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Removal of TDS and TSS from Industrial Wastewater using Fly Ash

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Abstract

Fly ash is one of the most abundant waste materials; its major components make it a potential agent for the adsorption of pollutants contaminants in water and wastewaters. In this study, fly ash obtained from burning of mazut was dried and sieved into different fractions (600, 300, 150, 75µm). A pilot plant with an industrial discharge flow of 200L/hr was designed for reducing total Dissolved Solids (TDS), total suspended solids (TSS), conductivity and pH from industrial wastewater. The concentrations of (TDS), (TSS), conductivity and pH in industrial discharge flow had an average range of 80000, 750, 120000 mg/L and 13 respectively. The optimization of the treatment process using 5, 8, 12, 15 g/L fly ash dosage had succeeded in improving the removal efficiency of (TDS), (TSS), conductivity and pH to 90%, 92.3%, 90% and 93.5% respectively.

Keywords: Adsorbent; Wastewater; Fly ash, Low cost

1 Introduction

Industry contributes to the emission of large quantities of pollutants and increases the concentration of elements that cause water pollution and that harm living organisms [1]. Several methods are applied for the treatment of wastewater and water [2-10]. Adsorption is considered the most flexible technique among many methods used for the treatment of water and waste water. Scientists have found that the most used material for water and wastewater treatment is active carbon because it is highly effective for adsorption. [11]. If it is possible to convert some solid waste and agricultural waste into valuable applications such as absorbent materials used in treating sewage and water from pollutants, then it is one of the important and beneficial uses of that waste [12]. Given the solid waste as low-cost adsorbents can be used, emission controls can have a double-fold benefit. First, the amount of waste materials might be partially reduced, and second, if created, the low cost adsorbent might minimize wastewater pollution at economic cost. In order to extract different types of contaminants from water and wastewater, various industrial waste such as slag, fly ash, sludge and red mud are investigated as adsorbents.

Fly ash contains boron, selenium, manganese, arsenic, chromium, vanadium, sodium and cadmium in abundant quantities [13]. Fe_2O_3,SO_3, CaO, Al_2O_3, MgO, Na_2O, SiO_2, TiO_2, and K_2O are the most important constituents of fly ash[14]. The properties of fly ash differ according to the type of coal from which this ash was issued, as there are four different types of coal whose properties depend on the chemical composition, temperature, ash content and the origin of geological coal. Lignite, anthracite, sub-bituminous and bituminous are the most common type of coal. The composition of fly ash from burning bituminous is mostly calcium, magnesium and silica.

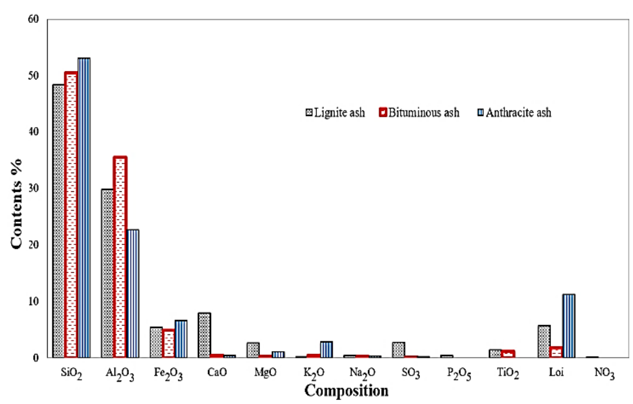

Figure 1: Lignite, anthracite coal and bituminous Chemical composition

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The extent to which fly ash contains calcium, silica, ammonia, and iron oxide defines the fly ash category, and they are two class classes f and c, as it is the main difference between the two categories [15-16]. Fig. 1 displays the chemical composition of anthracite, bituminous, and lignite ash from coal. Fly ash can be used to separate heavy metals from wastewater as an adsorption method. [17-20]. The adsorption processes can be regulated using mass transfer, particle diffusion, chemical reactions and methods [21]. The key components in fly ash are SiO_2 and Al_2O_3, where SiO_2 material is more susceptible to heavy metal adsorption because of complex lone pair hybridization [22] or lone pair electron. Because of its high removal of different contaminants, such as many heavy metal elements, fly ash has demonstrated to scientists its high efficacy in the treatment of industrial and waste water, and scientists are currently looking to use effective methods to enhance the surface properties of fly ash to make it more capable and effective in removing pollutants. Chemical treatments using acid or alkali as well as physical methods such as laser, ultrasonic, microwave, or plasma therapy are among these methods. The mazut fly ash (MFA) is a combustion product produced by the burning of mazut at power stations. This fuel is a heavy residual oil of the petroleum refineries distillation or cracking units. MFA is obtained from flue gas purification machines. MFA is generally known as toxic waste; however, certain studies indicate that MFA inorganic matter can be of industrial value to recover useful elements, including V and Ni [22–28]. In fact, the carbonaceous fraction of MFA can be used as a black pigment for cementitious content production [29].

