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Adsorption Treatment Removal of Toxic Heavy Metals from Gold Mine Wastewater using Wood Ash Adsorbent

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Abstract
The quality of water in our environment is deteriorating everyday due mining activities of the natural resources with the consequences of polluting the natural water bodies in the vicinity of the mining operations. The aim of this study is to use wood-ash as absorbent to treat gold mine effluent wastewater discharged from the mine to remove toxic heavy metals U, Cd, Cr, Ba, and Pb. Digestion of the mine water was carried out. Adsorption study was used for the treatment removal of toxic metals present in gold mine waste water. Physicochemical analysis was conducted on the mine water. The treatment process was conducted by optimizing dosage, contact time, and pH of the effluent discharge to obtain optimum result. The treated and untreated samples were analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES). The results showed that as the adsorption of dosage increase, the adsorption capacity and percentage removal increase with decrease in each metal concentration. The effect of pH showed that as pH increase, the adsorption capacity and percentage removal also increase for each metal. The results of contact time effect shows that the adsorption capacity of each metal increase with increase in contact time. However, the optimum dosage, pH, andcontact time removal of toxic heavy metals are 1.50 g, pH 6 and 60 minutes respectively. In conclusion, wood-ash is a good low cost adsorbent because of the high percentage removal of toxic heavy metals in gold mine wastewater.
KEYWORD:*Mine Water, Heavy Metals, Wood-Ash, Adsorption study and inductively coupled plasma optical emission spectroscopy*

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I. INTRODUCTION

Different industrial effluents containing heavy metals contribute significantly to environmental pollution by polluting the surface and underground water [1-3]. Mining process requires large volume of water consumption to generate wastewater that can pollute the natural water resources in the environment. Mining by its nature consumes as well as diverts water which can pollute natural water resources of the area of mining. The origin and impacts of mining on water resources arise from several stages of the mining cycle: the mining processes itself and/or at mineral processing and operational stage. It is one of the major activities causing water pollution and most of the mining areas are facing acute problems of potable water both in terms of quantity and quality [4]. Persistent excavation of mineral resources from the earth has led to production of mine water which can be acidic or basic or neutral in nature when in contact with water and oxygen of the air. Mine water generated from the mine has long been utilized as a readily accessible and steady source of water supply for domestic, agricultural and industrial purpose all over the world [5]. Unscientific mining, improper mine water disposal and unsanitary conditions has threatened the quality of mine water and consequently human health in most parts of the world by naturally occurring pollutants and anthropogenic pollutants [6]. The presence of water generated in mining sites has created a range of operational and stability problems. Thus, requires proper drainage to avoid slope stability problems and action to minimize oxidation of metallic sulfides and corrosion of mining equipment. The quality of the mine water depends on a series of geological, hydrological and mining conditions, which vary significantly from mine to mine [7].

Heavy metals are elements having atomic weights between 63.5 and 200.6 with specific gravity greater than 5.0. Heavy metals are toxic, dangerous and injurious to human health and the entire environment. Heavy metals found in industrial wastewater include barium, lead, chromium, mercury, uranium, selenium, zinc, arsenic, cadmium, silver, gold, and nickel [8, 9, 10]. Environmentalists are seriously concern especially on three classes of heavy metals which are toxic metals such as Hg, Cr, Pb, As, Cd, Ba, Mn, Cu, Sn, Ni, Zn, Co, etc., second class include precious metals like Pd, Pt, Ag, Au, Ru etc. and third class are radionuclides like Ra, Am, U, Th, etc [11]. The major toxic heavy metals are lead, mercury, arsenic, cadmium, barium, and chromium and they are on top the toxicity list among other metals. Heavy metals like Hg, As, Cr, Cd, Pb, Ba, are in the limelight due to their major negative impact on the environment [11]. Heavy metals are very toxic to the plants and humans when they are consumed beyond the permissible limits. There are two types of heavy metals which are essential and Non-essential heavy metals base on their effect in the plants and they are classified as essential and non-essential heavy metals. These heavy metals become toxic to living organisms when exceed their permissible limit. Heavy metals such as Fe, Cu and Zn are essential to both plants and animals (12]. The concentration of heavy metals in solution and essential micronutrient metals are also called as trace elements due to their concentration in trace amount (10 mg L^{-1}) in the environmental matrices are Cu, Fe, Mo, Zn, Mn, Ni and Co etc. The excess uptake of trace heavy metals than it is required in the plants and animals is called toxic effects [12, 13, 14, 15, 16]. Some of the essential heavy metals like Cu, Fe, Zn, Mn, and Mo play biochemical and physiological functions in plants and animals.

Adsorption treatment Wood charcoal was used to treat some soil samples and the result showed great reduction in the concentration the of these heavy metals (Cd, Pb, and Zn) bioavailability [17, 18]. There are different treatment methods of toxic heavy metals such as chemical precipitation [19, 20], Nano filtration [21, 22, 23], solvent extraction [24, 25], ion exchange [26, 27], reverse osmosis [28], and adsorption [29, 30]in order to clean the polluted wastewater. However, of all these treatment methods, adsorption is particularly found to be the most attractive and interesting scientific technique because of its high efficiency, very effective, low cost, easy to handle and readily available for different adsorbents. The adsorption of Cd(II), Pb(II), Zn(II), Ni(II), and Cu(II) ions using novel modified cellulose adsorbent revealed the adsorption capacities for the various metal ions increased with increase in temperature, and the maximum adsorption occurs at pH 5 [9, 31, 32, 33]. Low cost adsorbent like wood ash and wood carbon were reported to be good adsorbent which can effectively and efficiently remove heavy metals from wastewater [32, 33]. The aim of this study is to use adsorption treatment to remove toxic heavy metals from gold mine water using wood ash as adsorbent.

