Recent Trends in Civil Engineering and Built Environment Vol. 2 No. 1 (2021) 236-244
© Universiti Tun Hussein Onn Malaysia Publisher's Office

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Potential Studies of Permeable Concrete With Palm Oil Fuel Ash (POFA) in Treating Laundry Greywater

Sarah Mohd Sidin[1], Radin Maya Saphira Radin Mohamed[1]*

[1]Faculty of Civil Engineering and Build Environment,
University tun Hussein Onn Malaysia, Batu Pahat, Johor, 84600, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2021.02.01.026
Received 30 January 2021; Accepted 28 April 2021; Available online 30 June 2021

Abstract: Laundry greywater contain various pollutant with high concentration such as organic carbon, bacteria, and solids. To protect the fresh water quality, it is forbidden to directly discharge laundry greywater runoff to the stream. Therefore, the study is aimed to treat the laundry greywater by using permeable concrete with palm oil fuel ash (POFA). The focus of this study is to discuss and summarize the major finding of these collective studies related to: (a) Laundry greywater characteristics (b) The efficiency of the palm oil fuel ash (POFA) as adsorbent materials in wastewater related study based on previous studies analysis. Review analysis indicated that UPOFA has larger specific surface area (1.962 m^2/g) and has substitute cement by 20, 40, 60 and 80% of weight. The optimum dosage of POFA is 8 g/L to remove pollutant in sewage wastewater and the 4 g/L for domestic wastewater. The findings advocate that the certain amount of POFA successfully reduce a large amount of pollutant in the wastewater due to presence of high concentration of alumina, calcium, potassium and silica that can be used for synthesising active compounds .

Keywords: Palm Oil Fuel Ash (POFA), Laundry Greywater, Permeable Concrete

1. Introduction

Laundry greywater is substantially less polluted than domestic wastewater due to lack of urine, fecal and toilet paper in it. However, the pathogens and other pollutants in laundry greywater can cause disease that necessitate greywater care and recommendations to ensure public health. In 2020, Shaikh & Ahammed [1] found that the generation of greywater in low-income countries are within the range of 14-140 Litre/person/day while in high income countries are within 62-223 Litre/person/day and laundry greywater produced higher concentration of solids, organic carbons and bacteria. The variation of greywater generation might be due to family size and different laundry washing method, washer machine consumes higher water compared with manually wash.

*Corresponding author: maya@uthm.edu.my

Improper greywater management system has led to the indiscriminate dumping of greywater, which has contributed to environmental problem which can cause eutrophication of freshwater. The increase in eutrophication rates was a problem since it leads to lower concentration of dissolve oxygen, excessive growth of phytoplankton and increase algae bloom. The addition of anthropogenic nutrients to the Shenzhen Bay accounted for more than 80% of the overall loads that leads to eutrophication [2].

Pervious concrete is comparable with permeable pavements which it has pore that effective in reducing greywater runoff pollutants loads by passes the runoff through the porous pavements. Properly built pervious concrete can be efficient in the treatment of contaminated water by eliminating the unwanted pollutants due to present of interconnected voids spaces [3]. The interconnected space allow filtration to occur and improved the quality of the greywater runoff. Hydroxide compound is present in concrete when using ordinary Portland cement (OPC) and appearance of carbonate species due to carbonization process at the atmosphere which dissolve metals are likely to be separated from the solution when moving through these tortuous flow channels and passing through these complexions [4]. POFA is one of the agro-adhesives whose chemical composition contain a large quantity of silica and has great potential to be used as a cement substitution [5].

1.1 Greywater (GW) from urban runoff

The definition of greywater is a water produced from houses such as bathtubs, shower, hand basins, kitchen sinks, dish washer and laundry machines. Greywater is a fraction of household wastewater that have lower pollutant concentration [6]. Greywater from urban runoff consist of body care product, food residue, oil, body fat, hair, bleaches and develop pollutants that have been distinguished such as organic carbon, total solid, total suspended solid, and nutrients [7]. The greywater contribute over 50% of residential waste water [8]. The runoff from greywater is usually discharge into stream network and carries amount of dissolve nutrients and led to low dissolved oxygen. Greywater runoff contamination is one of the issues in growing cities in many urban area with conventional impermeable pavement [9]. However, contamination related to urban overflow is getting less attention due to difficulty to quantify [10]. The primary source of organic carbon, suspended solid and surfactants in the greywater is from laundry and kitchen sink, while phosphorus and endocrine disrupting chemicals are released primarily from dishwasher and bathroom. There are two types of greywater based on concentration of the contaminants that is light greywater (LGW) and dark greywater (DGW). Water releases from bathroom, hand basin, sinks and bath tubs are considered as LGW [1]. Whilst dark greywater (DGW) comes from kitchen sinks and laundry [11]. Light greywater contributes 15% of organic carbon and dark greywater can contribute maximum of 74% of the total organic carbon load to urban runoff [7]. Greywater and stormwater runoff containing organic nitrogen (N) is a source of potentially eutrophication in water bodies [12].

