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Compost-Based Activated Carbon Analysis as a Filter of Waste-Washing Wastewater Treatment in Compost-Adsorption Reactor

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Abstract— The approach of this paper is to give evidence that compost, commonly produced by organic waste treatment, can be further utilized and treated as a precursor of activated carbon for Waste-Washing Wastewater treatment. The inorganic waste treatment generates harmful Waste-Washing Wastewater as by-product which is unreliable to total zero waste term in the integrated solid waste management. The Application of Compost-Based Activated Carbon is as filter for contaminant adsorption to be made as Compost Adsorption reactor for optimum treatment. The results show that Compost Adsorption treatment has a very good efficiency of high-turbidity removal and allows phosphate removal.

Keywords— total zero waste; compost-based activated carbon; waste-washing wastewater treatment

I. Introduction

Zero Waste (especially the one targeted to be achieved in 2020 in Indonesia) has been set to ensure that no waste will end up as prolonged waste that stored in an open nature. In spite of its promising future, it intensively needs people's full responsibilities and willingness to treat waste by applying proper municipal solid waste management. By this management, all kind of waste category needs to be sorted as organic (degradable) and inorganic (reusable and recyclable) waste, that leaves a small portion of commingled waste that needs to be land filled with routine covering. Material Recovery Facility (MRF) and Unit Pengolahan Sampah/UPS (English: Solid Waste Treatment Unit) are the sites where zero waste optimization is quite promising since all the sorted materials can be treated properly according to each category characteristic, for MRF is intended to all inorganic and UPS is for organic. Table 1 describes main activities should be done for proper solid waste management. Almost all treatments for each category require water to treat the waste, especially to wash the reusable and recyclable waste to remove away the dirt attached in the waste materials. In a developing MRF called Zero Waste Indonesia (ZWI) which located in Depok, West Java, it approximately needs 3 m^3 /day of water to wash and clean the inorganic waste, mostly recyclable waste.

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In accordance with that large demand of water for a house-hold scope, there cannot be avoided for the ZWI to discharge the contaminated waste-washing wastewater (3W) to the ground or surface water current, unless if any treatment unit is applied. As this happens, the term "total zero waste" cannot be any longer appropriate for this waste management since it produces contaminated (and sometimes harmful) wastewater to the environment that will eventually pollute the surface and ground water.

Apart from the adverse 3W production, according to Ministry of Public Work and Housing, there is another high prioritisation to combat organic waste as it is produced more than a half of the entire household solid waste generated, while household solid waste generation is 50% of all solid waste generation composition [1]. This makes government in Indonesia emphasizes composting to be applied in all areas to reduce organic waste and to produce compost product at once. Since it utilises all-natural decay ability, organic waste requires no added energy to ensure composting process occurs as it supposed to. In UPS Merdeka, Depok, West Java, because of the organic waste treatment in the city has been well-managed, the compost amount has been increasing and can fulfil more than the public would need for soil fertilizer.

It has to be noted that compost contains carbon as the most significant macronutrient, which often represented as carbon-to-nitrogen ratio or C/N [2]. The most ideal mix of compost materials' C/N content should be 20:1 to 30:1 in total, while each material can contain from 12:1 to 850:1 [3]. Therefore, compost in UPS Merdeka is a carbonaceous material which comprises of most food and yard waste and leaving it has a good C/N content In the other hand, almost of all carbonaceous materials can be activated to produce activated carbon (AC), and AC has the ability of contaminants adsorption in water and has been used for a long time in typical water filtration. For this reason, compost is expected to be able to be activated by making it as compost chars first [4] and to be later made as Compost-based Activated Carbon (CBAC). Towards this end, the total zero waste can be maximally achieved since there is a brand new application of treating waste (from waste-washing process) by waste treatment product (of degradable composting process).

We have to bear in mind that the AC adsorption (in filtration) is commonly and effectively used only as remover of trace organic impurities and decolourizer in potable water [5], which means it can hardly treat highly contaminated water since the 3W has numbers of high content of impurities.

