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Reduction of Chemical Oxygen Demand (COD) Effluent of Plastic Recycling Processing Plant using LD Slag

N. A. Zainuddin, M. F. Rosley, F. I. Anuar, N. M. Sarwani

***Abstract:** In wastewater plastic recycling processing plant, commonly contain high chemical oxygen demand (COD) concentration. Coagulation-flocculation, adsorption and foam fractionation are the examples of treatment processes that can reduce COD concentration in wastewater. Steel slag can be used as an alternative to remove COD concentration of wastewater adsorption process. Linz-Donawitz (LD) slag can be obtained from steel manufacturing plant. LD slag also contains alkali oxides, porous characteristic, large surface area and contain an easy solid-liquid separation. This research is to study the percentage reduction of COD in wastewater using LD slag as adsorbent. This research will investigate the effect of particle size, dosage amount and contact time between LD slag and COD reduction. From the experiment, the highest percentage COD removal for particle size is 0.2mm, the dosage amount is 6 gram and the contact time is at 60 min. Comparison of COD removal by using coagulation -flocculation, adsorption using activated carbon and adsorption using LD slag processes was done. LD slag can reduce 2% higher of COD compared to activated carbon. LD slag should be invested more in wastewater treatment process.*

***Keywords:** Adsorption, COD Reduction, Linz-Donawitz Slag, Recycling Plastic Wastewater.*

I. INTRODUCTION

The high chemical oxygen demand (COD) contains in the wastewater that has been discharge without any proper treatment can cause an impact to the aquatic life in the river. Nowadays, production of plastic had increase in number. This could also means in increasing more of plastic use.

Plastic is a dangerous substances that could lead to many environmental effects [1]. For the plastic recycling processes, the influent discharge contain high COD concentration. Therefore, treatment need to be done prior of discharging [2]. In fact, ensuring compliance on discharge according to Environmental Quality (Industrial Effluent) Regulations 2009 is as important to prevent harmful consequences towards the environment [3-4]. High value of COD in the effluent can lead to a serious depletion of dissolved oxygen which disturbs the normal aquatic system [5].

According to Environmental Quality (Industrial Effluent) Regulations 2009 based on the seventh schedule, the acceptable COD contain discharge are 80 mg/L for standard A and 200mg/L for Standard B [6]. There are many treatment method for COD reduction in industrial effluent such as aerobic and anaerobic treatment, coagulation-flocculation, foam fractionation, advanced oxidation process and adsorption [7-11].

LD slag or also known as steel slag waste is a new alternative to be use as an adsorbent [8]. LD slag can be obtained from any steel manufacturing plant. LD slag contains many alkaline oxides, porous characteristic, large surface area, high density and easy for solid-liquid separation[2,9-11]. LD slag can be used as an adsorbent to remove various pollutants from wastewater such as heavy metals and organic matter [10]. Study done by [11] showed that the LD slag as a wetland substrate was feasible to decrease COD. The removal of COD from wastewater by LD slag is mainly based on the oxide minerals released from the LD slag which it can adsorb and precipitate organic matter [12].

In this research, comparison on the reduction percentage of COD between coagulant-flocculation process and adsorption process using LD slag was done. The optimization of pH and chemical dosage rate will determine the percentage removal of COD in coagulation-flocculation treatment process.

In this study, coagulant used is ferric chloride ($FeCI_3$). According to studies done by [13] on the effects of pH on COD reduction found that the $FeCI_3$ result were remarkable compared to the other coagulant which includes alum, polyaluminium chloride (PAC) and ferrous sulphate [13]. Adsorption has been found to occur in many natural physical, biological and chemical system [14]. For example, in laboratory research, industrial application and water purification systems.

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* Correspondence Author
N. A, Zainuddin.*, Faculty of Chemical Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia. Email: nurain1465@uitm.edu.my
M. F. Rosley., Faculty of Chemical Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia. Email: farhan95rosley@gmail.com
F.I. Anuar, Faculty of Chemical Engineering, Universiti Teknologi MARA, Shah Alam Selangor, Malaysia. Email: farahizattyanuar@gmail.com
N. M. Sarwani, Faculty of Chemical Engineering, Universiti Teknologi MARA, Shah Alam Selangor, Malaysia. Email: nursyahzani96@gmail.com.