The composite composition of Total Dissolved Solids (TDS) is a mixture of both organic and inorganic compounds in a suspended chemical, ionized or micro-granular (colloidal) form. In general, the practical meaning is that the solids (often abbreviated TDS) must be low enough to withstand filtration by a two micrometer sieve size [30]. Complete hardness, organic ions, bicarbonate, alkalinity, sulphate, sodium, calcium, nitrate, magnesium, phosphate, iron, chloride and carbonate can be used. For aquatic life, a certain level of those ions is necessary in water. Changes in concentrations of TDS can be harmful. The flow of water into and out of an organism's cells is determined by water density. In industrial wastewater, steel production, pharmaceutical manufacturing, mining activities, oil and gas exploration, and food processing facilities are major sources of TDS. Furthermore, salts used for road deicing may make a major contribution to the charging of water sources by TDS. Concentrations of TDS in water vary in various geographical regions due to varying mineral solubility. Total solids values range between 30, 65 and 195: 1100 mg/l for water in contact with granite, rocky areas and sedimentary areas. [31-34]. The concentration of ions in the water gives it the ability to pass electric flow, and this property is expressed by electrical conductivity [35-36]. There is a strong direct relationship between the presence of ions in the water and between the conductivity, for example, water that contains a small number of ions has a weak conductivity, so we find that the distillate will not be used as an electrical insulator [37]. In contrast, water that contains a large number of ions is highly conductive, as is sea water, which is characterized by its high conductivity [38].

On account of their negative and positive charges, ions bear power [39]. They break into particles which are negatively charged (cation) and positively charged (anion) as electrolytes dissolve in water. As the dissolved compounds break in water, the amounts of each negative and positive charge remain equivalent. This means that while water conductivity increases with added ions, electrically neutral conductivity remains [40]. pH is similar to temperature; each of them has a specific value. The pH value ranges from 0 to 14. As the number 7 expresses that water is neutral. The lower the number than 7 is an indication of the acidity of the water, and the higher the number than 7, the more alkaline the water is [41, 42]. The reason for the decrease in the pH below number 7 is due to the presence of hydrogen ions and the reason for the increase in the pH above number 7 due to the presence of hydroxyl ions. In neutral waters, the concentration of both hydrogen and hydroxyl ions is $10^{\wedge-7}$ M. For example, if the hydrogen concentration increases, the hydroxyl concentration decreases with it, and vice versa, so that their sum does not exceed $10^{\wedge-14}$ [43]. pH is very important for the life of living things in the water, as all of them will die if the pH drops or increases to a high degree. The pH has an effect on the presence of heavy and toxic metals in the water and their solubility in it. The best pH number suitable for living organisms in the water ranges between 6.5 and 9 [44-47].

2 Materials and Methods

2.1 Aim of Study

Industries in developed countries have seen rapid growth in recent years. These factories discharge wastewater that carries high levels of dissolved solids and demand for chemical oxygen. These effluents, which comply with the regulations imposed on industrial sectors, should be handled for safe disposal. This research aims to improve the efficiency of TSS, TDS, Conductivity and pH removal of industrial wastewater by adding an inexpensive adsorbent such as fly ash.

2.2 Preparation of adsorbent

Raw fly ash was collected as a solid waste material from mazut burning, which used in one of the brick factories in Giza, Egypt. For the adsorption of contaminants from the industrial wastewater effluent, FA was used. FA collected from burning of mazut was dried and sieved into various fractions (600, 300, 150, 75µm) using test sieve shaker (Endecott EF1) in soil and foundations laboratory, faculty of engineering, portsaid university, Egypt. The size fractions were preserved in glass bottles for use as an adsorbent. Fly ash with particle size of 300–600 µm was used in all the experiments.

