Performance of Spent Mushroom Farming Waste (SMFW) Activated Carbon for Ni (II) Removal

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Abstract. The feasibility of a low cost agricultural waste of spent mushroom farming waste (SMFW) activated carbon for Ni(II) removal was investigated. The batch adsorption experiments of adsorbent dosage, pH, contact time, metal concentration, and temperature were determined. The samples were shaken at 125 rpm, filtered and analyzed using ICP-OES. The fifty percent of Ni(II) removal was obtained at 0.63 g of adsorbent dosage, pH 5-6 (unadjusted), 60 min contact time, 50 mg/L Ni(II) concentration and 25 °C temperature. The evaluated SMFW activated carbon showed the highest performance on Ni(II) removal compared to commercial Amberlite IRC86 resin and zeolite NK3. The result indicated that SMFW activated carbon is a high potential cation exchange adsorbent and suitable for adsorption process for metal removal. The obtained results contribute toward application of developed SMFW activated carbon in industrial pilot study.

Keywords: Activated carbon, adsorption, Ni(II) removal, spent mushroom farming waste (SMFW).

1. Introduction

Increasing industrialization has led to increase environmental problems due to the presence of metal in wastewater. Ni(II) was selected for treatment due to its widespread applications in industrial processes such as mining, electroplating and nickel-cadmium batteries. Ni(II) is a trace metal and is beneficial to human at low concentration. However, it accumulates become high concentration. A long-term exposure time, it causes chronic effects to human health such as lung cancer, renal disorder and skin dermatitis [1].

Most of the conventional methods in metal removal such as precipitation, membrane filtration, solvent extraction and electrodialysis are found to be inadequate [2]. This is due to high cost and inefficiency in low concentration of metal [2]. Conversely, adsorption technique is a treatment technology that gains attention of researches. Adsorption is a physico-chemical process where contaminants are bound to the carbon surface by intermolecular attraction using adsorbent. It offers advantages of low cost and simple operation [3].

Recently, the development of cost effective, highly efficient as well as eco-friendly materials as adsorbents is of great concern [2]. Activated carbon (AC) is one of the most widely used adsorbents for the adsorption of pollutants [4]. AC from SMFW is a low cost adsorbent consisting of sawdust and rice husk. Previous study by [1] in removing Ni(II) using raw SMC has shown that SMC has a potential in application of metal removal. Many previous studies by [5],[6], [7], [8] and [9] have carbonized sawdust and rice husk to generate high porosity of AC. This shows that both components of sawdust and rice husk have a great potential to produce high porosity of carbonaceous AC and suitable for application on adsorption of metal removal. Therefore, AC from SMFW has been selected in this study as there is lack of sufficient literature review on utilization of SMFW in AC preparation and application on metal removal.

This study aims to evaluate Ni(II) removal by spent mushroom farming waste (SMFW) activated carbon. The objectives of this study include optimization concerning performance on Ni(II) removal of the following parameters: adsorbent concentration, pH, contact time, Ni(II) concentration and temperature. Comparison with the commercial resin Amberlite IRC86 and zeolite NK3 were used to evaluate SMFW activated carbon performance on Ni(II) removal as they are widely used in local market.

2. Materials and methods

2.1 Materials

Spent mushroom farming waste (SMFW) used for preparation of activated carbon was provided by C&C Mushroom Cultivation Farm, Johor, Malaysia.

2.2 Activated carbon preparation

The preparation of AC from SMFW was accomplished using potassium hydroxide (KOH) as activating agent. The KOH is responsible for the enhancement of pores formation due to the intercalation of metallic potassium (K) in the carbon structure. The SMFW was impregnated with 3 M KOH for 24 hours respectively. The slurry was then dried at 80°C for 24 hours. The impregnated precursor was carbonized in furnace at 500°C with heating rate of 10°C/min. The produced char was washed with hydrochloric acid and distilled water to remove residual KOH and dried at 80 °C. Finally, the prepared AC was sieved to size of 150 micrometer and kept in drying cabinet prior to use. The AC preparation was indexed according to the procedure by [10].

2.3 Batch adsorption experiment

Batch adsorption experiments were carried out by weighted SMFW activated carbon adsorbent from 0.1 – 0.8 g. 50 ml of 50 mg/L Ni (II) solution was added into 250 mL Erlenmeyer flask and was agitated in an incubator shaker at 125 rpm for 60 minutes at 25 ^{o}C. The solutions were filtered and the filtrates were analyzed using ICP-OEM (7300DV, Perkin Elmer, USA). The parameter study includes initial pH in the range of 2 to 6, contact time of 1 min, temperature of 5 ^{o}C to 45 ^{o}C and Ni (II) concentration in the range of 10 to 60 mg/L. The sample was prepared in duplicated and the percentage of Ni (II) removal was calculated as described as equation (1)

$$percentage\ of\ metals\ removal = \frac{C_o - C_f}{C_o} x\, 100\% \qquad (1)$$

where;

C_o= initial Ni (II) concentration (mg/L)
C_f = (final) Ni (II) concentration in solution (mg/L).

