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Removal of heavy metals from industrial wastewater using fly ash on pilot scale

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ABSTRACT

The separation of Cu, Zn and Fe ions from industrial wastewater using fly ash (FA) was applied and evaluated. Fly ash was developed from Mazut's incineration, used in brick factories. Fly ash has been dried and sieved into various particles size (600, 300, 150, 75µm). A pilot plant with flow rate 200 L/ hr of industrial wastewater discharge was designed and implemented. The process was conducted to study the efficiency of Cu, Zn and Fe ions removal from industrial wastewater using fly ash. Efficient reduction of heavy metals in presence of micro-particles of fly ash is achieved up to 100 %. Concentrations of fly ash are used within the range of 5-15 g / L. Low cost adsorbent shows high efficient removal from industrial wastewater of Cu, Zn , and Fe.

Key words : Adsorbent; wastewater; fly ash; heavy metals, low cost.

1. INTRODUCTION

Heavy metals have a mass of more than 5 g per cubic centimeter and atomic weights of between 63.5 and 200.6 [1, 2]. Contamination of the water caused by the application of heavy metals in the atmosphere has created alarm around the world. Heavy metals ions are found in industrial wastewater as a result of chemical industries such as battery manufacturing, mining, fertilizer production, metal plating, fossil fuel, paper and pesticides, complex plastics, tannery, metallurgy and mining. There are considerable studies on the harmful impact on human health of metals like lead, cadmium, zinc m mercury, chromium, and arsenic. Potential metal toxic symptoms incorporate problems of expression, weakness, problems of sleeping, active behavior, high blood pressure, low concentration, mood swings, irritability, insomnia, heightened allergic reactions, occlusion of the arteries, autoimmune conditions and memory loss[3].Varieties of techniques were employed for separating heavy metals of water [4-7].Choice of a particular treatment method is focused entirely on the economics and degree of the initial concentrations of heavy metal[8-11]. During cycles of chemical and physical preparation the heavy metals are normally extracted in water treatment systems. The raw water may be water from the brackish sea, salt water or water from the soil[12-15].Adsorption, oxidation, mixing of ions bioremediation, membrane, filtration, reverse, osmosis precipitation, coagulation, lime softening and electrochemical therapy are the conventional techniques used to remove metal ions [16, 17]. The recycling process refers to converting the waste into materials that can be used. The recycling process reduces the waste of useful materials and also decreases the consumption of energy and raw materials [18-22].Adsorption using recyclable materials is considered the most flexible method in all of the methods used for handling water and wastewater. It has been shown that activated carbon is a very effective adsorbent, and is widely used to extract various forms of contaminants from water and wastewater[23-25]. Converting solid waste into price low adsorbents for handling treated wastewater and water from various facilities is an effective and beneficial use (where possible) of solid waste. Since solid waste can be used as price low adsorbents, decreases in emissions will give a double-fold benefit. Firstly, the waste volume products could be partly decreased and secondly, the low cost adsorbent will minimize pollution of wastewater at fair cost. Different agricultural waste such as red mud, slag and various sources of sludge are studied as adsorbents to remove particular types of water and wastewater pollutants[26-29].