1.2 Palm oil fuel ash (POFA)

Huge amount of solid waste by-products that are generated in a variety of forms such as seeds, empty fruit bunches along with crude palm oil. Solid waste of palm oil residues is used as a fuel to produced steam for the generation of electricity to address energy problems. An ash by-product (POFA) is produced after burning and remain 5% by weight of the residue [5]. Burning of these solid fuels present environmental issue by produce dark smoke and transport partially carbonized fibrous particulate due to incomplete combustion of fuels [13]. The use of waste product that is POFA to create a replacement of lime-stone for non-renewable source can help to sustain the environment. POFA are suitable to be use in concrete production as it follow the chemical specification of ASTM C618 with regards to the usage of a binder pozzolanic material with a value of less than 10% of loss of ignition (LOI) [14]. High amount of silicon dioxidein POFA indicates a good pozzolanic properties that is suitable to manufacture high quality concrete. Interaction between Al_2O_3 and SiO_2 with Ca $(OH)_2$ in a cement paste will produce pozzolanic material. Thus, high amount of SiO_2 could increase the hydration of cement to generate additional hydration gel (C-S-H) needed in concrete manufacturing [14]. The chemical properties of POFA has been determined by previous researchers as shown in table 1.

Table 1: Chemical composition of POFA from previous studies

Researcher	Silicon dioxide SiO_2 (%)	Aluminium oxide Al_2O_3 (%)	Iron Oxide Fe_2O_3 (%)	Calcium Oxide CaO (%)	Magnesium Oxide MgO (%)	Sodium Oxide Na_2O (%)	Potassium Oxide K_2O (%)	Sulphur Trioxide SO_3 (%)	Loss on Ignition LOI (%)
[15]	57.8	2.3	9.6	3.6	1.40	0.56	3.50	-	20.7
[14]	26.1	8.54	4.69	54.8	0.358	0.186	0.97	2.77	0.53
[16]	47.22	2.24	2.65	6.48	5.86	1.22	11.86	9.19	5.42
[17]	43.6	11.40	4.7	8.4	4.8	0.39	3.50	2.80	18.00
[5]	57.71	4.56	3.30	6.55	4.23	0.50	8.27	0.25	10.52

2. Review on Method

2.1 Palm Oil Fuel Ash (POFA)

The experimental findings used in this study mainly collected from journal and article published in various online science databases such as scopus, science direct and google scholar. The method for processing preparing the materials used as well as the test and equipment involved according to the reearchers by reffering their journal and article published.

The POFA ashes obtained from palm oil mill were dried for 24 hours before being sieved and then immersed in the water to isolating an unfinished burnt materials. The floated substance is known to be organic material and were seerated from the POFA. Finally, the filtered POFA were dried in the oven for 24 hours at 105 ˚C ± 5 ˚C in order to eliminate moisture content before the POFA is sieved by using preference sieve size to extract larger particles. Further grinding using the same method to achieve ground POFA (GPOFA) with combustion in a gas furnance at a high temperature up to 500 ± 50 ˚C to extract unburned carbon and to produce POFA with greater fineness.

The mixture proportion of permeable concrete from different researcher with different water cement ratio are given in Table 1. 10%, 20%, 30%, 40%, 50%, 60%, 80% of POFA by weight of cement were added to the control mix to produce other mixture sample. There is no standard procedure for permeable concrete [18]. The same technique as producing normal concrete is used which is fill up the mould every 50mm height with 25 times hand tamping. Table 3.1 shows the size of mould used in different studies.