The commonly adsorbent used is activated carbon because of it is highly porous, amorphous solid consisting of micro crystallites with graphite lattice [15-17]. Activated carbon can be manufactured from carbonaceous material such as coal, peat, wood or nutshells. Most adsorption process using activated carbon can reduce more than 70% of COD in the treatment of wastewater [12].

LD slag contains various amounts of metals and chemical components that can be helpful for various applications and treatment [16-19]. The average percentage of COD removal using LD slag is 70% [17]. The objective of this research is to find the efficiency of LD slag as an adsorbent to reduce COD on wastewater of plastic recycling processing plant. If it is efficient to reduce more of COD in wastewater, it could be invested on industry to be use as an adsorbent to treat wastewater before discharge into public drain.

Therefore, in this study LD slag is used in adsorption to determine the efficiency of COD reduction in wastewater from plastic recycling processing plant. The study of dosage of LD slag, particle size of LD slag and contact time between LD slag and wastewater are investigated to achieve the highest percentage of COD reduction.

II. METHODOLOGY

A. Sample preparation

i. Wastewater Sample

The wastewater was collected from the influent discharge point at plastic recycling processing plant. The sample was stored in a laboratory at room temperature. The initial pH and COD value for the raw wastewater sample is 6.3 and 823 mg/L.

ii. LD Slag

The LD slag was obtained from a steel making industry. The LD slag obtained were in a bulky and bigger size. The LD slag has been grounded to the desired particle size which is from 0.2, 0.4, 1.18 and 2.0 mm using a jaw crusher branded Pascal model type 1397_00_C and sieve into specific particle size with sieve tray machine.

iii. Chemical Preparation

$FeCl_3$ with concentration of 4%, sodium hydroxide (NaOH) with concentration of 7.5% and anionic polymer with 0.2% concentration was used in this research. Dilution was done by using (1).

$$m_1 v_1 = m_2 v_2 \qquad (1)$$

B. COD Measurement

The HACH method 8000 has been adopted to be used as the COD measurement of the sample. For the COD vial sample preparation, 2 mL of sample from the treated wastewater is added into the COD reagent. The COD vial is shaken to allow the reagent to be mixed with the distilled water. The COD vial is added into the COD reactor (DRB 200) at 150℃ and 2 hours. After 2 hours of heating, the vial should be cooled down first at room temperature before taking it's reading using colorimeter (DR 900).

C. Coagulation-flocculation Studies

The experimental studies were conducted in a 500 mL beaker, with effective working volume of 300 mL to determine the optimum pH, coagulant dose and polymer dosage value of the coagulation-flocculation process by using jar test. The initial pH and COD is recorded for each beaker. The flocculator branded Stuart Flocculator Jar Test (6-place) is set to 120 revolution per minute (rpm) for rapid mixing for 7 min to let the wastewater to be homogenous. NaOH or $FeCl_3$ is added to vary the pH value before. After the polymer is added, the speed of the flocculator is set to 60 rpm for slow mixing for 5 min so that bridging process can occur during the flocculation process. Then, turn off the stirrer and allow for settling for 45 min.

For the optimum pH studies, the pH value varies from 4, 5, 6, 7, 8, 9, 10, 11 and 12. While, for optimum dosage of $FeCl_3$ and dosage of polymer is set to 0.5 mL and 0.2 mL respectively at constant at each beaker. For the optimum coagulant dosing, the dosage of $FeCl_3$ varies from the value of 0.3 mL, 0.4 mL, 0.5 mL, 0.6 mL, and 0.7 mL at constant pH and 0.2 mL of 0.2% polymer at each beaker. While, for the optimum flocculant dosing, the flocculant dosage varies from the value of 0.2 mL, 0.4 mL, 0.6 mL, 0.8 mL and 1.0 mL at constant pH and coagulant dosage.

The sample from each beaker is taken after 45 min of settlement. The sample is then used to determine the lowest COD to indicate the optimized pH. This method is referred to the research of [13]. Percentage reduction can be calculated using (2).

$$Percentage\ reduction = \frac{COD\ initial - COD\ final}{COD\ initial} \times 100 \qquad (2)$$

D. Adsorption Studies for Treated Wastewater

For each set of experiment, the speed of the rotation of the impeller is set to 120 rpm. The treated water sample was filtered using filter paper and vacuum compressor. 2 mL of the treated water sample is added into the COD vial for COD measurement. Percentage reduction of COD can be calculated using (2).