Fly ash (FA) is used to remove heavy metals from water such as nickel, zinc, copper, cadmium, chromium, and lead for a specific purpose. FA has shown to be an effective adsorbent for separating several heavy metals from water. Some attempts have been made to modify the surface of fly ash particles using eco-friendly methods in order to obtain superior adsorption capacity[30-32].Fly ash has proven its effectiveness in industrial wastewater and domestic wastewater treatment due to its composition and micro/nano structure. Considerable efforts are made to improve the adsorption capacity of fly ash. Among these methods are chemical methods using acid or alkali, physical methods such as laser, ultrasonic, microwave, or plasma treatment [33-34].The mazut fly ash (MFA) is a combustion product formed by the mazut burning at power plants. This fuel is a heavy residual oil for distillation or cracking systems of the petroleum refineries. MFA is obtained from purifying machines for the flue gas. MFA is commonly considered as toxic waste; however, some studies suggest that inorganic MFA may be of industrial benefit for the recovery of useful elements, including V and Ni. The carbonaceous fraction of MFA can be used as a black pigment for the production of cementitious content[25].The chemical properties and composition of fly ash depend on the properties and composition of the precursors. Fly ash contains many types of diffusible elements such as boron, selenium, cadmium, arsenic, sodium, manganese, chromium and vanadium. Typically, it contains hydroxides, oxides, and sulphates of calcium and iron[26]. Fe_2O_3, SO_3, Al_2O_3, MgO, CaO, K_2O, SiO_2, TiO_2 and Na_2O are the most essential constituents of fly ash[27]. Fly ash consists of four different kinds of coal. Type of coal varies in features including heating capacity, ash content, geological origin, and chemical composition.Zinc plays a crucial role in controlling the physiological and biochemical processes roles of dozens other living tissues. The production of zinc in abundance, however, contributes to outstanding health concerns such as stomach pain, skin inflammation, cramps, diarrhoea, and anemia[3]. Manufacturing sources of zinc contain brass plating, wood pulp manufacturing, soil and processing of paper newsprint, steel work with galvanizing bars, zinc and brass metal works. Zinc conc. waste in the literature 's specific waste streams range from 1mg/L to over 48,000 mg/L. Zinc is released into the atmosphere through removal or trapping of sediments, farming operations, groundwater contamination or from a combination of these sources[28].Copper is one of those things which represents a real threat to security. Despite its being important for human health, the above concentration limits can be very dangerous, resulting in anaemia, kidney injury, stomach intestinal pain, eventual death and coma [29]. Copper is often known as an irritant to the skin that causes dermatitis, scratching and keratinization of the feet and sole of the hand[30]. If 0.8 mg/L is absorbed in water, it is carcinogenic to wildlife. Babies may be exposed to pink disease if copper is introduced into water. It kills both fish and aquatic plants from source for miles downstream. This metal is widely spread globally since it is produced spontaneously and primarily through human action.

2. MATERIALS AND METHODS

2.1. Aim of Study

This research aims to study the ability of adsorption and removal of Cu, Zn and Fe ions from industrial wastewater using fly ash generated from Mazut combustion.

2.2. Preparation of adsorbent

Raw fly ash was obtained from burning mazut, which was used in one of the brick factories in Giza , Egypt, as solid waste material. FA has been used to adsorb ions from the effluent of industrial wastewater. Fly ash was dried and sieved into different fractions (600, 300, 150, 75μm) using a sieve shaker (Endecott EF1) in soil and foundations laboratory, engineering faculty at Port Said university , Egypt. Fractions of the size were retained for use as an adsorbent in glass bottles. For all the experiments, fly ash with particle size 300–600 μm was used.

2.3. Model Description and Operation

Research was conducted in this study using a pilot scale adsorption unit. The pilot plant consists of four tanks. Tank 1 is a chemical feed unit made of galvanized tin sheets with wastewater capacity27 L. Tank 2 is a circular mixing tank made of sheets of galvanized tin (50 cm diameter and 10 cm deep). Tank 3 is a circular sedimentation tank, made of galvanized tin sheets (100 cm diameter and 15 cm depth). The fly ash was naturally settled to the bottom of the settling tank.Tank 4 is a glass tank with filtration flow rate = 0.5 m^3/m^2/ hr. The designed filter is (35 * 35 * 80 cm^3) tank perforated at the bottom with 9 holes 0.5 cm in diameter for each. It was made from glass and contains a filtration media of two layers; a bottom layer of 20 cm in depth of gravel with gradation between 3mm to 20mm lays under a layer of sand with 30 cm in depth. The total mixing tank volume was 20L, with a 40-minute detention period. The sedimentation tank has a total volume of 120 L, with a one hour detention period. The water flow is 200L/hr at room temperature, as shown in Figure 1 and Figure 2.