II. MATERIALS AND METHODS

2.1 SAMPLING AND SAMPLE COLLECTION

Samples of gold mine waste water were collected from different locations using high density polyethylene or plasticbottle containersfrom Ilesha mine site. One sample was spiked with acid labeled as spiked and the other was labeled un-spiked withoutspiking with acid and water samples were transported in ice cooler on ice to the laboratory and preserved in a fridge regulated at 4 ^{0}Cprior to analyses.. Hand trowel was used to collect the sample (sand) into a plastic bottle and the plastic bottle was dipped into mine wastewater in the site for sample collection. 5 mls of nitric acid was added to the waste mine water to prevent it from oxidation. Then the samples were taken to the laboratory for filtration. The filtrate was subjected to physicochemical analysis and inductively coupled plasma optical emission spectroscopy (ICP-OES).

2.2 DESCRIPTION OF SAMPLE LOCATION

The gold mine water was collected in Osun State in Ilesha west in a gold mining industry located at a latitude 7.623902^{o}N and longitude 4.715154^{o}E.The gold mining site in Osun State, Nigeria appeared to be illegal mining site which has led to complain of the residents around the mine. Many indigenes and residents have had their means of livelihood taken away as these individuals mine the valuable resource at their expense without recourse to environmental protection of the inhabitants.Illegal mining sites are so rampant operating in Ilesha mine site within Osun State and all these activities have caused a lot of damages to the environment since government has failed to intervene into the situation. More so, people in the environment are complaining bitterly due to the havoc it caused to them. According to the residents, these miners continue to enter farmlands in search of gold and other mineral resources. Counting their losses, the residents of Ilesha west Osun State lamented that they have resorted to walking long distances to get water for their daily use.

2.3 CHEMICALS USED

Chemicals used such nitric acid, hydrochloric acid, were purchased from Merck chemicals while hydrogen peroxide was purchased from TUNNEX Chemicals. All the chemicals were used without any other further treatment.

2.4SAMPLE DIGESTION

50 mL wastewater sample was digested at 85° C in 12 ml of aqua regia (HCl/HNO_3 v/v) in ratio 3:1 on a hot plate in a fume cupboard until white fumes was observed. The sample was allowed to cool to room temperature and then diluted with 20 ml of 2 % Nitric Acid (v/v). The mixture was then transferred into a sample bottle after filtering using Whatman No.42 filter paper and made to the mark with distilled water. The sample was analyzed using Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP – OES).

2.5BATCH ADSORPTION STUDY

Batch adsorption study was carried out using wood ash as adsorbent to remove toxic heavy metals from gold mine wastewater. The treatment process was carried out by optimizing the following parameters which are dosage, contact time and pH.

Effect of Dosage

50ml of mine water was weighed into four separate 250 mL conical flasks and different dosage of wood ash was added as 0.5 g, 1.00g, 1.5g and 2.00g respectively. The samples were subjected to shaken with a shaker for 2 hrs. After shaking, the filtratesamples were collected and transferred into sample bottles were labeled and kept for analysis.

Effect of Contact Time

50ml of the mine water was added into four separate conical flasks and optimum dosage of the wood ash sample was added to each of the conical flask and subjected to constant shaking on a shaker. The first flask was shaken for 30mins;1 hour, 1 hr 30 mins, 2 hrs. Samples were filtered and collected in sample bottles and kept for ICP-OES analysis.

Effectof pH

50 ml of the adjusted mine water to pH 2.00 – 10.00 measured and transferred into five separate conical flask.1g of the woodash was weighed and added to each of the five conical flasks containing the mine water. The samples were s. Analysis was then carried out on the sample.

2.6 ANALYTICAL TECHNIQUES

pH, EC, and TDS of the mine water as received aredetermined usingHach water quality multifunction pH meter. The multifunction pH meter was calibrated with buffers pH 4.0, 7.0, 12 and the electrical conductivity meter was calibrated using 10 μScm^{-1}, 500 μScm^{-1} and 1288 μScm^{-1} standard KCl solutionsbefore testing the wastewater solution. The toxic and trace heavy metalswere determinedusing Variance Liberty II inductively coupled plasma optical emission spectroscopy (ICP-OES) analytical technique.

III. RESULTS AND DISCUSSIONS

3.1 PHYSICOCHEMICAL ANALYSIS

Physicochemical parameter results of gold mine wastewater presented in Table 1 revealed that the pH of the gold mine waterwas observed to be below the WHO allowable range for drinking purpose of 6.5 - 8.5 of the Nigeria Standard for Drinking Water Quality (NSDWQ)/World Health Organization (WHO) standard drinking water permissible limits. The results of the EC and the TDS are within the WHO/NSDWQ standard limit of drinking water [34, 35].