Table 2: Pervious mix design from previous studies

References	Type	W/C (%)	Void ratio (%)	Mix proportions (kg/m^3)		
				Water	Cement	Aggregate
[19]	OPC	35	15-30	104	297	1188-1337
[20]	OPC	30 35	15-30	120 140	400	1800
[21]	OPC	33	15-35	104	314	888
	10% fly ash	37			282.6	
	20% fly ash	41			251.2	
[22]	OPC	30	20-25	85	283	1620

Laundry greywater sample shall be obtained from sites that indicative of the water supply which is taken directly from the laundry machine pipe before the greywater dispense to the drainage. The storage and holding time and sampling container are arrcording to APHA method. Some sample analytes may dissolve or absorbed into plastic container wall. Correspondingly, plastic container contaminants may leach into samples. Glass container are preferable compared to plastic due to potential contaminants from phthalate ester. The sampling container should be marked with the date, place and period the sample was taken.

2.2 Testing Methods

Slump test is conducted according to BS EN 12350-2 to determine the workability and quality of the concrete during first stages where the concrete is still freshly mix. The test is compressive strength which is performed according to ASTM C39 after the concrete already hardened and have been curing for 28days before the test [9]. The compressive strength was determined on 7, 14, 28 and 90 days, respectively to show the strength improvement of the samples.

The polluted water sample collected in-situ and the sample are stored in a secure location to avoid conditions that could alter the sample properties. The research carried out in order to collect relevant data and to determine the significant parameter for water sample which is performed according to APHA.

3. Review and Discussion

3.1 POFA absorption for pollutant in wastewater

Figure 2 shows the result of absorption percentage of heavy metals after treatment of wastewater prove that POFA have a favourable impacts on the adsorption of heavy metals. The value of an adsorption for mercury is 97.92% which is the highest and followed by Lead [Pb] at 97.35%. By comparing figure 2 [25] result with figure 3 [26] that shows the removal of mercury (II) ion value is 98.93% it can be presume that the result is consistant and it shows that POFA is a good adsorption for filteration.

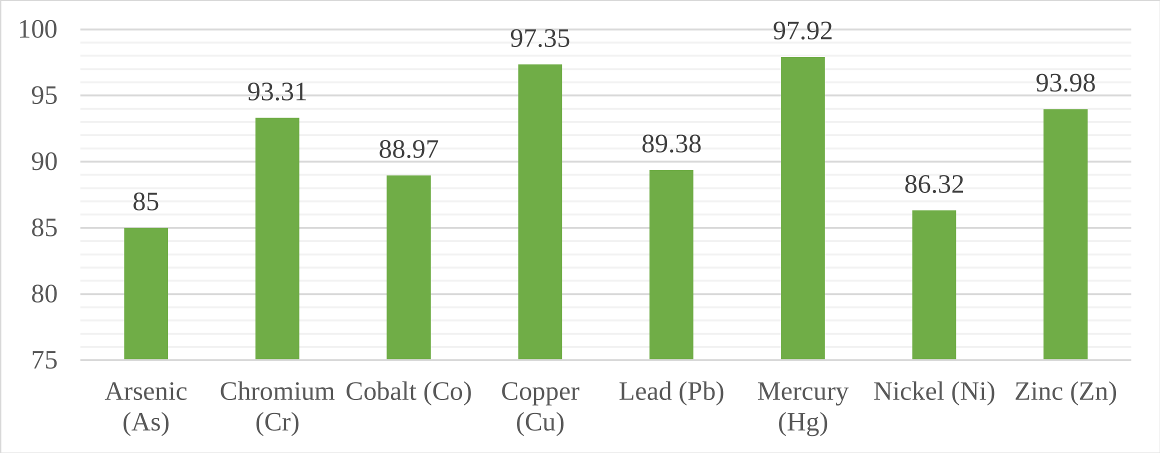

Figure 2: Comparison of heavy metal absorption in wastewater by using POFA [18]