2.4 Evaluation of prepared adsorbent

The evaluation of SMFW activated carbon was carried out corresponding to the optimum condition prepared in batch adsorption experiment. 0.63 g of SMFW activated carbon was weighed in 250 mL Erlenmeyer flasks. The samples were agitated at 125 rpm for 60 minutes at 25°C in an incubator shaker. The solutions were filtered and the filtrates were analyzed using or ICP-OES (7300DV, Perkin Elmer, USA). Experiment was repeated using Amberlite IRC86 and zeolite NK3.

3. Result and discussion

3.1 Adsorbent amount

Figure1 shows the effect of increasing adsorbent concentration on the percentage removal of Ni(II). Ni(II) percentage removal was increased from 14.26% to 55.03% by increasing the adsorbent concentration at 0.1 g to 0.8 g. This is due to the availability of more active binding sites of surface functional groups and higher surface area [11]. The trend is identical for Ni(II) removal by almond husk activated carbon and doum seed activated carbon by [12] and [13] respectively. According to study by [1], half-saturation constant of fifty percent Ni(II) removal was applied since the experimental data did not show a clearly defined saturation stage. For this study, the half saturation constant of 0.63 g is determined using the sigmoidal curve fitting with r^2 of 0.9918.

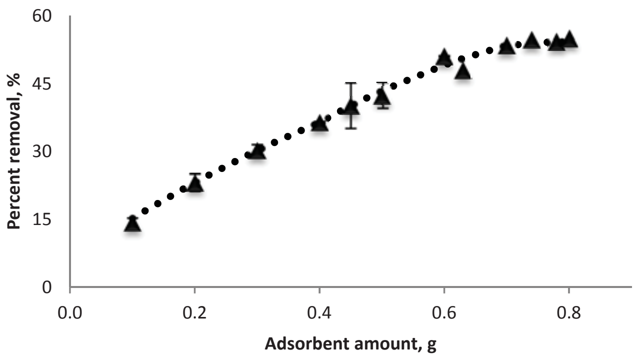

Figure 1. Effect of adsorbent amount on Ni(II) percent removal.

3.2 pH

Figure 2 illustrates the effect of pH ranging from 1 to 6 on percentage removal of Ni(II). The percentage removal of Ni(II) has gradually increased up to pH 4. An increase in metal ion removal as pH increased can be explained on the basis of a decrease in competition between proton (H^+) and positively charged metal ion at the active binding sites of surface functional group. Meanwhile, a decrease in positive charge of proton (H^+) has resulted in a lower repulsion of the adsorbing metal ion [7]. At saturation range pH 4-6, no further increase in Ni(II) removal was observed due to saturation of active binding sites of surface functional group by the cations. At alkaline pH, lower binding sites were attributed to metal hydroxide precipitation of $Ni(OH)_2$ [11], [13], [14], [3] and [2] described a similar trend of pH using olive stone activated carbon and sugarcane baggase pith activated carbon respectively. Table 1 shows the comparison of optimum range for Ni(II) removal using various types of activated carbon. This developed SMFW activated carbon has a comparable optimum pH with other recent studies. The pH 5-6 has been chosen in this study due to its highest performance of ion exchange between cation in the solution and surface sites as well as minimal use of chemical on pH adjustment.

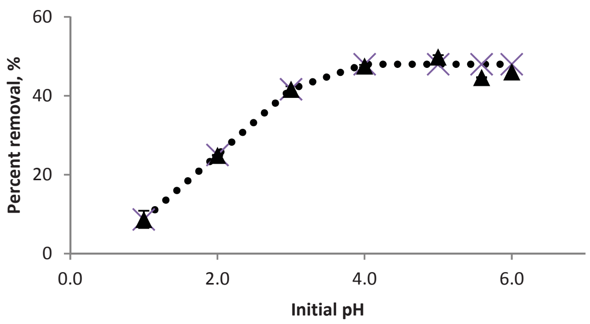

Figure 2. Effect of pH on Ni(II) percent removal.

Table 1. Comparison for optimum pH with other adsorbent using activated carbon

Types of activated carbon	Optimum pH	References
Doum seed coat	7.0	(Foo and Hameed, 2012)
Sugarcane bagasse pith	6.5	(Krishnan *et al*., 2011)
Enteroporpha prolifera	5.95	Gueye *et al*., 2014)
*Rosa-Canina-L*fruits	5.0	(Erdogan *et al*., 2005)
Spent mushroom farming waste	5.59	This study

3.3 Contact Time

The effect of contact time on Ni(II) percentage removal is illustrated in Figure 3. The percentage removal of Ni(II) increased at the beginning and gradually achieved equilibrium at 60 min for a 46.22% Ni(II) removal. Rapid Ni(II) removal at the beginning of the reaction was due to the availability of active binding sites of surface functional group that became saturated at equilibrium stage. A similar trend of observation was obtained from Ni(II) removal using Khulays activated bentonite and activated carbon from lignin of papermaking black liquor by [15].