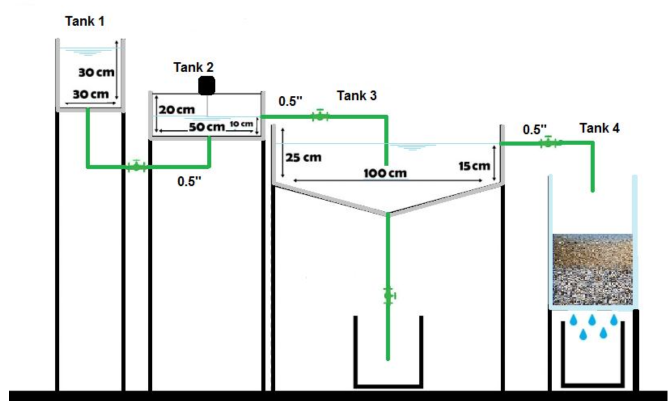

Figure 1: Section elevation of wastewater pilot plant using FA

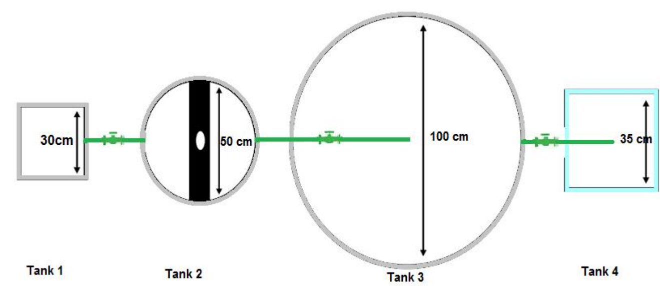

Figure 2: Plan of pilot plant.

2.4. Sample Collection Points

The samples are collected from two sampling points at the pilot plant. Sampling points are very important to study the characteristics of wastewater at different units. First position is designed to be at the feeding stream; second, from the filtration unit where downstream pilot plant effluent is discharged.

3. EXPERIMENTATION

3.1. Experimental Work

In mixing tank, the dosages of FA used ranged from 5 g/L to 15 g/L followed by 40 minutes of shaking at 100 rpm. After mixing with adsorbent, the mixture is introduced to the filtration unit. The experimental work was divided into four groups using FA (with 5, 8, 12, and 15 g / L dosages). Samples were collected 3 times a day.

3.2. Analysis of Wastewater

Cu, Zn, and Fe ions are measured in each units namely; wastewater influent, mixing unit and the filtration unit. The influent wastewater samples were collected fromindustrial zone. The samples were taken at 9 a.m., at daily intervals, 11 a.m., and 1.00 p.m. (3 times a day). It was found that the peak of contamination at 1:00 pm. The water and wastewater analysis criteria were determined using Plus-Atomic Absorption Spectrometer

3.3. Analyses of water samples

Water samples were carried out as per standard water and wastewater condition analysis technique (APHA et al . 2005).The pH measurement was per pH metre. GBC Scientific Equipment Ltd.-932 Plus-Atomic Absorption Spectrometer was used to measure the heavy metals.

4. RESULTS AND DISCUSSION

4.1. Effect of FA dose

The adsorption of ions on FA was tested by increasing the volume of FA in the test solution. The initial concentration of heavy metals and temperature are constant at equilibrium time (5, 8, 12 and 15 g/L) as shown in Figure 3. pH of industrial wastewater is in the range of 10.8 to 12.8. The max. removal levels of 100, 80.95 and 99.86 percent are found at the adsorbent conc. of 15 g/L for Cu, Zn and Fe.