Table 1 Waste Material Category with Its Treatment Activities

Material	Category of Material (major examples)	Treatment	Requirement	Production	By-product generation
Organic	Degradable (food waste, yard waste, toilet paper, cardboard, etc.)	Composting process	Composting basin, **water**	**Compost**	Leachate
Inorganic	Reusable (plastic, iron and ribbon-made material, etc.)	Cleaning, repairing, crafting	**water**, tools, paint, etc.	New goods	**Waste-washing Wastewater (3W)**
	Recyclable (plastic, iron-made material, etc.)	Washing, shredding, recycling	**water**, waste shredder	Shredded materials	**Waste-washing Wastewater (3W)**

According to the process chosen (adsorption), therefore the Compost Adsorption reactor is considered to represent this new innovation for wastewater treatment unit. For showing the best analytical unit's efficacy, a Compost Adsorption reactor is required to represent its performance and capacity under the real application. Chemical and physical parameters (phosphate and visual turbidity, respectively) also have been set to explain its removal capacity thoroughly of the removal of detergent-affected content as well as the turbid-causing solid in the 3W. Phosphate (represented as PO_4) is widely known as parameter that is increasingly arising as the detergent content of water is getting higher. As waste-washing processes require detergent to washed the material away, then phosphate is considerably important to show the Compost Adsorption reactor performance. While turbidity is the majorly concerned parameter that can show water purification process.

II. Methods

An inductive approach as the research strategy was used in this paper, which a case study was done in a developing MRF named Zero Waste Indonesia (ZWI) for assessing its wastewater (3W) generated. The idea later came out and led to the hypothesis, started with the capability of compost as carbonaceous material to be converted into compost chars to produce the activated carbon used in the filtration unit. To fulfil this research strategy, an experimental methodology was conducted by a field experiment of using Compost Adsorption reactor, and a laboratory experiment to test the determined parameters. The chosen parameters were the chemical and physical ones, they were phosphate and visually-turbidity, respectively.

A. *Materials*

For the CBAC making that uses CCC (char, chemical, cook) methods [6], there were needed any organic compost taken from UPS Merdeka, some grams of technical $CaCl_2$ solid to solute as chemical reagent , distilled water, a can container, metal spoon, and a house-hold oven. For the Compost Adsorption reactor needs, there were required all used or second-hand materials (no bought ones) like a transparent bucket, two 600 ml-used bottles, a knife/cutter, glue gun, as well as the filling filter media materials like coarse and fine gravel, and sand. For the laboratory work for chemical testing, it was needed the molybdate reagent and a spectrophotometer to test the phosphate content. As for the physical parameter testing, there were used for cleaned glass bottle to give the best comparison.

B. *Procedures*

Compost precursor was requested and taken from the waste treatment unit (Bahasa Indonesia: Unit Pengolahan Sampah/UPS) Merdeka which is located in Depok, West Java. The compost was later being filtered by a range of 1-mm^2-to-4 mm^2 sieve to select its finer grains. This was done because the smaller grain size of compost offered a quicker charring process and lower oven temperature during the process. The charring process should be done to assure that carbon is the only content left from the compost as it is the only material that can be activated by the chemical reagent. By using a typical household oven, fine-grained compost was baked until they were all changed into chars with all-black surface. Then, the compost chars were prepared to be activated by a 25% solution of $CaCl_2$ (Calcium Chloride) which can be widely found in any chemical stores. To make the 25% $CaCl_2$ solution, one-fourth part of technical anhydrated-$CaCl_2$ was measured to be later added to three-fourth part of distilled water. It was used the term of weight/volume, as the weight (in grams) is equivalent to the volume term (in mL), therefore to make 1000 mLs of 25% $CaCl_2$, 250 grams of $CaCl_2$ solid equals with the adding of 750 mL of distilled water. The solution was then poured to the compost chars to be made like paste, and then it was stored in a dark and room-temperature room for a 24-hour long.

The paste was later washed away with distilled water to ensure the absence of any trace organic contaminants, and then filtered with a clean tea filter that had been previously washed by distilled water. Then the char was dried in an oven for a 30-minute long or until the char was all dry. After the CBAC was prepared, the Compost Adsorption reactor was made with AC filtration [7] principals (See Figure 1 and 2). For assessing the effluent discharge in the Compost Adsorption reactor, 600ml-bottle that had been cut its bottom part was positioned upside-down, and then the filtration media were arranged (coarse grains in the bottom/bottle's smaller opening).

After the field experiment was all done, there were 2 samples stored in 2 clean and sterile bottles; AC and 3W. These samples were brought into laboratory of Health and Environmental Engineering in Faculty of Engineering, Universitas Indonesia to be checked their phosphate content.