Table 1: Physicochemical Analysis of Gold Mine Wastewater, (n = 3)

Parameters	Gold (Au) Mine Water	WHO permissible limit	(NSDWQ)
pH	5.9 ± 0.01	6.5-8.5	6.5-8.5
EC	154 ± 1.98	(1000-500) µS/cm	(1000-500)µS/cm
TDS	77 ± 2.15	(1000-500) mg/L	(1000-500) mg/L

3.2BATCH ADSORPTION STUDY

3.2.1 DosageOptimization

Figures 1-5 revealed theresults ofwood ash effect of the removal of toxic heavy metals from gold mine wastewater by adjusting the adsorbent dosage from 0.5-2.0g. The result of the maximum adsorption treatment removal efficiency of U in Figure 1 was 42.21% at 0.5g, 69.75% at 1.0g, 78.96% at 1.5g, 86.90% at 2.0g. The result of the maximum adsorption treatment removal efficiency of Ba removal in Figure 2 was 44.81% at dosage 0.5g, 76.29% at 1.0g, 91.53% at 1.5g, 96.39% at 2.0g. The result of the maximum adsorption treatment removal efficiency of Cd in Figure 3 showed that the percentage dosage removal was 30.54% at 0.5g dosage, 65.04% at 1.0g, 85.23% at 1.5g, 86.74% at 2.0g. The result of the maximum adsorption treatment removal efficiency of Cr in Figure 4 was at 48.86% at 0.5g, 74.07% at 1.0g, 91.03% at 1.5g, 99.52% at 2.0g. The result of the maximum adsorption treatment removal efficiency of Pbin Figure 5 was 57.04% at 0.5g, 89.32% at 0.1g, 94.34% at 1.5g, 96.12% at 2.0g. The percentage removal increases with decrease in adsorption capacity. The optimum dosage was found to be 1.0 g of wood ash adsorbent.Similar trend of metal removal was observed that as the pH increase and the adsorption capacity was observed at 1.5 g dosage of wood ash.Similar trend of metal removal was observed as the dosage increase, more metals are removed.