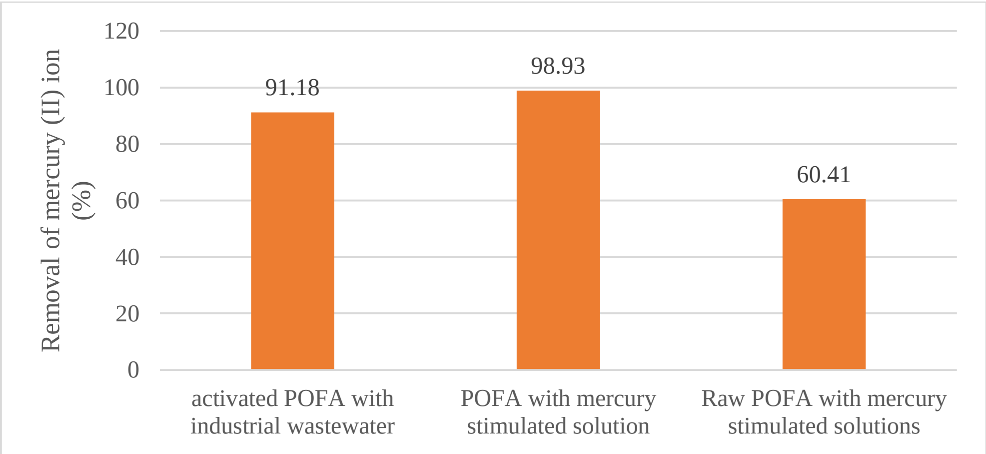

Figure 3: Comparison removal of mercury (II) ion using raw and activated POFA for mercury stimulated solution and industrial wastewater [19]

POFA in 2.00 to 3.15mm particle size are used as an adsorbent media to treat sewage wastewater [28]. Table 4 shows the percentage removal increasing when the POFA amount increase until 8 g and it suddenly decreases as the POFA keep increasing further. 8 g is the optimum dose of POFA that reach the highest removal value of 65%, 63%, 100% and 97% for COD, ammonia nitrogen, nitrate and phosphorus respectively. Upon optimum dose further absorption will not occur, the amount of removal decreases as the dosage of POFA increases. The use of 4g of POFA is the most efficient amount of COD and ammonia nitrogen removal in domestic wastewater. The removal of COD in stage 1 which are using 0 g/L POFA is low due to early phase of floc formation, by increasing the amount of POFA the removal of COD also increasing until 4 g/L. On stage 4 removal of COD start decreasing due to a reduction of POFA particles to create floc formation. The palm oil fuel ash clearly contain large amount of alumina, calcium, potassium and silica which can be used to synthesize active compounds. Thus, it shows that POFA is suitable to be use to absord pollutant in laundry greywater such as ammoniacal nitrogen, COD and phosphorus.

Table 1: Removal of pollutant in different amount of POFA

References	Type of water	POFA dosage (g/L)	COD	Ammonia Nitrogen	Nitrate	Phosphorus
			Removal (%)			
[28]		3	39	55	100	83

[28]	Sewage wastewater	5	55	59	100	90
		8	65	63	100	97
		12	49	6 0	100	93
		17	43	59	100	86
		23	41	57	100	86
		30	38	57	100	90
[29]	Domestic wastewater	0	70.3	95.3	Non reported	Non reported
		2	91.6	99	Non reported	Non reported
		4	97.8	99.3	Non reported	Non reported

3.4 Discussions

An analysis of the literature review on the use of POFA as a cement substitution in concrete emphasize sustainability practice. The present of POFA in concrete making can help on reduction of cement usage and beneficial towards the environment. There are significant amount of byproduct that are being dump at landfill without any use. The use of byproduct to produce permeable concrete for water filtration increase the filteration performance compared with normal permeable concrete. A composite of POFA can be used to remove COD, ammonia nitrogen, nitrate and phosphorus from waste water highly effective, low cost and eco friendly adsorbent.

4. Conclusion

POFA shows a good performance to be used as a binder in concrete. By using ultrafine POFA, the workability of the concrete improved and the setting time is prolong as the substitution of POFA increasing from 20%, 30%, 40%, 60% and 80% the workability of the concrete increasing to 114mm, 121mm, 132mm and 135mm respectively which can reduce the shrinkage crack on the concrete during hardening process. In addition, POFA has large proportion of silica and pozzolanic properties that help to boost the concrete strength by develop a pozzolanic reaction that produce calcium-silicate-hydrate. However, this reaction only shows the boost of concrete strength in days 28 result and the highest strength achieve by adding 20% UPOFA in OPC is 9% higher which is 52.4MPa. Whilst the highest concrete strength achieve in high strength concrete is 12.5% which is 103.5 by adding 40% UPOFA.

The efficiency of the palm oil fuel ash (POFA) as an adsorbent materials in wastewater related study based on previous studies analysis. The result of treated wastewater shows the highest removal achieve for COD, ammonia nitrogen, nitrate and phosphorus are 65%, 63%, 100% and 97% respectively at 8g/L dosage of POFA which is the optimum value for pollutant removal from sewerage wastewater. In addition, the optimum dosage of modified POFA in pollutant removal for domestic wastewater is 4g/L with removal of 97.8% for COD and 99.3% for ammonia nitrogen respectively. Raw POFA alteration increased the surface area of composite POFA and the surface area of an absorbent increased to the area required for adsorption. It can be concluded that the use of modified POFA have high capacity of adsorption and have the potential to remove pollutant according to the national water standard and it is safe to be release to the nearby stream.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for providing the facilities its support for this studies.

