PALM KERNEL SHELL ACTIVATED CARBON FOR WASTEWATER TREATMENT: A CONTINUOUS ADSORPTION SYSTEM

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Activated carbon from biomass is an alternative adsorbent for the industrial sector. It is popular because of its well known efficiency for the removal of pollutants and heavy metals in wastewater treatments, abundance raw material, low price, and ease of use. Activated carbon from oil palm biomass is therefore considered as environmentally sustainable and economically viable. Oil palm biomass is generated from the mill and is available at the mill site. Owing to these advantages, the raw material, transportation, and operating costs can be minimised. Palm kernel shell (PKS) is a suitable precursor for activated carbon production due to its high density, high carbon content, and low ash content. Activated carbon from palm kernel shell (AC-PKS) can be produced by carbonising the biomass at temperature below 500°C and converting it to biochar activate at high temperature of above 800°C through physical or chemical activation methods. The two-in-one carbonisation activation system was developed to improve production efficiency by combining the separate processes of carbonisation and activation into a single system (Nahrul Hayawin *et al.*, 2018). The two-in-one carbonisation activation system has been patented as a state-of-the-art technology for carbonising oil palm biomass and simultaneously producing activated biochar carbon from oil palm biomass using a self-sustained system (P20120522(MY); P20120636(ID); P20120638(PH); P20120637(TH)). The AC-PKS produced has a great surface area of 935 $m^2 g^{-1}$. The treatment of palm oil mill effluent (POME) final discharge using AC-PKS has been tested on a continuous pilot-scale plant, resulting in a great reduction of pollutants in POME final discharge. The performance of the system and the effectiveness of AC-PKS were compared with activated carbon coconut shell (AC-COCONUT) using similar range of dosage and treatment time. In comparison with AC-COCONUT, the AC-PKS had performed effectively in reducing biological oxygen demand (BOD), chemical oxygen demand (COD), colour, suspended solids (SS) and ammoniacal nitrogen by 84.72%, 94.55%, 98.90%, 91.85% and 99.90%, respectively compared to 78.61%, 71.00%, 89.80%, 77.41% and 64.20% when using AC-COCONUT (Nahrul Hayawin *et al.*, 2020).

NOVELTY

The continuous adsorption system relates to a concept of a green process without the use of chemicals for POME final discharge treatment comprising two important principles, *i.e.* (1) pre-treatment by a biological method using extended aeration activated sludge process and (2) activated carbon process (*Figure 1*). The green process for POME final discharge treatment comprises the following steps:

1. Production of activated carbon oil palm kernel shell using the physical activation method
2. Biological treatment method using effective microbes in activated sludge process
3. Physical-chemical adsorption on the activated carbon treatment process
4. Treated POME final discharge can be used as a recycle water for the backwash of sand filtration and activated carbon column
5. Spent activated carbon can be reactivated or used as an organic fertiliser for vegetative plants as it contains beneficial enriched nutrients such as nitrogen, phosphorus, and potassium from the adsorption of POME final discharge.

THE BENEFITS

A novel integrated system comprising an activated sludge process with suspended packing system

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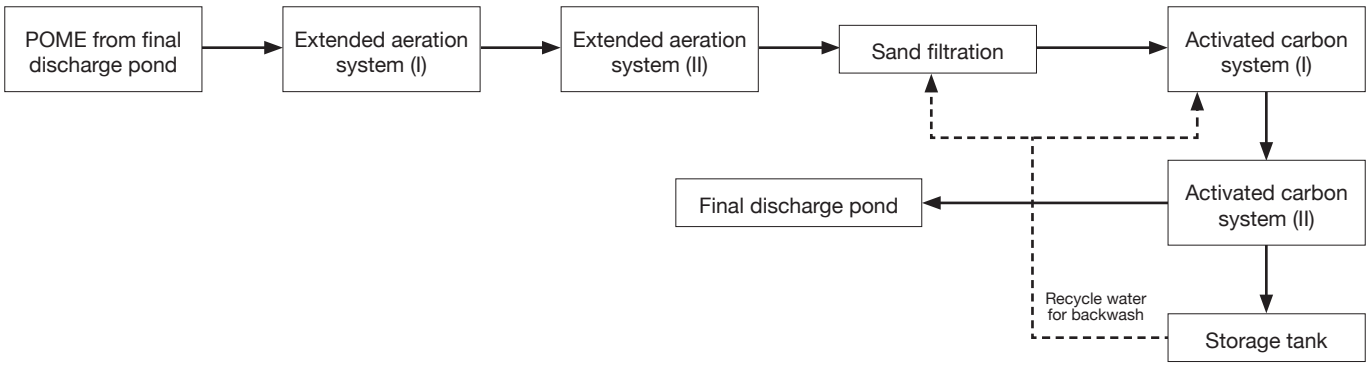

Figure 1. The patented process flow system for the integration of extended aeration with bio-filtration activated carbon on colour adsorption in palm oil mill effluent (POME) final discharge.

and bio-adsorption system in series was developed for POME final discharge treatment. Almost 100% of BOD, COD, SS and colour could be removed during the first 24 hr, producing clear water and almost 90% removal throughout the process. The activated sludge process with suspended packing system mainly contributes to the reduction of BOD, COD and suspended solids sand filtration while activated carbon is mainly responsible for the high removal of pollutants (BOD, COD, SS) and colour through physical-chemical adsorption as well as enrichment of the spent activated carbon by adsorption of the nutrients in POME (Nitrogen, Phosporus and Potassium). After treating POME with the integrated system, the pH of the wastewater is alkaline. The treated POME is non-toxic towards aquatic biota. The integrated system has the capability to integrate with the existing treatment system in the mill, *e.g.* aerobic pond + activated carbon system, ultrafiltration (UF) + activated carbon system, membrane + activated carbon system, final discharge pond + activated carbon system, *etc*. Therefore, this will streamline the wastewater treatment processes, reduce costs and ensure high efficiency. This process will provide more advantages particularly to the palm oil industry, and generally to other industries to meet the standard requirements.

ECONOMIC FEASIBILITY

The estimated cost to build up the continuous adsorption system with a capacity of 50 m^3 hr^{-1} is RM350 000. The net present value (NPV) at a 10% discount rate is RM216 836. A profitability index of greater than 1, which is 1.62, and an internal rate of return IRR of 23% can be achieved, therefore the investment is expected to be financially feasible. The installation of the proposed integrated system will be more profitable in the long run installed by the palm oil millers where the electricity is generated from the energy and steam released during the carbonisation of PKS. Revenue can be generated from the biofertiliser (spent activated carbon) and treated water (recycled water for wet scrubber / cooling tower *etc*).

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