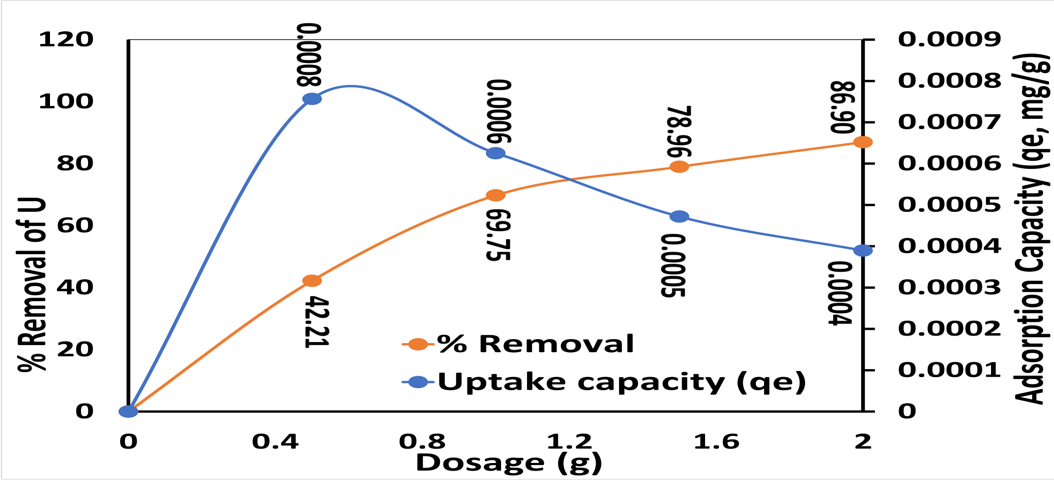

Figure 1: Wood ash Adsorption Dosage Treatment of Uin Gold Mine Water

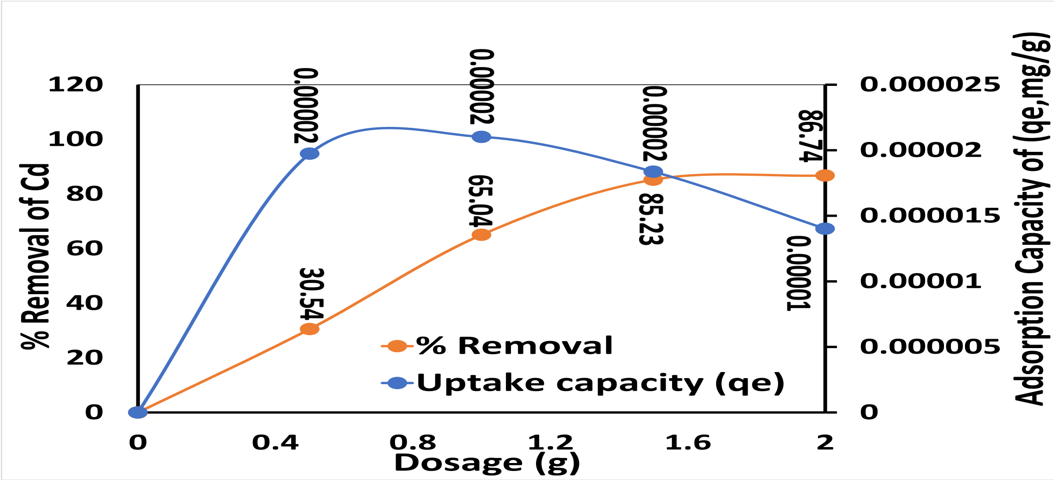

Figure 2: Wood ash Adsorption Dosage Treatment of Cd Gold Mine Water

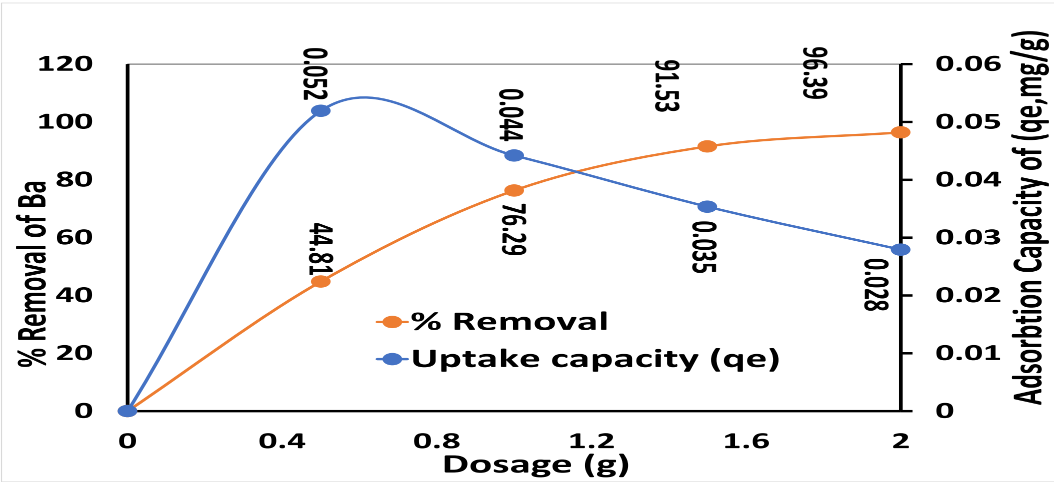

Figure 3:Wood ash Adsorption Dosage Treatment of Barium In Gold Mine Water

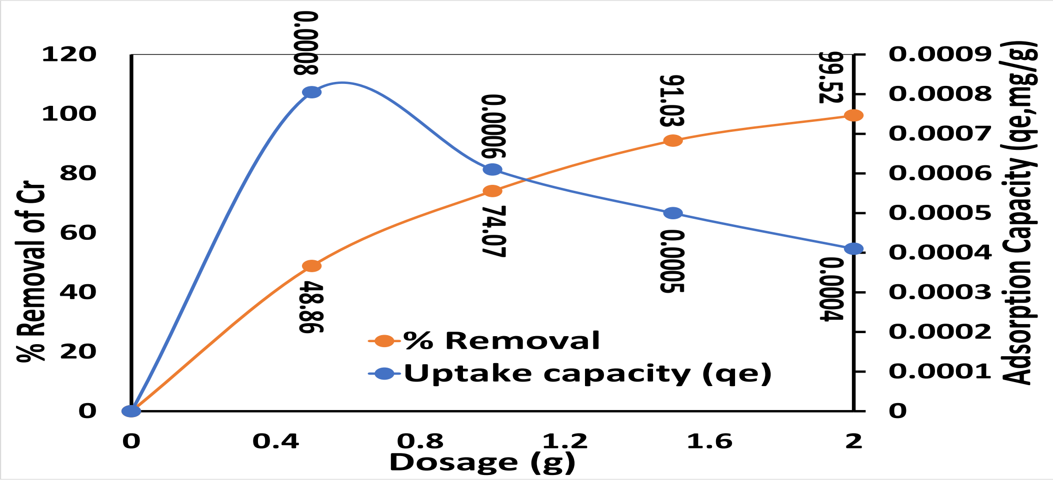

Figure 4: Wood ash Adsorption Dosage Treatment of Crin Gold Mine Water

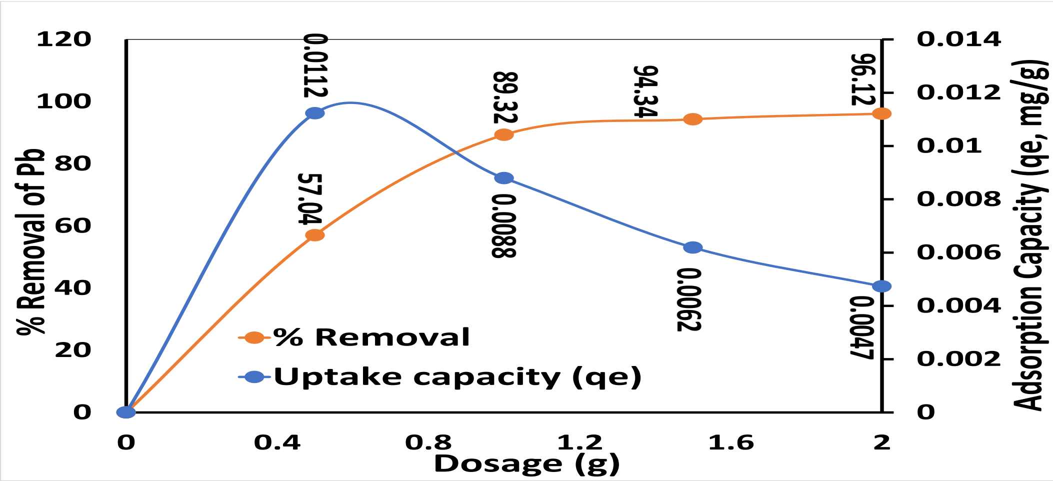

Figure 5: Wood ash Adsorption Dosage Treatment of Pbin Gold Mine Water

3.2.2pH Optimization

Figures 6-10 revealed the results ofpH effect on the removal of toxic heavy metals fromgold mine wastewater by varying the pH from 2.00 to 10.00. The maximum pH adsorption treatment efficiency of U was 54.61 % at pH 2.0, 82.07 % at pH 4.00, 92.66 % at pH 6.00, 94.77% at pH 8.00 and 95.43 % at pH 10.00.Figure 7 present the effect of pH adsorption of Cd results in the maximum absorption of 26.66% at pH2.00, 74.89% atpH 4.00, 86.89% atpH 6.00, 92.27% atpH 8.00, and 93.63% at pH 10.00. The maximum pH adsorption treatment efficiency of Ba in Figure 8 was 42.88 % at pH 2.0, 79.86 % at pH 4.00, 89.44 % at pH 6.00, 92.52% at pH 8.00 and 94.45 % at pH 10.00. The maximum pH adsorption treatment efficiency of Cr in Figure 9 was 37.94 % at pH 2.0, 66.78% at pH 4.00, 87.01 % at pH 6.00, 96.38% at pH 8.00 and 97.44 % at pH 10.00. The maximum pH adsorption treatment efficiency of Pb in Figure 10 was 44.91% at pH 2.0, 83.01% at pH 4.00, 91.02% at pH 6.00, 93.31% at pH 8.00 and 95.33% at pH 10.00. %. Similar trend of metal removal was observed that as the pH increase and the adsorption capacity was observed at pH 6.00.

