 %	99.4 %
Passing 0.075 mm (No. 200)	4.94 %	12.02 %
Grain size distribution	Uniformly graded	Well graded
Liquid Limit	NP	31 %
Plastic Limit	NP	21.55 %
Coefficient of Uniformity, Cu	2.55	6.15
Curvature of soil, Cv	1.02	1.74
USCS Classification	Poorly Graded Sand (SP)	Clayey Sand (SC)
Porosity	50 %	43.75 %
Permeability, k (cm/s)	1.21×10^{-3}	2.7×10^{-3}
pH	7.92 (alkaline)	5.04 (acidic)

Meanwhile, **Table 2** shows the properties of the coconut coir fibre.

Table 2. Properties of Coconut Coir Fibre

	Fibre Properties
Length, mm	50-100
Diameter, mm	0.10-0.45
Specific gravity	1.12-1.15
Elongation at failure, %	25
Water absorption, %	110-130

3.2. Effects of Filtration Towards pH

Buffering capacity of soil is the ability to resist change in pH (James & Riha, 1986). By definition, the pH of a soil is the measurement of the concentration of hydrogen ions in soil water which is known as an acid cation. According to Figure 6, fibre medium shows the least changes in pH follow by ODEC sand and Sulaman soil. This can be explained by the porous structure of the fibre which there is a little interaction of the water with the medium. For ODEC sand, its pH is alkaline (7.92) which will uptake the hydrogen ion from the water sample and increase the pH of the effluent. For Sulaman soil medium, it is acidic with pH 5.04, the hydrogen ions in the medium are mixed with the water samples and decreased the pH of the effluent.

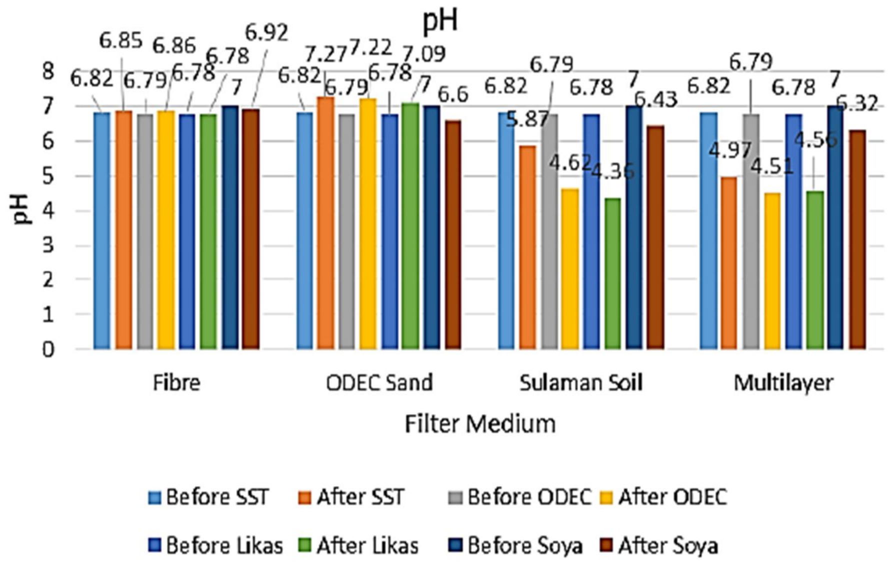

Figure 6. pH of Water Before and After Filtration

3.3. Effects of Filtration Towards COD

Based on Figure 7, it was found that the fibre medium had the least removal of concentration of COD followed by ODEC sand and Sulaman soil. According to Siegrist et al (Siegrist et al., 2012), the contact time between wastewater constituents and the soil grain surfaces and their associated biofilms must be long to do the natural disinfection. Sulaman soil medium had reduced the most COD value with 11.79 % removal efficiency due to its low porosity and permeability. Besides that, the clay content in the Sulaman soil will trap the water inside the medium for a longer time to trigger the treatment.