References

[1] Shaikh, I. N., & Ahammed, M. M. (2020). Quantity and quality characteristics of greywater: A review. In *Journal of Environmental Management* (Vol. 261). Academic Press. https://doi.org/10.1016/j.jenvman.2020.110266

[2] Zhou, Y., Wang, L., Zhou, Y., & Mao, X. zhong. (2020). Eutrophication control strategies for highly anthropogenic influenced coastal waters. *Science of the Total Environment*, *705*, 135760. https://doi.org/10.1016/j.scitotenv.2019.135760

[3] Shabalala, A. N., Ekolu, S. O., Diop, S., & Solomon, F. (2017). Pervious concrete reactive barrier for removal of heavy metals from acid mine drainage − column study. *Journal of Hazardous Materials*, *323*, 641–653.

[4] Haselbach, L., Poor, C., & Tilson, J. (2014). Dissolved zinc and copper retention from stormwater runoff in ordinary portland cement pervious concrete. *Construction and Building Materials*, *53*, 652–657. https://doi.org/10.1016/j.conbuildmat.2013.12.013

[5] Tangchirapat, W., Saeting, T., Jaturapitakkul, C., Kiattikomol, K., & Siripanichgorn, A. (2007). Use of waste ash from palm oil industry in concrete. *Waste Management*, *27*(1), 81–88. https://doi.org/10.1016/j.wasman.2005.12.014

[6] Boano, F., Caruso, A., Costamagna, E., Ridolfi, L., Fiore, S., Demichelis, F., Galvão, A., Pisoeiro, J., Rizzo, A., & Masi, F. (2020). A review of nature-based solutions for greywater treatment: Applications, hydraulic design, and environmental benefits. In *Science of the Total Environment* (Vol. 711). Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2019.134731

[7] Noutsopoulos, C., Andreadakis, A., Kouris, N., Charchousi, D., Mendrinou, P., Galani, A., Mantziaras, I., & Koumaki, E. (2018). Greywater characterization and loadings e Physicochemical treatment to promote onsite reuse. *Journal of Environmental Management*, *216*, 337–346. https://doi.org/10.1016/j.jenvman.2017.05.0

[8] Oktor, K., & Çelik, D. (2019). Treatment of wash basin and bathroom greywater with Chlorella variabilis and reusability. *Journal of Water Process Engineering*, *31*(April), 100857. https://doi.org/10.1016/j.jwpe.2019.100857

[9] Liang, X., Cui, S., Li, H., Abdelhady, A., Wang, H., & Zhou, H. (2019b). Removal effect on stormwater runoff pollution of porous concrete treated with nanometer titanium dioxide. *Transportation Research Part D: Transport and Environment*, *73*, 34–45. https://doi.org/10.1016/j.trd.2019.06.001

[10] Pistocchi, A. (2020). A preliminary pan-European assessment of pollution loads from urban runoff. *Environmental Research*, *182*. https://doi.org/10.1016/j.envres.2020.109129

[11] Ghaitidak, D. M., & Yadav, K. D. (2013). Characteristics and treatment of greywater-a review. *Environmental Science and Pollution Research*, *20*(5), 2795–2809. https://doi.org/10.1007/s11356-013-1533-0

[12] Lusk, M. G., Toor, G. S., & Inglett, P. W. (2020). Organic nitrogen in residential stormwater runoff: Implications for stormwater management in urban watersheds. *Science of the Total Environment*, *707*. https://doi.org/10.1016/j.scitotenv.2019.135962

[13] Yusoff, S. (2004). *Renewable energy from palm oil e innovation on effective utilization of waste*. *14*(2006). https://doi.org/10.1016/j.jclepro.2004.07.005

[14] Hamada, H. M., Jokhio, G. A., Yahaya, F. M., Humada, A. M., & Gul, Y. (2018). The present state of the use of palm oil fuel ash (POFA) in concrete. *Construction and Building Materials*, *175*, 26–40. https://doi.org/10.1016/j.conbuildmat.2018.03.227

[15] Nagaratnam, B. H., Mannan, M. A., Rahman, M. E., Mirasa, A. K.,Richardson, A., & Nabinejad, O. (2019). Strength and microstructural characteristics of palm oil fuel ash and fly ash as binary and ternary blends in Self-Compacting concrete.