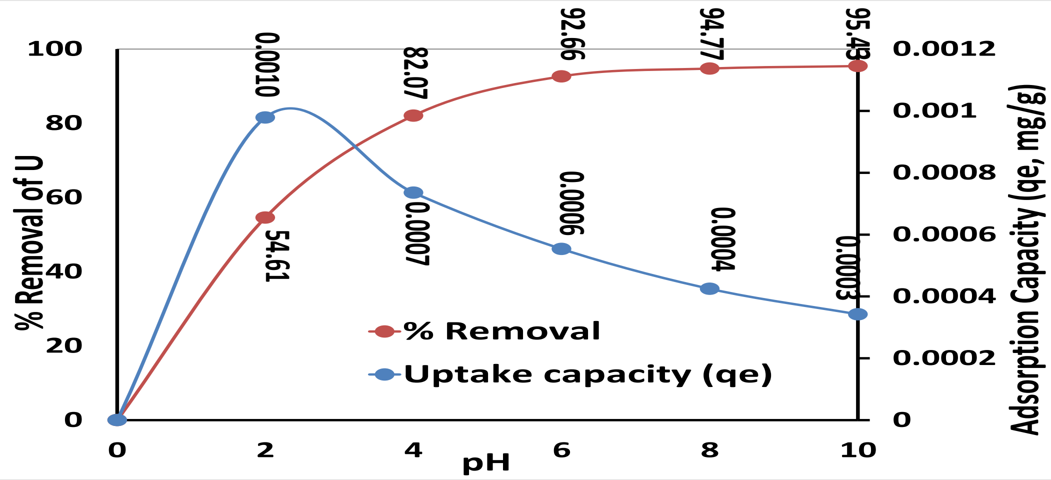

Figure 6: Effect of pH on Wood ash Adsorption of U in Gold Mine Water

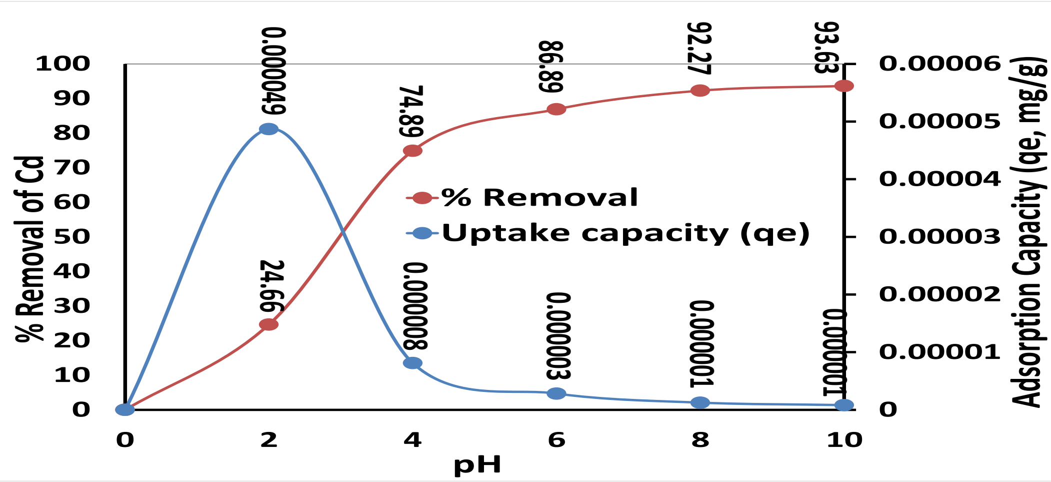

Figure 7: Effect of pH on Wood ash Adsorption of Cd in Gold Mine Water

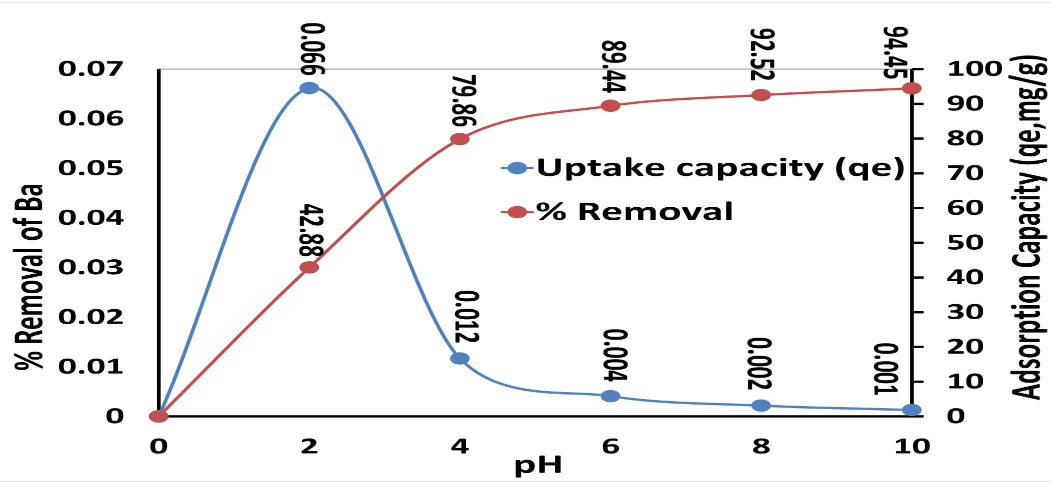

Figure 8: Effect of pH on Wood ash Adsorption of Ba in Gold Mine Water

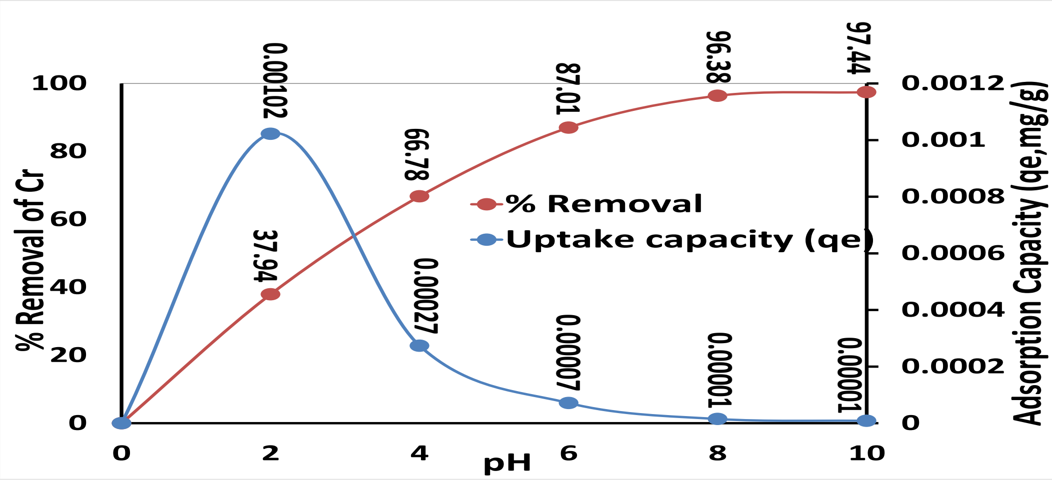

Figure 9: Effect of pH on Wood ash Adsorption of Cr in Gold Mine Water

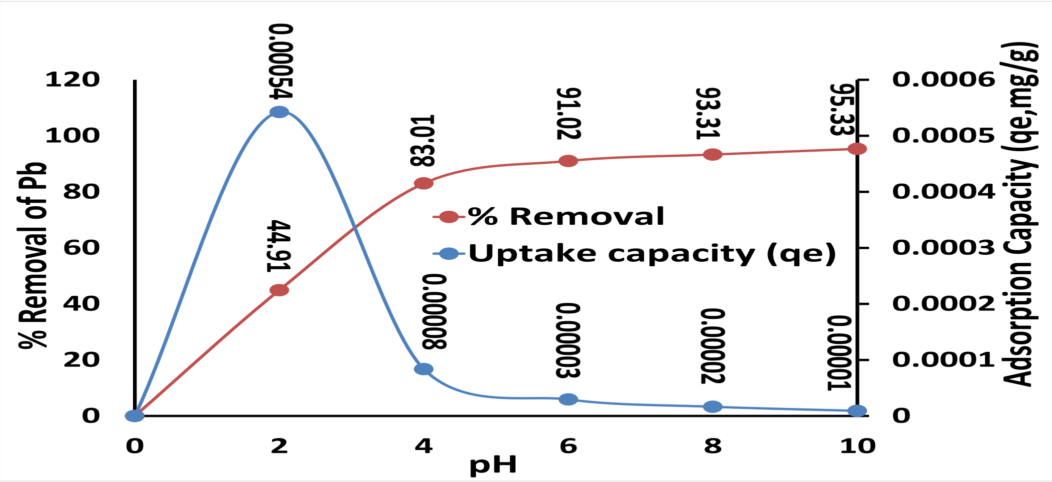

Figure 10: Effect of pH on Wood ash Adsorption in Gold Mine Water

3.2.3 Contact Time Optimization

Figures 11-15 revealed theresults of contact timeeffect on the removal of toxic heavy metals from gold mine wastewater by varying the treatment time from 30-120 minutes. The maximum adsorption treatment efficiency removal of U in Figure 11 was 21.70 % at 30 minutes, 76.43 % at 60 minutes, 84.93 % at90 minutes, and 86.19% at 120 minutes.The maximum adsorption treatment efficiency removalof Ba in Figure 12 was 36.18% at 30 minutes, 88.13% at 60 minutes, 97.58% at 90 minutes, and 98.12% at 120 minutes. The maximum adsorption treatment efficiency removal of Cd in Figure 13 was 30.54% at 30 minutes, 72.11 at 60 minutes, 85.91% at 90 minutes, and 92.93% at 120 minutes. The maximum adsorption treatment efficiency removal of Cr in Figure 14 was 33.32% at 30 minutes, 78.99%at 60 minutes, 86.77% at 90 minutes, and 88.04% at 120 minutes. The maximum adsorption treatment efficiency removal of Pbin Figure 15 is 46.25% at 30 minutes, 87.64% at 60 minutes, 91.85%, and 93.69%. Similar trend of metal removal was observed as the time increase and the adsorption capacity was observed at 60 minutes.

