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Sustainable Utilization and Application of Palm Oil Fuel Ash in Various Industry: Review Article

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Abstract

In this article, the utilization and application of Palm Oil Fuel Ash in various Industry has been reviewed. POFA can be utilized to various industry such as wastewater treatment and using as alternative renewable resources. Malaysian Palm Oil Board (MPOB) in 2012 reported that the plantation area of palm oil covers about 5.07 million hectares in Malaysia. The United States Department of Agriculture reported that the production of palm oil in years 2016 and 2017 was estimated to be 64.5 million metric tons. Southeast Asian countries are the main palm oil producers. Palm oil fuel ash (POFA) is one of the significant materials produced as a by product of the palm oil industry. The quantity of POFA being produced is increasing with time due to the increase in the production of palm oil. Leaving this waste material without any further utilization is in itself an environmental challenge. Malaysia is one of the largest exporters and producers of palm oil all over the world. Production of POFA in Malaysia alone is approximately 10 Million tons/ year. Whereas, just 104 tons/year of POFA are being produced in Thailand, which continue to increase with time. This paper presents a review of the applications POFA on various industry as reported by previous studies that have been conducted to find out POFA properties and its effects. POFA is are by product and considered an environmentally-friendly substitute for various industry in replacement in production emphasizes the importance of this practice towards sustainability.

Keyword: - pofa, oil palm , wastewater, sustainability

1. Introduction

Oil palm, *Elaeis guineensis* is a tropical plant that was introduced by British to South East Asia in 1875 (Basiron, 2007). The oil palm industry is the one of most successful industry in the agriculture sector and it is considered as lifeblood for billions of people around the world. About 85% of world's oil palm supply is shared between Malaysia and Indonesia (Surendran et al., 2017). This plays an important role in bracing the Malaysian economy and hence called as 'golden crop of Malaysia'.

The current production of oil palm in Malaysia is about 19 million metric tons. This accounts for about 8% of gross national income. Oil palm produces 4 tons of oil per hectare of land (Zwart, 2013). Despite of these benefits, a kilo gram of palm oil produces four kilo grams of biomass. An oil palm fruit bunch contains 21% palm oil, 6–7% palm kernel, 14–15% fiber, 6–7% shell and 23% empty fruit bunch is produced. The world's oil palm demand is increasing every year and hence the plantation area is also keep on increasing 80 million tons of oil palm biomass was produced in 2010 and it was anticipated to increase to 100 million in the year 2020 (Rahman et al., 2014; Umar et al., 2014). Apart from these the oil processing plants also produces a considerable amount of waste. The biomass wastes include empty fruit bunches, kernel shells, fronds and trunks. The chemical composition of each wastes are listed below (table-1).

A decade before the disposal of oil palm wastes are a serious problem. Firstly, the transport cost in Malaysia is cost forbidding, it ranges between RM 66-10- 230.11/ metric ton of waste (Ooi et al., 2014). Secondly the limited availability of the landfills and finally the Environmental department of Malaysia banned the open burning due its effect on the air. Hence the waste management of these wastes is challenging.

Table 1 Chemical composition of oil palm waste (Ooi et al., 2014)

(%)	Cellulose	Hemicellulose	Lignin	Extractives	Ash
Oil palm trunk	30.6	33.2	28.5	3.6	4.1
Oil palm frond	39.5	29.8	23.3	1.7	5.7
Empty fruit bunch	37.9	35.0	24.0	2.7	1.5
Pressed pericarp fibers	39.9	28.9	20.3	-	3.6

2. Oil Palm Waste As An Alternative Source Of Energy

In recent years the above mentioned oil palm wastes are utilized as an alternative fuel for the stem generation (Teoh, 2010). It was stated that the energy used from the oil palm fiber and shell adequate to run a processing plant of 750 KWh energy. Malaysia's government states that the oil palm biomass can take over the form of the primary fuel. The contribution of renewal biomass was about RM 6379 per annum (Ooi et al., 2014). Hence this effect may probably receive a huge investment attention. However, this process of energy generation will lead to a bi-product called palm oil fuel ash (POFA). The huge amounts of these wastes are disposed by dumping them in landfills.