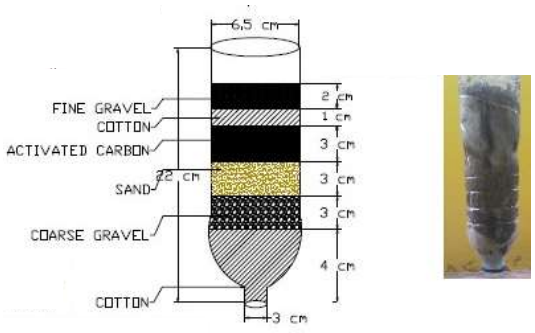

Figure 1 Compost Adsorption Reactor

III. Results

A. *Compost Adsorption Reactor Design and Analysis*

The Compost Adsorption reactor is a treatment unit that consists of activated carbon adsorption-filtration. As for the filtration type, this vertical is chosen as it requires less spaces and there only needs to catch the water effluent from the influent to the AC reactor one, so there would not need of any connecting wire that flowing the water artificially. The picture below is the detail of Compost Adsorption reactor water flow scheme.

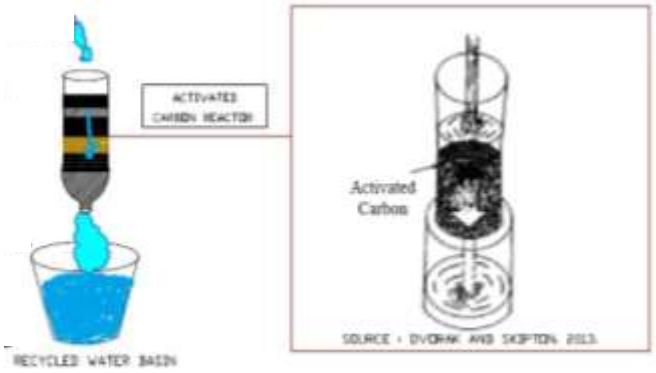

Figure 2 Compost Adsorption Reactor's Water Flow Scheme

B. *Result and Comparison of Chemical and Physical Parameters*

1) Chemical

In Table 2, There are the laboratory testing data of phosphate content in samples taken. The asterisk signs indicate that it is the 3W sample. However, as it was used double sampling for each kind sample while working in laboratory to test phosphate parameter, so there actually are two numbers of concentration for sample.

Table 2 Phosphate Concentration Data in Samples and the Removal Efficiency of Reactor

No	Sample in reactor	Initial concen-tration (mg/L)	Phosphate concentration (mg/L)	Removal efficiency (%)
1	AC reactor	16.1	10.34	35.77

2) Physical

(a) (b)

Figure 3 Comparison for Visual Turbidity of Samples; (a) AC Reactor and (b) Waste-Washing Wastewater (3W)

According to Figure 3 shown above, there is a very significant difference between each bottle of sample, that it can easily depict from the picture that the effluent water discharged from Compost Adsorption reactor (Figure 3, a) is show that most turbidity has been removed away during the detention time in the Compost Adsorption reactor compared to the 3W turbidity (Figure 3, b).

IV. Discussion

A. *Properties, Impurities, Treatment Consideration of 3W*

As discussed previously, most of the waste management activities generate wash wastewater (3W). To handle this, 3W. In the observation carried out in MRF Zero Waste Indonesia, the amount of 3W produced each day is 3 m^3 that equals to 1 ton of plastics processing in a day for maximum capacity of the crusher machine. The using of soap/detergent then makes the phosphate content is a major concern in this study alongside with the turbidity, colour, TSS, TDS, and the other contaminants that produced by the plastic waste that still contain the residue. Phosphate can cause eutrophication and algal bloom if wastewater from washing machines merges into water bodies without the right treatment. Also, with less phosphorous content in the wastewater, treatment plants can reduce chemical use and sludge [8]. It would be useful if a breakthrough is found and there is an efficient way to reduce the levels of pollutants in the wastewater, especially phosphate.