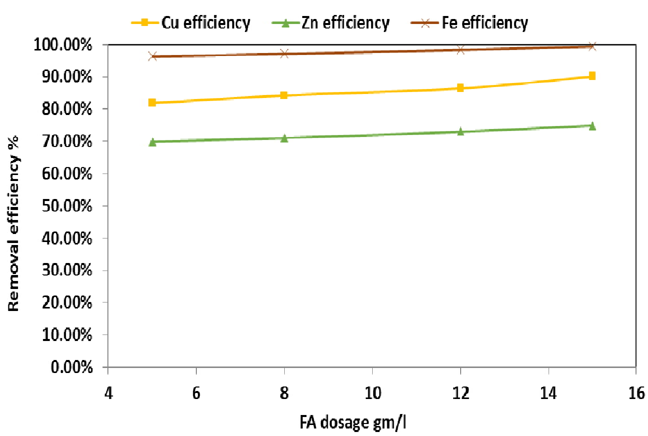

Figure 3: Effect of FA dose on Cu, Zn and Fe adsorption

4.1.1. Cu adsorption

The effect of the initial concentration of Cu ions on the adsorption efficiency was investigated. The initial concentration of Cu ions is varied from 0.42 mg/L to 2.01 mg/L, with an average of 1.22 mg/L.The adsorption efficiency was measured at the 5,8,12,15 g/L adsorbent dose. The results showed that the rising dosage of adsorbents has a positive impact on metal ion adsorption. After treatment, the effluent Cu value ranged from 0 mg/L to 0.08 mg/L with an average of 0.03 mg/L and a maximal efficiency of removal equals to 98.64 % at 15 g/L FA dose. Figure 4 Shows difference between Cu concentration values in influent and effluent for the different FA doses. Figure 5shows difference between Cu removal efficiency for the different FA doses. Figure 6Shows difference between the adsorption capacity ($q_{mg/g}$)values for the different FA doses.

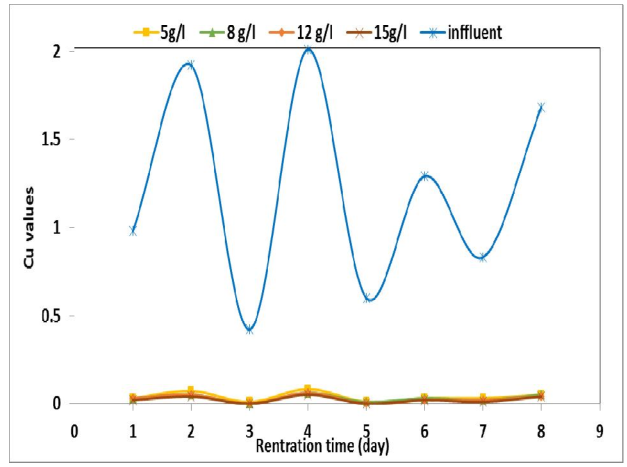

Figure 4: Cu concentration values in influent and effluent for the different FA doses.

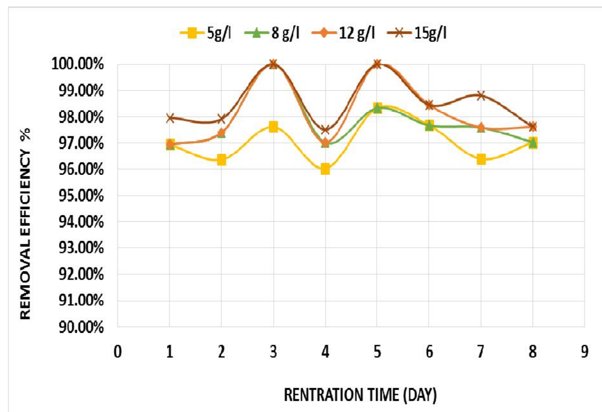

Figure 5: Cu removal efficiency for the different FA doses.

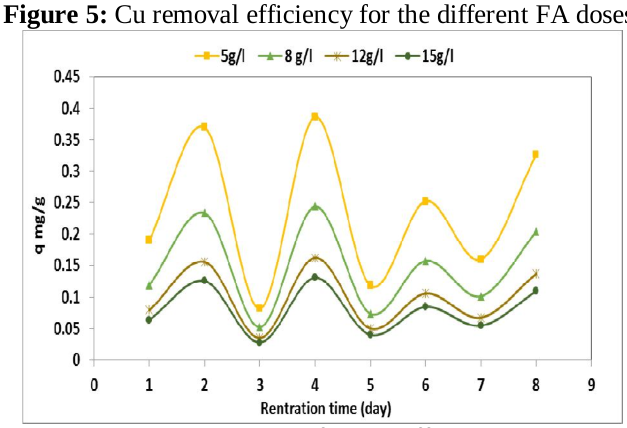

Figure 6: q mg/g values for the different FA doses.