i. Adsorption Studies using LD Slag

For the studies on optimum LD slag particle size, 300 mL of wastewater sample was prepared in 500 mL beakers to determine the optimize particle size of the adsorbent. The particle size used is 0.2 mm, 0.45 mm, 1.18 mm and 2 mm. The dosage amount and contact time was set constant at 2 grams and 120 min, respectively. For the studies on optimum dosage of adsorbent, the optimum particle size was used and the contact time was constant at 120 min, while the dosage was varied from 2, 3, 4, 5, 6 grams. To determine the optimum contact time, the optimum particle size and dosage amount was set constant while the contact time was used at 10, 20, 30, 40, 50, 60, 70, 80 and 90 min.

ii. Adsorption Studies using Activated Carbon

Wastewater sample of 300 mL was prepared in 1 unit of 500 mL beaker to determine the COD percentage reduction.

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Before adding activated carbon for adsorption, the wastewater was pretreat according to section C. This is to achieve the optimum value of pH, coagulant and polymer dosage before proceeding to adsorption process. The optimum value of activated carbon dosage and contact time can be referred on section D.i.

E. Adsorption Studies for Untreated Wastewater

For the adsorption studies using untreated wastewater using LD slag and activated carbon, the wastewater sample of 300 mL was prepared in a 500 mL beaker. An optimum value for adsorbent particle size, dosage amount and contact time was taken from D.i.

III. RESULTS AND DISCUSSION

A. Optimization of pH Adjustment

For the coagulation-flocculation studies, pH was varies from 4, 5, 6, 7, 8, 9, 10, 11, 12. As shown in Fig. 1 the percentage reduction is 74% at pH 6. The macroflocs produced in the beaker is thicker and treated water is clear compared to the other beakers. The treated water at pH value of 4 and 12 is cloudy compared to other beakers. This is because of the wastewater is too acidic and alkali respectively, hence the optimum coagulation process cannot be occurred [13].

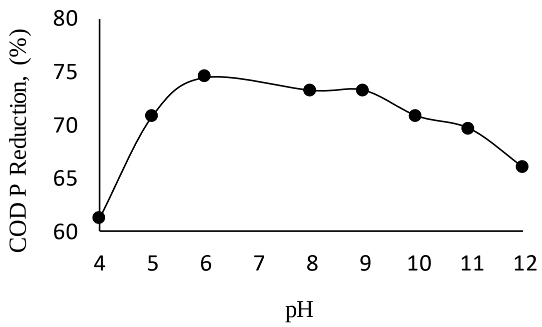

Fig. 1. Effect of pH on COD removal.

B. Optimization of Coagulant Dosing

In this work, $FeCl_3$ is the coagulant used in this research. Fig. 2 shows, the highest percentage reduction of COD is 80% was occurred at $FeCl_3$ dosage of 0.5 mL. The macro flocs produced when 0.5 mL of coagulant dosed is thicker compared to the other value of dosage. Less micro flocs seen in beaker because of the flocs had a balance dosage of coagulant to produce macro flocs during flocculation. When the coagulant is dose at higher than 0.5 mL, the reduction of COD decreased caused by the less produced macro flocs and contains more micro flocs after sedimentation. From my observation, when the coagulant is less dosage, the bond between the micro flocs is weak but when the coagulant is overdosed, it became more difficult for the micro flocs to form a bond.

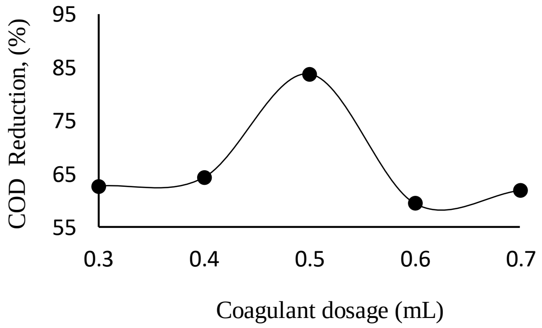

Fig. 2. Effect of coagulant dosing on COD removal.

C. Optimization of Flocculants Dosing

In this study, polyacryl amide is anionic polymer used for flocculation process. Fig. 3 shows that the 80% percentage reduction of COD is when the polymer is dose at 0.2 mL. The percentage reduction is also high at 0.8 mL dosage of polymer, but 0.2 mL is chosen because of the characteristic of the polymer that is slurry. If the polymer is added too much in flocculation process, the water would become slimy [19]. The polymer also acts as the stabilization of the micro flocs to become macro flocs and to reduce more of COD in the wastewater.