2.3 Model Description and Operation

The work was performed on a scaled pilot plant in this research. Four tanks were composed of the model system used. Tank 1 is a Chemical feed unit made of galvanized tin sheets with capacity of 27 L (30*30*30 cm). Tank 2 is a circular mixing tank made of galvanized tin sheets (50cm diameter and 10cm depth). A motor was used for mixing with 100 rpm in speed. Tank 3 is a circular sedimentation tank (100 cm diameter and 15 cm depth) made of galvanized tin sheets. The settled fly ash was natural scared slowly to the bottom of the settling tank. Tank 4 is a glass tank with flow rate = 0.5 m3 / m2 / hr. The designed filter is (35 * 35 * 80 cm3) 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.

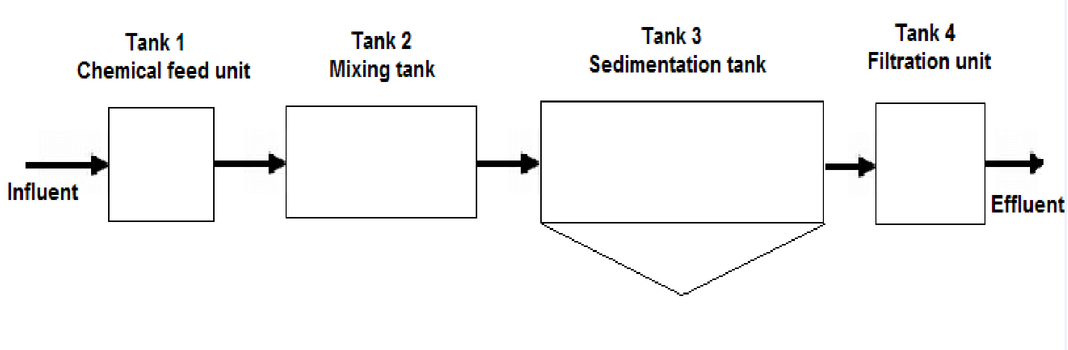

Figure 2. Flow chart of Pilot plant for the model

The mixing tank's total volume was 20L with a detention time of 40 minutes. The volume of sedimentation tank is 120 L. The water stays for an hour in this tank. With a constant temperature, the water flow was 200 L / hr as shown in Figure 2.

2.4. Sample Collection Points

The pilot plant had two collection points for the samples. To analyze the characteristics of wastewater, those points were very significant. The positions were first, the pilot plant influential; second, the downstream pilot plant effluent from the filtration unit.

3 Experimentation

3.1. Experimental Work

The dosages of FA used, in mixing tank, ranged from 5 g/L to 15 g/L followed by 40 minutes of shaking with speed of 100 rpm. After shaking of the samples they were subjected to analysis. After that stage of mixing with adsorbent goes to the filtration unit. The experimental work was divided into four groups using FA (with dosages of 5, 8, 12 and 15 g/L) each group was carried out in 8 days and samples were collected 3 times each day.

3.2. Analysis of Wastewater

In this research, the parameters of the industrial wastewater were measured before being treated and entered into the pilot plant, and the influential water produced after the treatment process was also measured. Water samples coming out of this model were collected over a 24-hour period and mixed well before measure. The samples were taken at 9.00 a.m. three times a day, at 11.00 a.m. at daily intervals. And, at 1.00 p.m., the peak time was contaminated.

2.3.1. Total dissolved solids (TDS)

Dissolved solids are considered the solids found in the filtrate that passes through a filter with a nominal pore size of 2μm or less. The conductivity electrode was used to assess the quantity of the dissolved solids in the influential wastewater from the filter to the mixing tank and the effluent, and calculated by ppm.

2.3.2. Total suspended solids (TSS)

This test used to measure the quantity of the suspended solids in the influent wastewater to the mixing tank and the effluent from the filter. The theory of this test is the residue that is ignited to 550 + 50 ° C from the filtered sample. The remaining solids are the stable suspended solids while the volatile solids are the weight lost after ignition.

2.3.3. Conductivity

The conductivity electrode was used to determine the quantity of the dissolved solids in the influent wastewater to the mixing tank and the effluent from the filter.