Figure 4 Waste-Washing and Grinding Process in MRF Zero Waste Indonesia (The Blue Colour is The Waste Being Washed)

B. *Properties of Compost Chars and CBAC*

Figure 5 (a) Compost Char Paste, (b) Compost-Based Activated Carbon (CBAC)

According to this experiment, compost chars (see figure 5, a) stand for the char or black-burned grains those produced after burning the compost grains in a 200-250°C oven for 1.5 to 2 hours long. Since the grains of compost have been filtered first, they have quite uniform grain size unless there was careless filtering process so that there are still coarse grains mixed. Compared to the making of typical common activated carbon from corn stillage or coconut shell, the making of compost char is far and a lot quicker as it only takes a half-time (or more) of coconut shell or corn stillage 4-hour to 6-hour charring [9] Gomez, n.d.). The heat required is also much lesser than the heat of it is commonly required, since according to Tsui and Roy (2008), the temperature of pyrolysis (charring) required for corn stillage reaches 900°C.

As for the activation process, all types of char require a-full-day storage in a dark and room-temperature condition for the chemical solution is in progress of soaking the ash. After a long-day period of waiting and char-paste washing to leave the char remains only in activated carbon form, there only should be needed around 30-minute-long to wait the paste until dried out, before it used as CBAC (see figure 5, b). According to Tsui and Roy (2008), the use of compost to be the precursor of AC is advantageous as compost is more thermally stable than the most agricultural waste. It also found out that even CBAC has less measured less area, but it has good affinity for the environmental pollutant like pesticide.

As the carbon activating procedures was not done in laboratory, the sterility is not guaranteed and therefore it can lead to error results. Moreover, the laboratory test was only done in a scope of wastewater contaminants removal instead of AC adsorption performance test with Methyl Orange test or Iodine test, thus accordingly make the authors cannot ensure whether or not the removal results was due to CBAC performance, as there have been still any other treatments like phytoremediation and filtration of media except the AC.

C. *Compost Adsorption Recycled Water Reusability and Quality Compared to Ground Water*

According to the chemical and physical results in section three, it is showed that the recycled water discharged from Compost Adsorption reactor has met and satisfied visual-turbidity required for being used as further waste-washing storage. But according to the phosphate content, it still shows a quite high concentration even for the sample taken from Compost Adsorption reactor. As according to Government Rules Number 82 (2001), the Compost Adsorption recycled water can only be classified as category of water number IV which utilised as irrigation water. But according to PAM Lyonnaise Jaya (water supply installation for western Jakarta) in a student excursion occasion, activated carbon has been the only and most effective treatment material that can adsorp phosphate. Therefore, a further experiment is going to be sooner continued with any advanced tests in all-laboratory environment work, so that the sterility and confidence limit can be increased.

D. *Advantages of Compost Adsorption Reactor*

There is one thing that Compost Adsorption reactor can give benefit while the usage of AC filtration reactor component can act effectively as the replacement of disinfection. It is so relieving after facing the fact that disinfection usually harms people with another harmful-adverse contaminant such as trihalomethanes (Dvorak and Skipton, 2013). The AC adsorbents are widely used as the remover for toxic materials contained in the water. Therefore, reducing as many contaminants in the 3W is the main goal of the Compost Adsorption reactor, and making the reactor well-applied and user friendly is our goal as authors.

Moreover, towards the drought calamity that most places in Indonesia are facing, the Compost Adsorption can effectively be utilized to purify the water taken from most surface water sites of rivers and lakes in Indonesia, where the water often shown in brown or even black due to high pollution. Therefore, it can hopefully help the dwellers to restrain from the lack of ground-clear water due to the drought happened after long lag of rains. With the help of Compost Adsorption reactor, people can produce a-lot cleaner water for at-least washing the clothes, and by with the addition of one more AC reactor, it hopefully can provide a cleaner and clearer water compared to the water produced only by one AC reactor. Towards this end, the water can fulfil the need of clean water for bathing and drinking (with a boiling first).

V. Conclusions

This research study demonstrated that compost as the product of degradable solid waste treatment (which is also part of organic waste that has been adversely impacted to society due to its lack of treatment awareness and responsibility) can be utilised as precursor for activated

carbon since it is a carbonaceous material. The AC is arranged in a Compost Adsorption reactor to treat 3W which is also a by-product of recyclable and reusable materials treatments in washing process. Although the Compost Adsorption performance indicates a significant removal of visual-turbidity and phosphate content, it cannot be thoroughly proven whether the removal is due to the significant work of Compost Adsorption filters or not, or whether there has already been a proper and sterile procedure of AC activation or not. Thus, there is a strongly required further research that indicates AC capacity and strength using proper AC test, and also there would be needed a full lab-scale compost char activation that guarantee the sterility and properness of every step done.

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