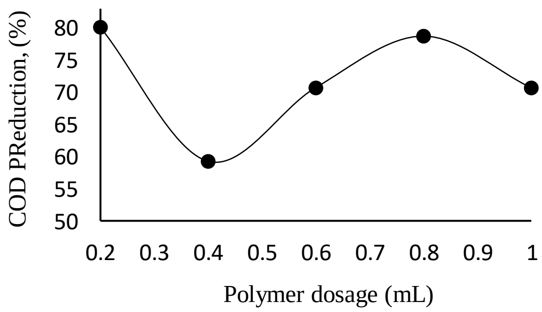

Fig. 3.Effect of coagulant dosage on COD removal.

D. Optimization of LD Slag Particle Size

The adsorption process is done by using a rapid mixing with the speed of 120 rpm. The results, shown in Fig. 4 confirm an increase in particle size of the LD slag decreases the percentage reduction of COD from the wastewater. This might cause from the surface area of the LD slag from each of the size [15]. When the size of the LD slag is small, the surface area is bigger thus making it to adsorb more. When the size of the LD slag is big, the surface area is smaller making it difficult and not much to be adsorb into the LD slag [20]. The optimize particle size is at 0.2 mm, where the percentage reduction is at 58%.

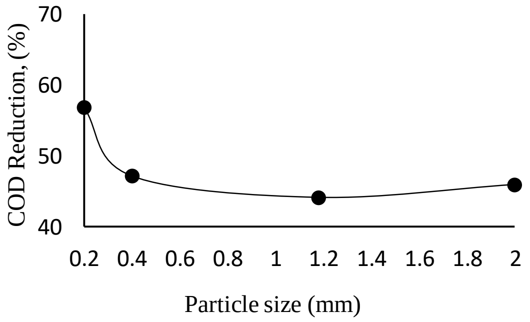

Fig. 4. Effect of particle size on COD removal.

E. Optimization of Adsorbent Dosing

In this adsorption process, rapid mixing is used to make sure the LD slag had contact with the wastewater. The speed of the mixing is set to 120 rpm. Fig. 5 shows that the increase dosage of LD slag increases the percentage reduction of COD. The particle size of the LD slag used in this is 0.2 mm which is the optimum size for the adsorption process. The highest COD removal is 67.21% was occurred at adsorbent dosage of 6 grams. But if the dosage had been increased more, it could lead the adsorbent to become scavengers and would possible increase COD rather than decreasing the COD from the wastewater [21].

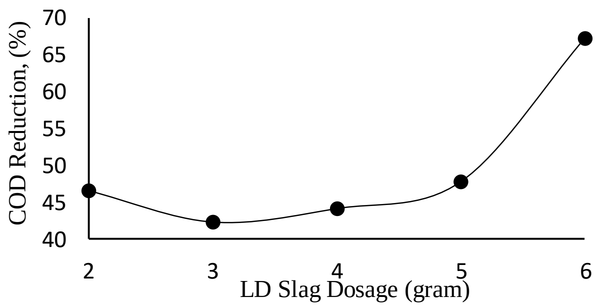

Fig. 5. Effect of adsorbent amount on COD removal.

F. Optimization of Contact Time

Rapid mixing is also used in this adsorption process. As the time of contact between the LD slag and wastewater increases, the percentage reduction of COD increases. As shown in Fig. 6, the highest COD removal is 74.50% was occurred at 60 min. Furthermore, above than 60 min the percentage reduction started to become constant and not significantly increase for COD percentage reduction. This is might cause from the limitation of the adsorption of COD into the LD slag [22]. So, the optimum time contact between LD slag and wastewater is selected to be at 60 min.

Equation (3) was used to obtain time for equilibrium constant as shown in Fig. 7. As shown in Fig. 7, it was verified that at time of 60 min is the optimum contact time for COD reduction using LD slag.

$$Qt = \frac{(CODi - CODf)Volume}{Mass} \quad (3)$$

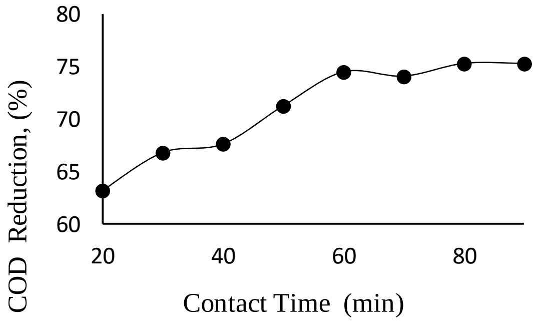

Fig. 6. Effect of contact time on COD removal.

