CHAPTER 8

ADSORBENT FEEDSTOCK FROM PALM OIL MILL EFFLUENT SLUDGE

Azrul Nurfaiz Mohd Faizal and Muhammad Abbas Ahmad Zaini

8.1 INTRODUCTION

Palm oil is widely recognized as one of the fastest-growing plantations, primarily in countries with equatorial climates, and is in high demand due to its diverse product lines and applications (Koh & Wilcove, 2008). The palm oil production data of various nations worldwide is presented in Table 8.1. Countries in Southeast Asia monopolize the plantation due to the region's favourable climate and soil conditions for palm oil tree development. Tropical climate induces high average annual rainfall (1780 mm – 2280 mm), 24 °C to 30 °C ambient temperature, and high humidity environment favours palm oil trees plantation in Indonesia, Malaysia, Thailand and Africa (Saad et al., 2021).

Palm oil production over the years has achieved an overall increment almost every year since 2016. Two of the world's leading producers of palm oil, Indonesia and Malaysia, have produced an average of 56.7% and 27.36% of the oil, respectively, over the last five years (Saad et al., 2021). It is expected that the production of palm oil and its effluent will keep rising in order to meet the demand for palm oil around the world. The oil extraction rate from palm fruit was approximately 10%, with the

remaining 90% of the fruit being discarded as waste (Awalludin et al., 2015). Palm oil mill effluent (POME) is the primary contributor among the products and wastes derived from fresh fruit bunches (FFB), as seen in Table 8.2.

Table 8.1 Global palm oil production from 2016 to 2020 (Source: Saad et al., 2021)

	Thousand Metric Tons				
Production	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**
Indonesia	36,000	39,500	41,500	42,500	87,000
Malaysia	18,858	19,683	20,800	19,000	39,000
Thailand	2500	2780	3000	2800	6200
Colombia	1146	1627	1632	1529	3340
Nigeria	990	1025	1015	1015	2030
Other	5845	5960	6077	5927	12,026
Total	65,339	70,575	74,024	72,771	149,596

Table 8.2 Composition of waste or product from fresh fruit bunch production (Source: Abdullah & Sulaim, 2013)

Product or Waste	**Weight of FFB Composition on Dry Basis (%)**
Palm oil	21
Palm Kernel	7
Fiber	15
Shell	6
Empty Fruit Bunch	23
POME	28

According to reports, the amount of POME released by the industry is 2.5 times greater than the production of crude palm oil (CPO), even for a well-performing palm oil mill (Madaki & Seng, 2013). Currently, the methane emission rate per ton of POME is 28 m^3 (Sodri & Septriana, 2022). This has the potential to contribute to global warming, as methane is one of the anthropogenic greenhouse gases, along with carbon dioxide.

Sludge, by definition, is residue generated from the treatment of wastewater (Zhang et al., 2017). Currently, the management of sludge disposal has emerged as a significant environmental challenge. For decades, the treated sludge was either utilized as fertilizer or disposed of in landfills. These practices are not eco-friendly because the hazardous substances from sludge may contaminate the soil. In a proper conduct, the related factories in Malaysia are required to compensate *Kualiti Alam* for the incineration-based disposal of sludge, which is undoubtedly costly.

In response to this issue, researchers have been investigating the conversion of sludge into adsorbent materials, a path initiated in the early 2000s (Ji et al., 2022). Several studies in this field utilized sewage sludge obtained from the energy recycling process of waste, urban wastewater treatment plants, and paper mill factories. Steam, CO_2, H_2SO_4, H_3PO_4, KOH, and $ZnCl_2$ are among the activating agents used in activation. The effectiveness of the derived adsorbents has been evaluated using synthetic pollutants such as methylene blue, phenol, copper, and mercury. Although sludge-based adsorbents have a smaller surface area compared to commercial ones, their performance is highly promising (Devi & Saroha, 2017).

While activated carbon is the most commonly used adsorbent for performing the adsorption process. It has remarkable capacity for the adsorption of a wide variety of organic and inorganic compounds (Aldawsari et al., 2020). The adsorption of pollutants onto activated carbon is primarily influenced by its physical and chemical properties, such as surface area, pore volume, and surface functionalities. Nevertheless, commercial activated carbon is plagued by several drawbacks. Its precursors like coal and petroleum pitch are non-renewable, while regeneration of the spent is relatively expensive.

The current situation has prompted the exploration of alternate options that are readily accessible and cost-effective to replace the non-renewable and costly commercial activated carbon (Lewoyehu, 2021). A promising candidate under this category is sludge of palm oil mill effluent. Adsorption, as a pollution control technique, stands out for its simplicity, cost-effectiveness, and scalability (Francis & Zaini, 2023;