2.3.4. pH-value

The pH-value is the acid or base intensity measured on a scale from 0.0 to 14.0. Technically it is the logarithm equivalent of the concentration of hydrogen ions. The pH-value was measured for the influent to the mixing tank without chemicals addition and the effluent from the filter. The pH-value was measured using the "Digital pH meter" For pH-value determinations the meter was calibrated using buffers of 4.0, 6.86 and 9.18.

4 Results and Discussion

4.1 Effect of FA dose

As shown in Figure 3, the percent removal of pollutants increased with the increase in the adsorbent dosage due to the increase in the area of the adsorbent surface. At the 15 g / l adsorbent concentration for TDS, TSS, conductivity and pH, the maximum average removal rate of 88.6, 91.44, 88, 90.08 percent occurred.

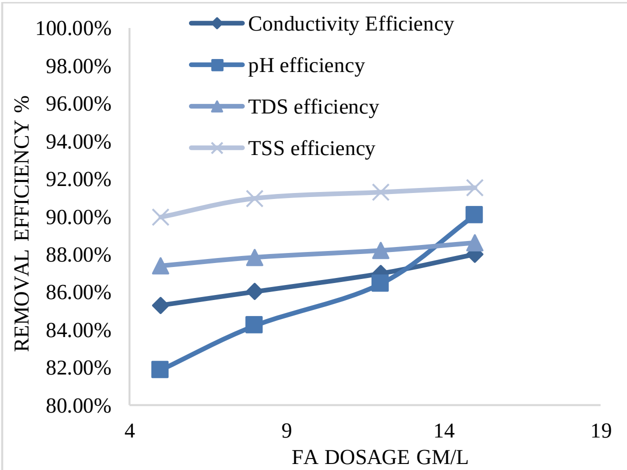

Figure 3: Effect of FA dose on pollutants removal

4.1.1 TDS

The total dissolved solids (TDS) of the influent during the 8 days ranged from 29110 mg/l to 90210 g/l with average of 62366 mg/l. After treatment, the TDS of the effluent ranged from 4321 mg/l to 10110 mg/l with average of 7094 mg/l and maximum efficiency of removal equals to 90.25% occurs at max TDS influent with 15 g/l FA dose. These results prove that FA is very effective in removing TDS due to accumulation of atoms on the surface area of the adsorbent (FA) and concentration of these materials. Figure 4. Shows difference between TDS concentration values in influent and effluent for the different FA doses. Figure 5. Shows difference between TDS removal efficiency for the different FA doses. Figure 6. Shows difference between q mg/g values for the different FA doses.

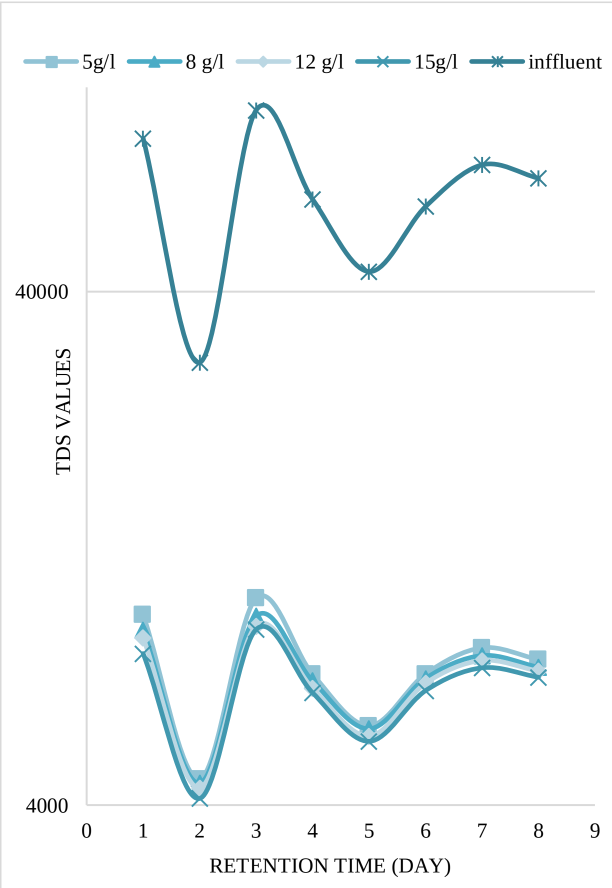

Figure 4: TDS concentration values in influent and effluent for the different FA doses