4.1.2. Zn adsorption

The initial concentrations of Zn ions in the influent wastewater are varied between 0.63 mg/L to 2.69 mg/L, with an average of 1.73 mg/L. Effluent Zn ions are in the range of 0.83 mg/L to 0.12 mg/L with an av. of 0.49 mg/L and a maximum efficiency of removal equals to 74.9%. Figure7shows the difference in influent and effluent concentration values of Zn for the different FA doses. Figure 8 shows the difference between the efficiency of Zn removal for the different FA doses. Figure 9Shows a difference between the values of $q_{mg/g}$ for different FA doses.

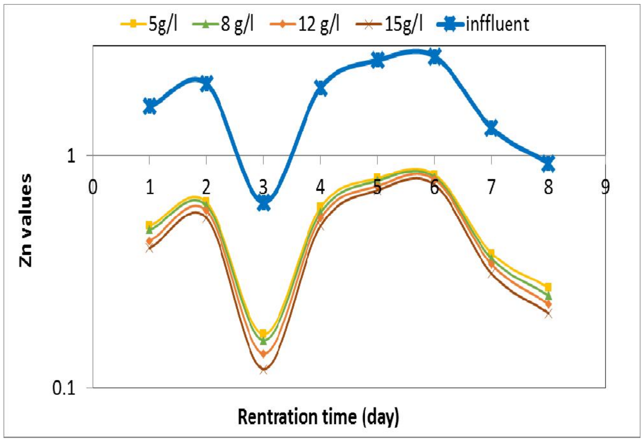

Figure 7: Zn concentration values in influent and effluent for the different FA doses

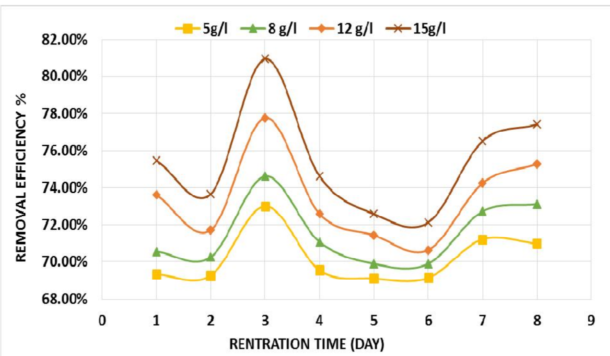

Figure 8: Zn removal efficiency for the different FA doses.

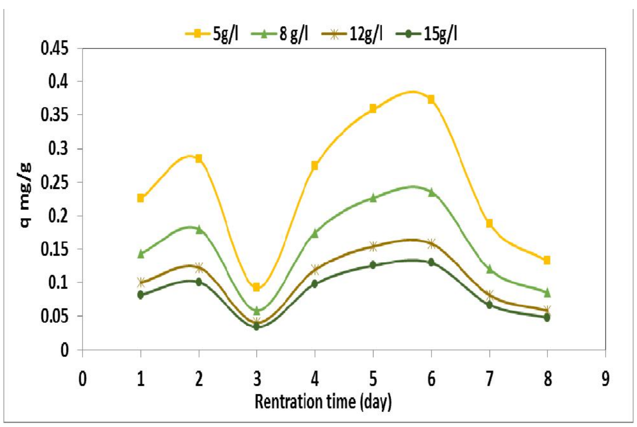

Figure 9: q mg/g values for the different FA doses.

4.1.3. Fe adsorption

The Fe ions are varied from 4.92 to 8.01 mg/L with average of 6.75mg/L in the influent. After treatment, the Fe ionsin the effluent are found to be 0.39 to 0 mg/L with average of 0.16mg/L and aximum efficiency of removal equals to 99.41% at 15 g/L FA dose. Figure 10shows difference between Fe ions values in influent and effluent using different FA doses. Figure 11shows difference between Fe ions removal efficiency using different amount of FA adsorbent. Figure 12shows difference between q $_{mg/g}$ values for the different FA doses.