[16] Karim, M. R., Zain, M. F. M., Jamil, M., & Lai, F. C. (2013). Fabrication of a noncement binder using slag, palm oil fuel ash and rice husk ash with sodium hydroxide. Construction and Building Materials, 49, 894–902.

[17] Abdul Awal, A. S. M., & Warid Hussin, M. (2011). Effect of palm oil fuel ash in controlling heat of hydration of concrete. Procedia Engineering, 14, 2650– 2657. https://doi.org/10.1016/j.proeng.2011.07.333

[18] Sonebi, M., Bassuoni, M., & Yahia, A. (2016). Pervious Concrete: Mix Design, Properties and Applications. *RILEM Technical Letters*, *1*(January 2017), 109. https://doi.org/10.21809/rilemtechlett.2016.24

[19] Lederle, R., Shepard, T., & De La Vega Meza, V. (2020). Comparison of methods for measuring infiltration rate of pervious concrete. Construction and Building Materials, 244, 118339. https://doi.org/10.1016/j.conbuildmat.2020.118339

[20] Borhan, T. M., & Al Karawi, R. J. (2020). Experimental investigations on polymer modified pervious concrete. In Case Studies in Construction Materials (Vol. 12). Elsevier Ltd. https://doi.org/10.1016/j.cscm.2020.e00335

[21] Saboo, N., Shivhare, S., Kori, K. K., & Chandrappa, A. K. (2019). Effect of fly ash and metakaolin on pervious concrete properties. Construction and Building Materials, 223, 322–328. https://doi.org/10.1016/j.conbuildmat.2019.06.185

[22] Aamer Rafique Bhutta, M., Hasanah, N., Farhayu, N., Hussin, M. W., Tahir, M. B. M., & Mirza, J. (2013). Properties of porous concrete from waste crushed concrete (recycled aggregate). Construction and Building Materials, 47, 1243–1248. https://doi.org/10.1016/j.conbuildmat.2013.06.022

[23] Zeyad, A. M., Megat Johari, M. A., Tayeh, B. A., & Yusuf, M. O. (2017). Pozzolanic reactivity of ultrafine palm oil fuel ash waste on strength and durability performances of high strength concrete. Journal of Cleaner Production, 144, 511–522. https://doi.org/10.1016/j.jclepro.2016.12.121

[24] Munir, A., Abdullah, Huzaim, Sofyan, Irfandi, & Safwan. (2015). Utilization of palm oil fuel ash (POFA) in producing lightweight foamed concrete for non-structural building material. Procedia Engineering, 125, 739–746. https://doi.org/10.1016/j.proeng.2015.11.119

[25] A Riduan et al. (2020). Palm Oil Fuel Ash [POFA]: innovative potential applications as heavy metal removal materials in gold mining wastewater Palm Oil Fuel Ash [POFA]: innovative potential applications as heavy metal removal materials in gold mining wastewater. https://doi.org/10.1088/1755-1315/497/1/012041

[26] Lederle, R., Shepard, T., & De La Vega Meza, V. (2020). Comparison of methods for measuring infiltration rate of pervious concrete. Construction and Building Materials, 244, 118339. https://doi.org/10.1016/j.conbuildmat.2020.118339

[27] Samad, K. A., Salleh, I. S. M., Zahari, M. A. K. M., & Yussof, H. W. (2019). Batch study on the removal of mercury (II) ion from industrial wastewater using activated palm oil fuel ash. Materials Today: Proceedings, 17, 1126–1132. https://doi.org/10.1016/j.matpr.2019.06.536

[28] Kumar, M., Abdul, A., & Hanafiah, M. M. (2020). Removal of ammonia nitrogen , nitrate , phosphorus and COD from sewage wastewater using palm oil boiler ash composite adsorbent. 149(2019), 23–30. https://doi.org/10.5004/dwt.2019.23842

[29] Wy, C., Jk, M., Yong, L., Wei, J., Sethupathi, S., & Aun, C. (2020). Chemosphere Ancillary palm oil fuel ash (POFA) in sequencing batch reactor for enhancing recalcitrant pollutants removal from domestic wastewater. Chemosphere, xxxx, 129050. https://doi.org/10.1016/j.chemosphere.2020.129050