4.1.2 TSS

The total suspended solids (TSS) of the influent during the 8 days ranged from 310 mg/l to 750 g/l with average of 572 mg/l. After treatment, the TDS of the effluent ranged from 35 mg/l to 72 mg/l with average of 51 mg/l and maximum efficiency of removal equals to 92.62% occurs at 15 g/l FA dose. These results prove that FA is very effective in removing TSS due to accumulation of atoms on the surface area of the adsorbent (FA) and concentration of these materials. Figure 7. Shows difference between TSS concentration values in influent and effluent for the different FA doses. Figure 8. Shows difference between TSS removal efficiency for the different FA doses. Figure 9. Shows difference between q mg/g values for the different FA doses.

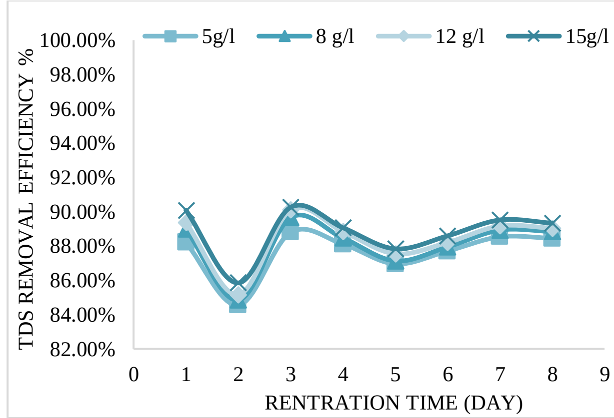

Figure 5: TDS removal efficiency for the different FA doses

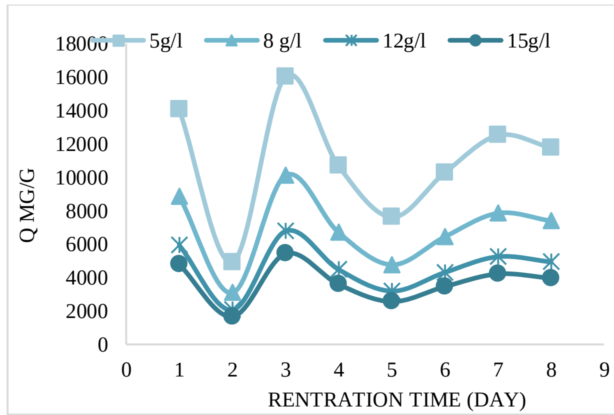

Figure 6: q mg/g values for the different FA doses

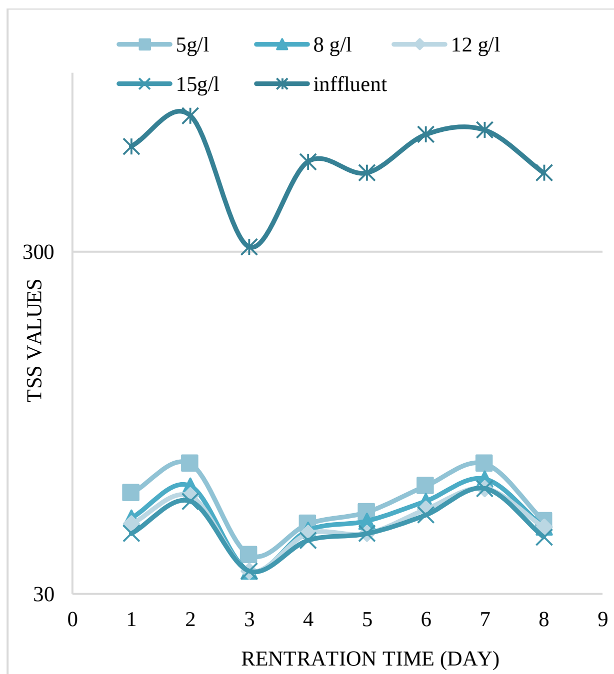

Figure 7: TSS concentration values in influent and effluent for the different FA doses