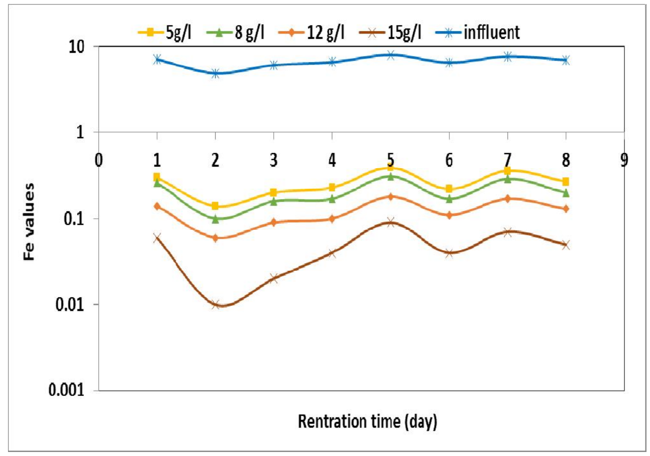

Figure 10: Fe values in influent and effluent for the different FA doses.

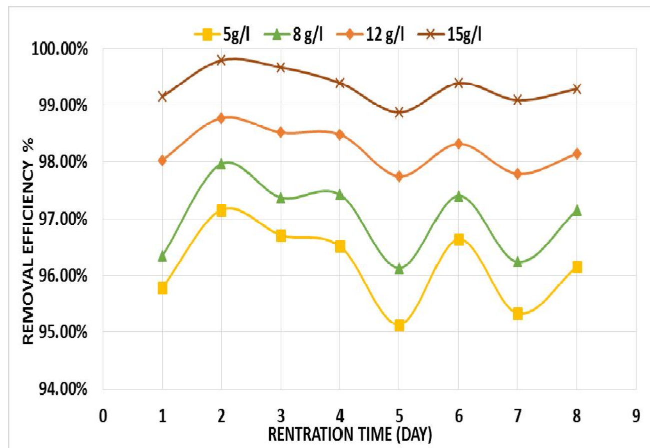

Figure 11: Fe removal efficiency for the different FA doses.

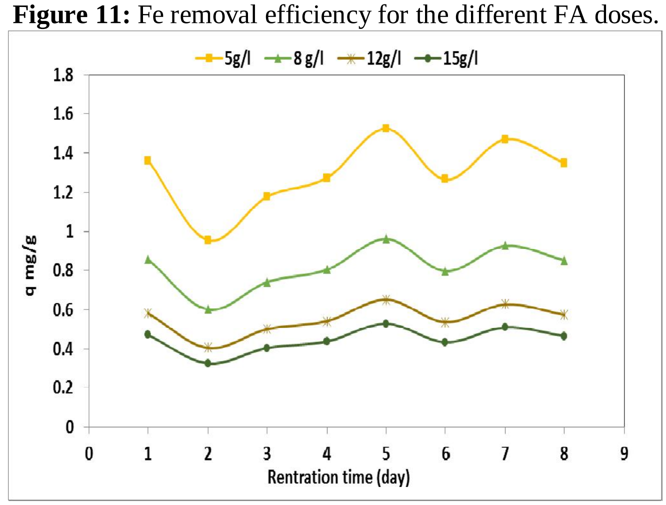

Figure 12: q mg/g values for the different FA doses.

5. CONCLUSION

Pilot plant was deigned and implemented to study the use of fly ash generated from mazut incineration as an adsorbent for Cu, Zn and Fe ions. The fly ash was dried in the first stage of and sieved into various fractions (600, 300, 150, 75µm). The Fly ash with particle size of 300– 600 µm showed high removal efficiency. It was noticed that fly ash particles are separated easily under gravity after adsorption process. Removal of Cu, Zn, and Fe ions has been removed from industrial wastewater using eco-friendly method. Fly ash adsorbent is available at a cheap price. The detention time of 30 minutes in the mixing unit showed remarkable results. Time of sedimentation is one hour to remove the fly ash after adsorption process. Efficiency of removal up to 100, 80.95 and 99.8% has been achieved for Cu, Zn and Fe, respectively using adsorbent dose (FA) 15 g/L.

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