The major disadvantage of dumping is lead can be released from POFA and pollute the soil, water and air if POFA is disposed without proper handling. However the toxicity characteristics leaching procedure (TCLP) method (1311) states that OPA is not a toxic waste as there is no significant amount of heavy metals (Jaturapitakkul et al., 2007; Yin et al., 2008). It states that the suitability of OPA to reuse as an alternative to its disposal.

3. Physicochemical Properties Of POFA

The POFA is produced as an agricultural waste as well as the industrial waste from the boiler industries. The scanning electron microscope (SEM) analysis of POFA which was ignited at 800^{o}C revealed that POFA constitutes of spongy and porous particles. More than half the percentage of POFA is larger than 500 µm this implies that POFA are coarse in nature with less surface area (Yin et al., 2008). The POFA should be grinded in order to increase the surface are by reducing the particle size.

The elementary composition of POFA of empty fruit bunches obtained from the mills of Segamat in the state of Johor, Malaysia is tabulated in table-2. When the samples were analyzed via energy dispersive X-ray (EDX) method a noteworthy observation was made that the OPFA are not a toxic to environment.

Table 2 Elemental composition of POFA (Yin et al., 2008)

Elements	Weight (%)
Nitrogen (N)	16.48
Oxygen (O)	56.30
Magnesium (Mg)	2.27
Aluminum (Al)	0.56
Silicone (Si)	4.65
Potassium (K)	16.04
Calcium (Ca)	1.36
Iron (Fe)	0.59
Zinc (Zn)	0.33
Other	1.42

A high weight percentage of potassium was observed in the POFA materials than the calcium, aluminium, zinc and iron. It was postulated that these metal ions might present in the oxidation state since the oxygen content on the POFA is really high (Chong et al., 2012). The elemental and loss of ignition experiments state that POFA contains a larger about of organic matters this due to the high percentage of cellulose and hemicellulose present in the raw sample (table-1). In recent value add POFA has been employed to various industries due to their physic-chemical properties. Industries such as agriculture, cement manufacturing are the most common industries where value added POFA were utilized.

4. POFA- Agriculture

A value added product of POFA with decanter cake is employed as a nutrient source for bio-compound fertilizer. As shown in table-2 POFA is rich in potassium. Potassium is the one of the most important mineral required for the plant growth and hence POFA can be satisfactory palm based fertilizer. Malaysian Palm Oil Board (MPOB) has formulated a fertilizer by using POFA by enriching it with some inorganic amendments (Haron et al., 2008).

According to Haron *(2008)* have evaluated the efficient and compared to the inorganic fertilizer. The results revealed that the value added fertilizer product of POFA has the better performance index. This could be due to various reasons, one such is the pH of POFA fertilizer is 7, which could reduce the acidity in the soil. Secondly the bio-fertilizers are effective in supplying the balanced level of nutrients which is high in nitrogen, potassium and phosphorus and low in calcium and magnesium. The significant increase in the growth of the plants was due to slow release of the organic material from the POFA and also the high concentration of organic carbon in POFA would increase the nutrient uptake in plants. Thus the value added POFA mixture is not only a cheaper bio-fertilizer, but also reduce the soil waste disposal problem.

5. POFA In Fabrication Of Cement Bricks

Another form of recycling of POFA is to investigate the utilization of POFA in Portland cement. The lack of calcium in POFA is extremely low (table-2) when compared to the conventional cement (≥ 30 wt %). In this case if cement is replaced with POFA, leads to the imbalance in the stoichiometry in turn leads to the loose of strength in the cement, this is because calcium plays an important role in strength. Apart from this POFA is rich in organic matters due to the cellulose presentation. It is believed that organic matters can interfere in the cementitious reaction and leads to the hydration. The hydration thus produced will lead to disturbance in the micro-structure, mechanical strength and in the leaching property (Rukzon and Chindaprasirt, 2009; Sata et al., 2004).

Hence the grounded POFA substituted in 10-30% in Portland cement has significantly increased the strength when compared to the conventional cement. Although the POFA is limited in calcium concentration, it is rich in the silica concentration. Hence the silica in POFA reacts with the calcium and strengths the cement by enhancing the interfacial bond. The other added advantage of POFA is that they are resistance to fire and has very low ability to spread the flame around. Hence this can be called as non-combustible material (Jaturapitakkul et al., 2007).