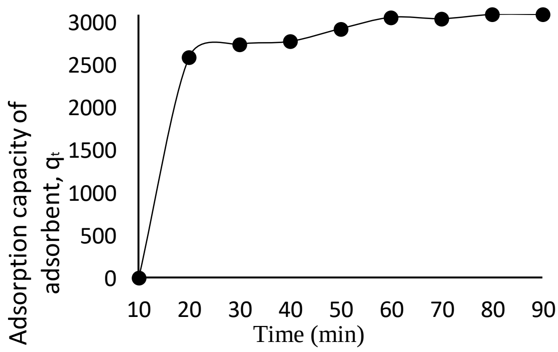

Fig. 7. Equilibrium constant.

G. Comparison Studies

In this comparison, 5 types of experiment had been done to compare the efficiency of COD reduction using coagulant-flocculation, pretreatment followed by adsorption using LD slag as adsorbent, adsorption using LD slag, pretreatment followed by adsorption using activated carbon and adsorption using activated carbon.

The highest percentage reduction of COD was adsorption using LD slag. The treatment for adsorption with LD slag using the particle size at 0.2 mm, 60 min and 6 grams of adsorbent dosage has the reduction of 84.75% which is higher 2% compared to adsorption with activated carbon. The reason of LD slag can reduce more COD compared to activated carbon is may cause by the particle size of the adsorbent [23]. The particle size of LD slag could be smaller than activated carbon. The smaller the particle size, the higher the surface area of the adsorbent. But, if the particle size is smaller than 0.2 mm, it could lead to less adsorption of COD through the adsorbent and will affect the COD reduction of the wastewater [24]. As the increasing dosage of adsorbent used in adsorption, it could turn the LD slag into a scavengers in the solution that may reduce the COD reduction of the wastewater [25].

The coagulation-flocculation treatment have reduce 58.28% of COD. The pH adjustment value is at 6.5, dosage of coagulant at 0.5 mL and the dosage of polymer at 0.2 mL. The value of pH adjustment, dosage of coagulant and polymer are the optimum value because of the highest percentage reduction of COD have been obtain by applying the optimum data.

The lowest percentage reduction of COD was the pretreatment followed by adsorption using LD slag, which is 27.39%. It was supposedly to increase of percentage reduction after the pretreatment, but it was the other way around which in decrease in percentage reduction when LD slag was used after the pretreatment [5]. This also might cause by the LD slag might have already turned into scavengers that cannot adsorb COD in the wastewater [26]. But, when the coagulation-flocculation treatment continued to adsorption treatment using activated carbon, the percentage of COD reduction increases to 76.73%. This shows that activated carbon is more suitable to be used after the coagulation-flocculation treatment compared to LD slag [27].

IV. CONCLUSION

This research can be concluded that LD slag can be used as an alternative adsorbent. The percentage reduction of 84.75% COD was obtained from this research shows that LD slag can reduce COD without pretreatment using coagulation-flocculation process. If pretreatment had to go first, the LD slag performance might not be functional, where only 27.39% COD reduction was occurred. For further studies, the dosage of LD slag should be increase and the kinetic of the wastewater with LD slag should be studied.

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AUTHORS PROFILE

N. A. Zainuddin received her B.Eng. Degree and M.Sc. in Chemical Engineering from Universiti Teknologi MARA, Malaysia. Currently, she is Lecturer at Faculty of Chemical Engineering, Universiti Teknologi MARA, Malaysia. Her general research interest in industrial wastewaterr treatment. N. A. Zainuddin is registered as graduate engineer under Board of Engineers Malaysia (BEM).

M.F.Rosley received his B.Eng. Degree in Chemical Engineering from Universiti Teknologi MARA, Malaysia. His work of research is in the field of wastewater treatment.
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F.I. Anuar received her B.Eng. Degree in Chemical Engineering from Universiti Telnologi MARA, Malaysia. Currently pursuing her M.Sc. in Chemical Engineering in Universiti Teknologi MARA, Malaysia. Her work on research is in the field of wastewater treatment and sustainable technology.

N.M.Sarwani received her B.Eng. Degree in Chemical Engineering from Universiti Teknologi MARA, Malaysia. Her work of research is in the field of wastewater treatment.

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