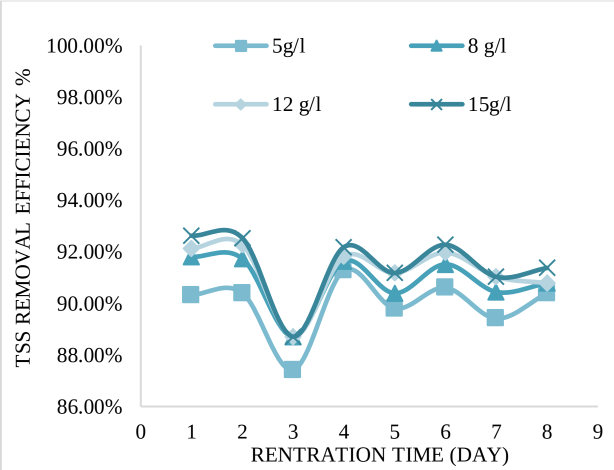

Figure 8: TSS removal efficiency for the different FA doses

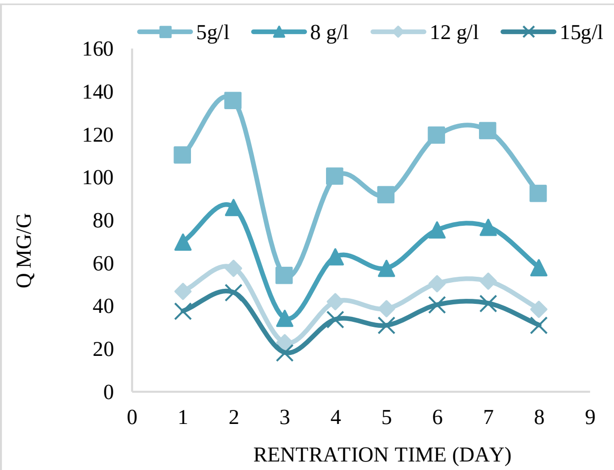

Figure 9: q mg/g values for the different FA doses

4.1.3 Conductivity

The Conductivity of the influent during the 8 days ranged from 45500 to 130700 g/l with average of 90863. After treatment, the Conductivity of the effluent ranged from 14990 to 2660 with average of 11837 and maximum efficiency of removal equals to 90.49% occurs at 15 g/l FA dose. These results prove that FA is very effective in reducing conductivity due to accumulation of atoms on the surface area of the adsorbent (FA) and concentration of these materials. The fly ash adsorbed heavy metals from industrial wastewater, reducing the electrical conductivity. Figure 10. Shows difference between Conductivity values in influent and effluent for the different FA doses. Figure 11. Shows difference between Conductivity removal efficiency for the different FA doses.

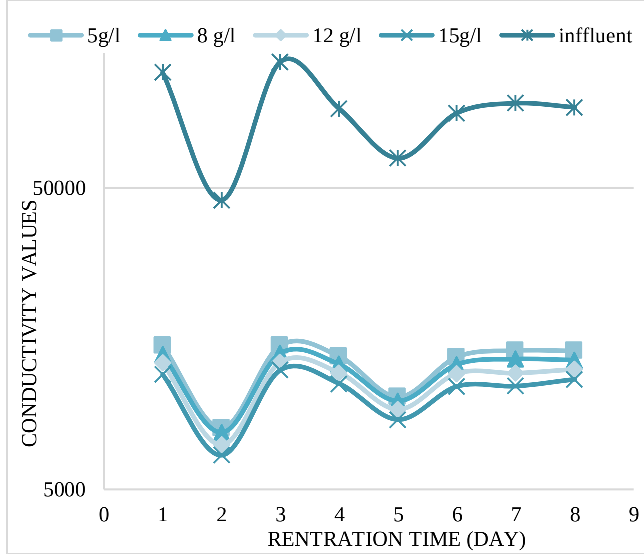

Figure 10: Conductivity values in influent and effluent for the different FA doses