6. POFA In Rubber Industry

The POFA is introduced in the cut the cost involved in the production of polymers. A study was conducted on this basis by adding POFA from 10 phr to 40 phr. However the results obtained were adverse with the reduced properties in tensile strength, elongation at, fatigue life and rubber-filler interaction (Najib et al., 2009). This is due to the hydrophilic nature of the ash and causes poor adhesion of ash to the natural rubber. This undesirable properties can be overcome by using hybrid fillers such as POFA/ silica (Ismail and Shaari, 2010) and POFA/halloysite monomers (Ismail and Haw, 2008). This helps to ash to adhere to the natural rubber and increase the tensile strength. A study on utilizing of POFA at low filler concentration at 1 phr increased the desirable qualities of the rubber. When 16% at 1 phr of POFA was loaded it significantly increased the tensile strength and elongation at break. The result obtained in this study was similar to industrially used carbon black in 50 phr (Ooi et al., 2013).

7. POFA In Reduce The Environmental Pollution

Apart from being an additive to the cement and rubber, POFA are wonderful absorbents of poisonous gas and heavy metal ions form the gases as well as from the liquid form. Sulfur dioxide is a poisonous gas produced from the combustion of fuel in solid and liquid form. Sulfur dioxide is considered as toxic to human health. 100% of 500 ppm sulfur dioxide was removed when POFA was mixed with calcium oxide and calcium sulfate. When the concentration of sulfur dioxide was 2000 ppm the POFA mixture was able to remove 90% of the sulfur dioxide in 26 minutes (Zainudin et al., 2005). Studies have conducted on the ability of in POFA chitosan to remove the dye materials from the solution. POFA successfully removed the dyes such as disperse blue, disperse red and acid green 25 dye for the aqueous solution (Hasan et al., 2008; Isa et al., 2007). However, the activity of POFA beads is based on the pH of the solution.

The heavy metal ions are commonly present in waste water of many industrial plants. In the point of public health and environmental protection, these effluents should be treated to remove the metal ions before their discharge. Most of the heavy metal ion removal techniques such as ion exchange, chemical precipitation and reverse osmosis are expensive and less effective (Ooi et al., 2013). Due to the POFA high adsorbent capacity, they are the potential candidate for the removal of heavy metal ions in cost effective manner. Various metal ions such as As, Cu, Cr, Cs, Fe, Hg, Ni, Pb, Zn are removed by the value added POFA products in the model solution (Ahmad et al., 2011; Aziz et al., 2014; Daud et al., 2017).

8. Challenges in the use of POFA

The chemical constituents are not similar to the POFA collected around the oil palm mill of Malaysia. A huge difference was observed in the concentrations of silicon oxide, calcium oxide, aluminum oxide and magnesium oxide. The mineralogical composition of POFA depends on various factors such as geographical conditions, fertilizers used, age of the palm, agronomic practice, soil chemistry and the oil palm growth process (Foo and Hameed, 2009). Further the ash obtained from the same tree has difference compositions due to different levels of nutrient absorbed and transported inside a tree is not uniform and it may vary from time to time. Hence this property might greatly affect the strength of the cement, the elasticity of the rubber etc. To prevent this variation, the oil palm raw materials should be selected before the combustion.

9. Conclusion

Concern about environmental protection has increased over the years from a global viewpoint. To date, the infiltration of oil palm ash into the groundwater tables and aquifer systems which poses a potential risk and significant hazards towards the public health and ecosystems, remain an intricate challenge for the 21st century. With the revolution of biomass reutilization strategy, there has been a steadily growing interest in this research field. Confirming the assertion, this paper presents a state of art review of oil palm ash industry, its fundamental characteristics and environmental implications. Moreover, the key advance of its implementations, major challenges together with the future expectation are summarized and discussed. Conclusively, the expanding of oil palm ash in numerous fields of application represents a plausible and powerful circumstance, for accruing the worldwide environmental benefit and shaping the national economy.

A forecast for the next decade indicates a drastic increase in the agriculture waste that is the oil palm residue. Therefore, the POFA disposal problem becomes a greater issue for the Malaysian government. POFA is potential additives for the bio fertilizer, cement, rubber and in waste treatments. Most of the researches conducted on POFA utilization are still under lab scale. Malaysian government should encourage the POFA in the industrial sectors.

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