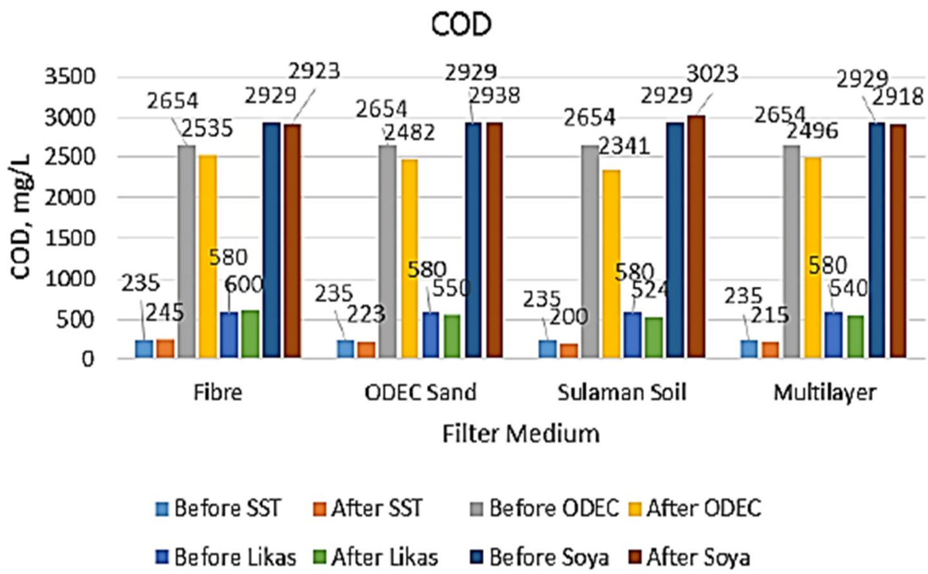

Figure 7. Chemical Oxygen Demand (COD) Before and After Filtration

3.4. Effects of Filtration Towards Turbidity

Based on Figure 8, Sulaman soil medium produced a clearer effluent compared to ODEC sand and fibre medium.

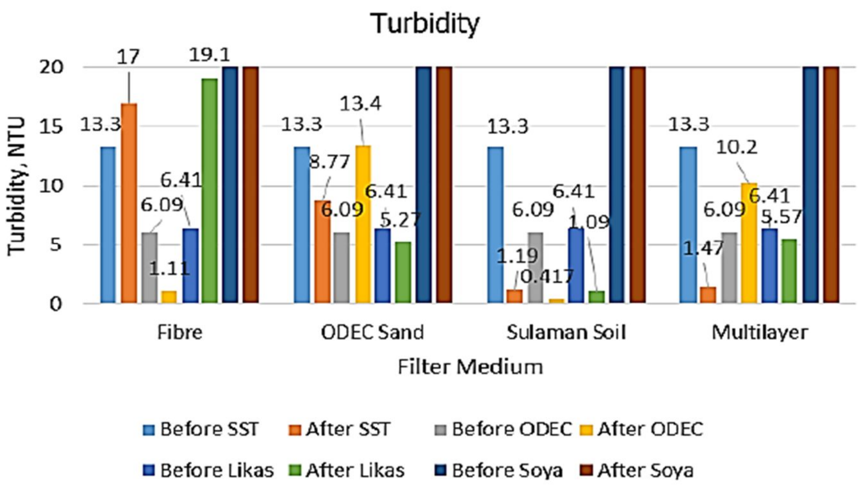

Figure 8. Turbidity Before and After Filtration

According to the SST water sample, the turbidity is reduced from 13.3 NTU to 1.19 NTU which is 91.05 % of removal rate. This is due to the low porosity of the medium which has a higher chance to trap the pollutants. As for fibre medium, the turbidity value increased after filtration due to the high filtration rate of influent that washed away the impurities inside the medium.

3.5. Effects of Filtration Towards Suspended Solid

Based on Figure 9, the ODEC sand and fibre medium show increment of suspended solid after filtration.