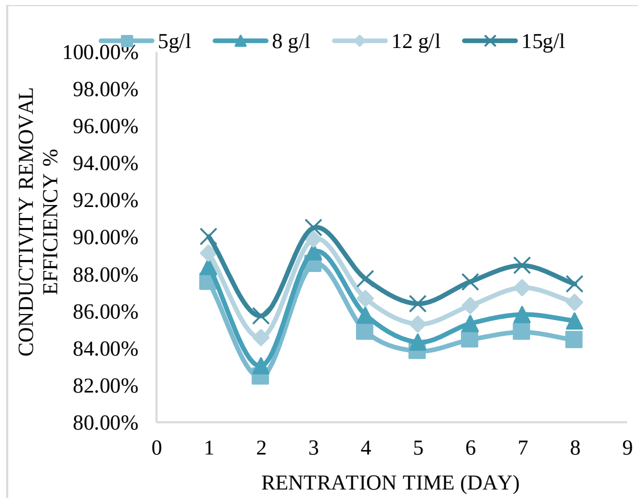

Figure 11: Conductivity removal efficiency for the different FA doses

4.1.4 pH

pH of the influent during the 8 days ranged from 10.8 to 12.8 with average of 11.8. After treatment, the pH of the effluent ranged from 7.3 to 8.1 with average of 7.6 and maximum efficiency of removal equals to 93.5% occurs at 15 g/l FA dose. These results prove that FA is very effective in removing pH due to accumulation of atoms on the surface area of the adsorbent (FA) and concentration of these materials. Figure 12. Shows difference between pH values in influent and effluent for the different FA doses. Figure 13. Shows difference between pH removal efficiency for the different FA doses.

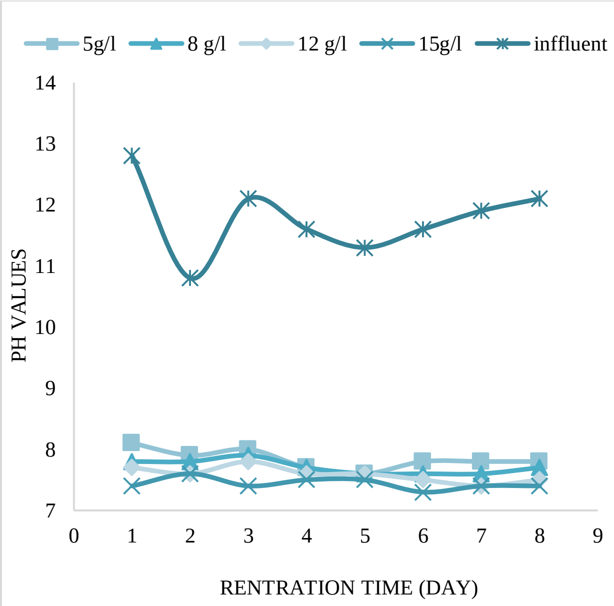

Figure 12: pH values in influent and effluent for the different FA doses

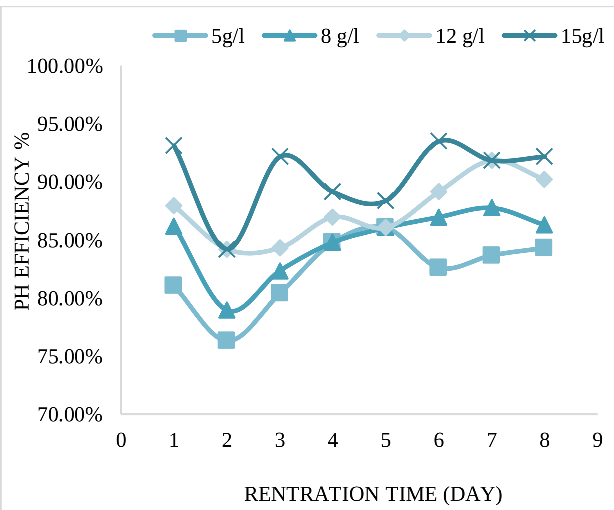

Figure 13: pH values in influent and effluent for the different FA doses

5 Conclusion

The Fly ash with particle size of 300– 600 µm achieved high sedimentation efficiency and did not produce particles floating on the surface. The detention time of 30 minutes in the tank was sufficient for mixing and one hour for the total sedimentation. The most effective dosage in removing TDS was 15 g/l of FA. 90 % of TDS were removed using this dosage. The increasing in the influent TDS values the increasing in removal efficiency. The highest efficiency of TSS removal was observed in the fourth dosage (dosage =15 g\l of FA & η =92.3%). The highest efficiency of conductivity removal was observed in the fourth dosage (dosage =15 g\l of FA & η =90%). The highest efficiency of pH was observed in the fourth dosage (dosage =15 g\l of FA & η =93%).

Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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