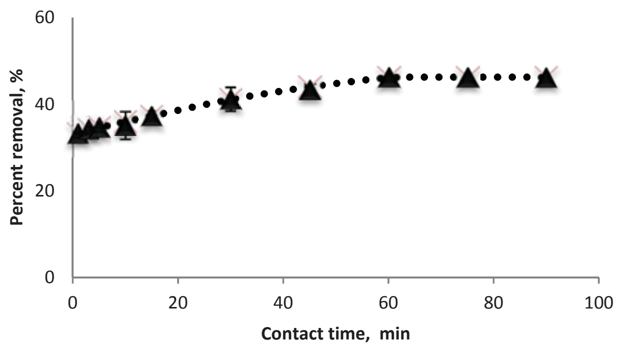

Figure 3. Effect of contact time on Ni(II) percent removal.

3.4 Ni(II) concentration

Figure 4 shows the effect of metal concentration on Ni(II) percentage removal. An increase of Ni(II) concentration from 10 ppm to 60 ppm caused a decrease in Ni(II) removal from 83.53 % to 48.59 %. At low Ni(II) concentration, more active binding sites of surface functional group were available. But, as the concentration increased, the number of ions competing for available active binding sites of surface functional group increased [13] thus, decreased in Ni(II) percentage removal. The Ni(II) concentration provides necessary driving force to overcome the resistance to the mass transfer between the aqueous and adsorbent [14]. This trend is consistent with the study by [13] and [2]using doum seed coat activated carbon and sugarcane bagasse pith activated carbon, respectively

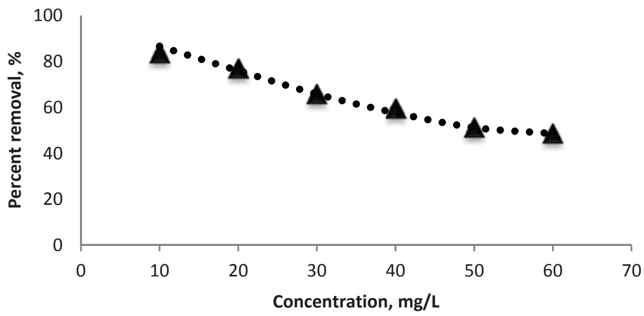

Figure 4. Effect of metal concentration on Ni(II) percent removal

3.5 Temperature

Figure 5 illustrates the effect of temperature on Ni(II) percentage removal. Percentage removal of Ni(II) increased from 39.15 % to 58.25 % with the increased of temperature from 5 °C to 45 °C. This observation revealed that at high temperature, diffusion rate increased and the adsorption process was enhanced. This trend of observation also revealed that Ni(II) adsorption was an endothermic reaction. Similar trend of temperature effect was observed by [12] using the almond husk activated carbon.

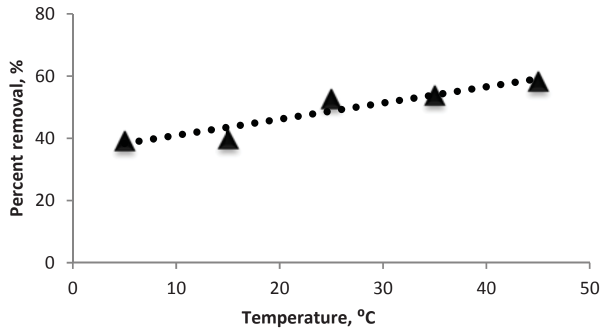

Figure 5. Effect of temperature on Ni(II) percent removal.

3.6 Evaluation of SMFW activated carbon

The SMFW activated carbon performance was evaluated with commercial materials of resin and zeolite under similar experimental design. The SMFW activated carbon showed the highest Ni(II) removal of 50.35% compared to commercial Amberlite IRC86 resin (39.31%) and NK3 zeolite (34.35%). The low Ni(II) removal of commercial Amberlite IRC86 resin was attributed to the weak acid resin having only carboxyl group as functional group. This is supported by [1] in removing of Ni(II) (46.61%) using Amberlite IRC86. Meanwhile, structure of zeolite NK3 consists of three dimensional tetrahedral frameworks of SiO_4 and AlO_4. The net negative charge replacement of Si^{4+} by Al^{3+} is balanced by exchangeable cation of potassium, sodium, calcium and Ni(II) ion in the solution [15]. The reaction could mainly be attributed to ion exchange to the microporous of zeolite sample and decreased the Ni(II) removal. This was supported by [16] in removing of Ni(II) (28%) using zeolite. This result also implied that the SMFW activated carbon has several typesof functional groups that contribute to adsorption process simultaneously. Thus, the SMFW activated carbon is the most outstanding adsorbent for Ni(II) removal.

4. Conclusion

The Ni(II) removal performance is evaluated using low cost agricultural waste of SMFW activated carbon. The fifty percent of Ni(II) removal was found at 0.63 g of adsorbent amount, 5-6 pH solution (unadjusted), 60 min contact time, 50 mg/L metal concentration and 25°C temperature. The effect of Ni(II) concentration and temperature on adsorption study were defined as inverse and direct relationship, respectively. The evaluation of Ni(II) removal showed that the SMFW activated carbon is a great adsorbent that showed highest performance compared to commercial resin and zeolite. This indicated that SMFW activated carbon has a high potential as cation exchange adsorbent for adsorption process.

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