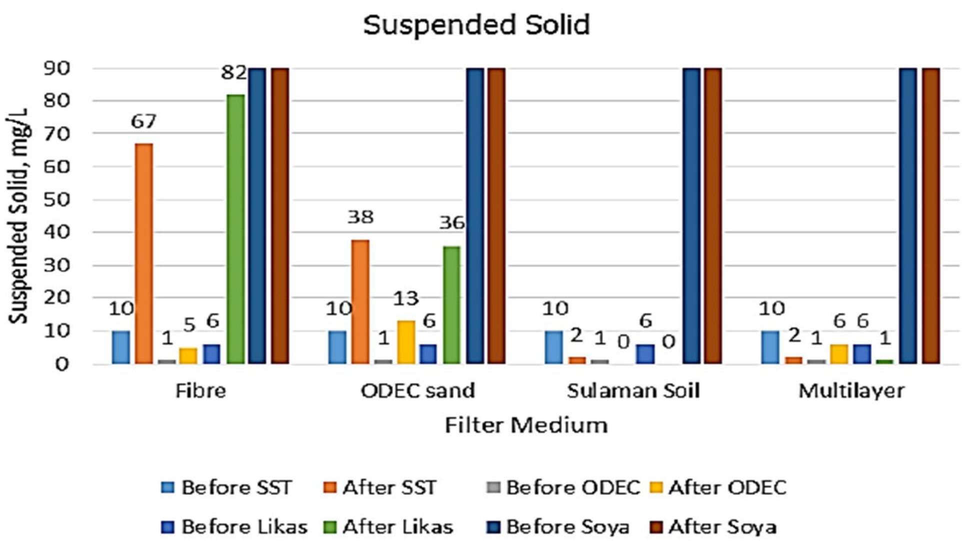

Figure 9. Suspended Solid Before and After Filtration

This is might be due to the high porosity and permeability whereby the impurities were washed out from the medium with the high flow rate of water. Thus, in order to get a better filtration efficiency, the filter medium must be cleaned. For Sulaman soil, it yielded a 100 % removal of suspended solid compared to ODEC sand and fibre medium. Thus, low porosity is better in removing suspended solid because the influent requires a longer time to flow through the medium and hence increasing the chances of trapping the suspended solid.

4. CONCLUSION

From the experiment, it was observed that when the parameters measured is chemically-related such as COD, pH and others, the soil medium filter less effectively. The removal rate of COD by ODEC sand and Sulaman soil medium were relatively low in overall. This is due to the short contact time between the wastewater constituents and filter medium and the incomplete treatment process.

When the measured parameters are physically-related such as suspended solid and turbidity, the soil medium acts somehow as an effective filter. For fibre and ODEC sand medium with higher porosity and permeability compared to Sulaman soil, the removal rates of suspended solid and turbidity are low. The chance to trap the suspended solids in high porous medium is low. For Sulaman soil medium, the porosity and permeability is low and the chances to trap all the suspended solids is high. Thus, Sulaman soil has the 100 % removal rate of suspended solids.

In conclusion, low porosity of soil medium will have a better filtration efficiency in physical-related parameter. The concentration of pollutants in water cannot exceed the limit of design assumption. In this study, all the filter medium failed to filter the soya water containing high concentration of chemical compounds. The fibre medium is the least effective filter due to its porous structure; however, it can be a good addictive layer to prevent clogging of the physical particles.

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REFERENCES

Bolong, N., Ismail, A. F., Salim, M. R., & Matsuura, T. (2009). A review of the effects of emerging contaminants in wastewater and options for their removal. *Desalination*, *239*(1–3), 229–246.

Chen, S., Yu, J., Wang, H., Yu, H., & Quan, X. (2015). A pilot-scale coupling catalytic ozonation–membrane filtration system for recirculating aquaculture wastewater treatment. *Desalination*, *363*, 37–43.

Cherry, J. A., & Freeze, R. A. (1979). *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall.

Holtz, R. D., Kovacs, W. D., & Sheahan, T. C. (1981). *An introduction to geotechnical engineering* (Vol. 733). Prentice-Hall Englewood Cliffs.

James, B. R., & Riha, S. J. (1986). *pH buffering in forest soil organic horizons: relevance to acid precipitation*. Wiley Online Library.

Janzen, N., Banzhaf, S., Scheytt, T., & Bester, K. (2009). Vertical flow soil filter for the elimination of micro pollutants from storm and waste water. *Chemosphere*, *77*(10), 1358–1365.

Kesraoui-Ouki, S., Cheeseman, C. R., & Perry, R. (1994). Natural zeolite utilisation in pollution control: A review of applications to metals' effluents. *Journal of Chemical Technology AND Biotechnology*, *59*(2), 121–126. https://doi.org/10.1002/jctb.280590202

Luo, Y., Guo, W., Ngo, H. H., Nghiem, L. D., Hai, F. I., Zhang, J., Liang, S., & Wang, X. C. (2014). A review on the occurrence of micropollutants in the aquatic environment and their fate and removal during wastewater treatment. *Science of the Total Environment*, *473*, 619–641.

Onur, E. M. (2014). *Predicting the permeability of sandy soils from grain size distributions*. Kent State University.

Zhu, I. X., & Bates, B. J. (2013). Conventional media filtration with biological activities. *Water Treatment*, *7*, 137–166.