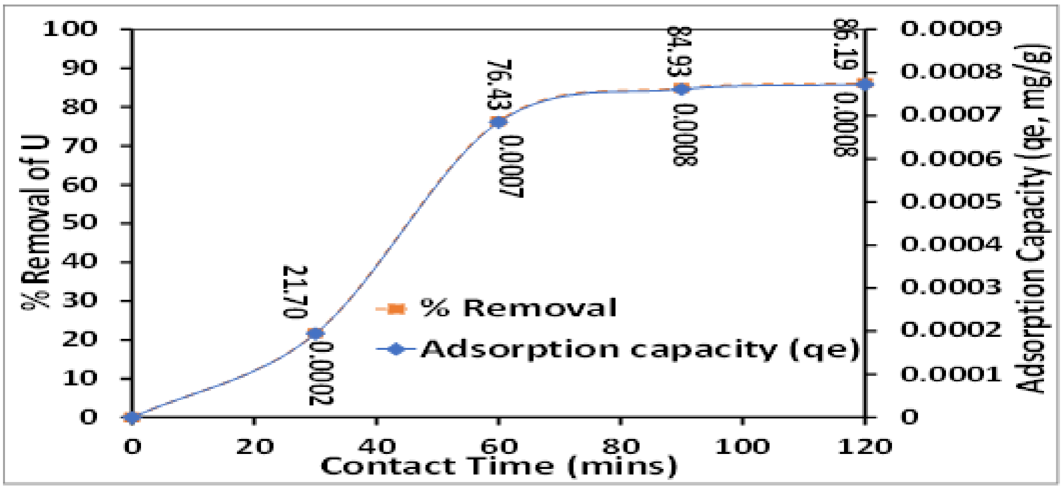

Figure 11:Effect of contact time removal of U in mine water

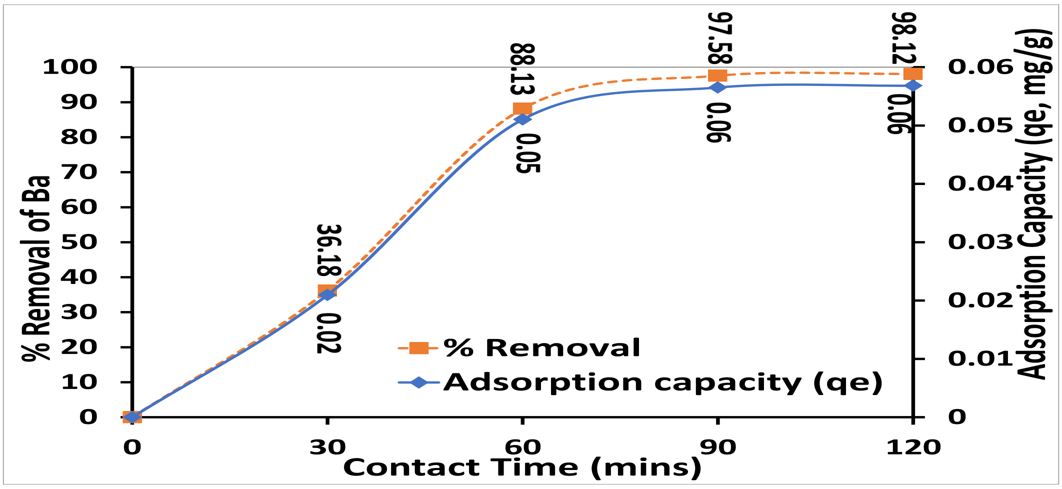

Figure 12:Effect of contact time removal of Ba in mine water

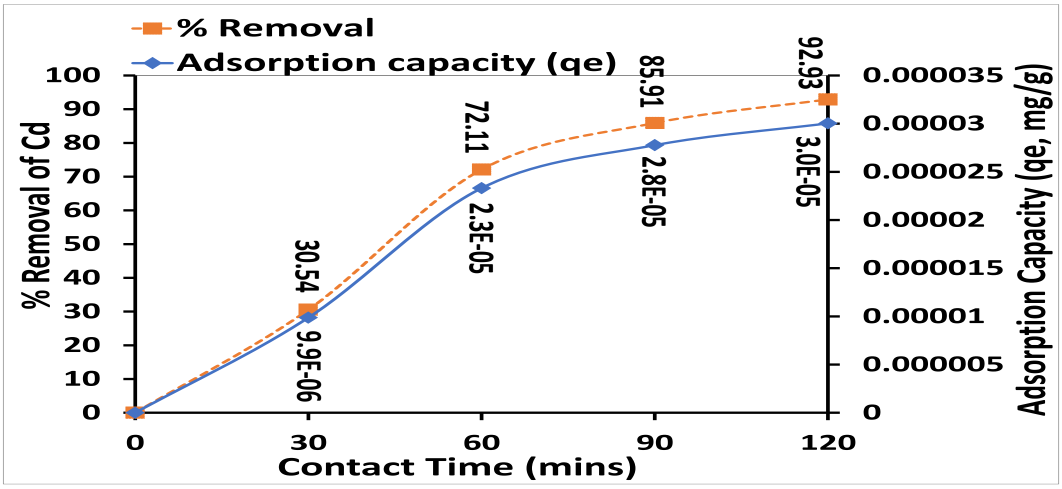

Figure 13: Effect of contact time removal of Cd in mine water

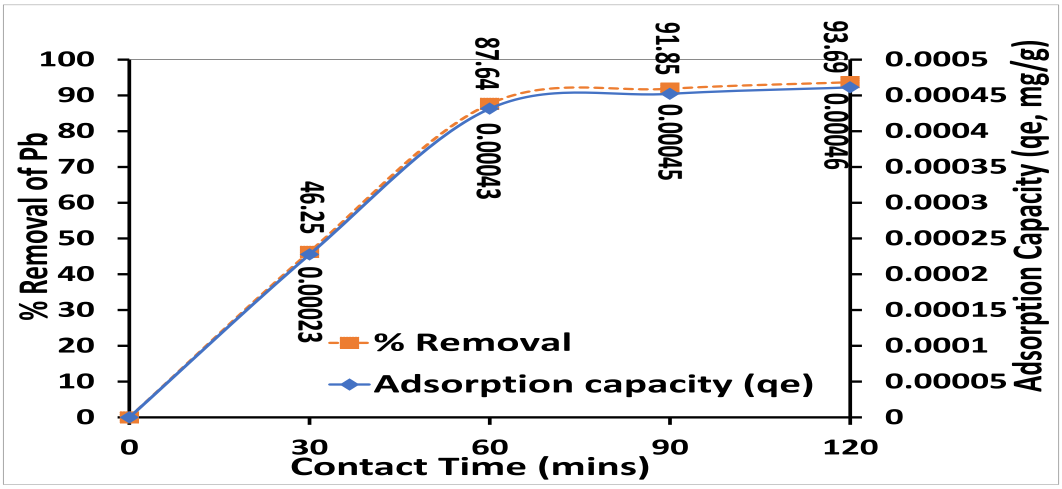

Figure 14: Effect of contact time removal of Pb in mine water

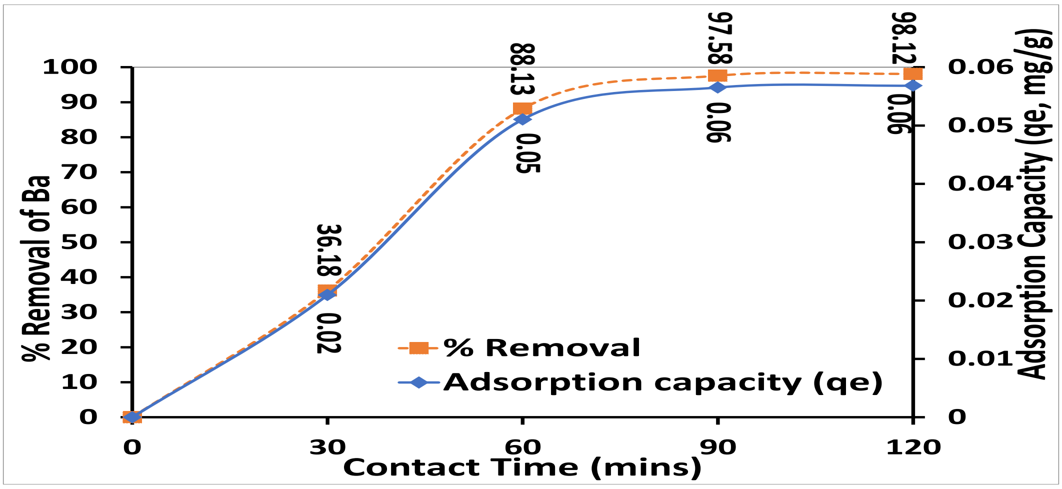

Figure 15:Effect of contact time removal of Cr in mine water

IV. CONCLUSION

This research study used wood ash adsorbent to remove toxic heavy metals from gold mine wastewater and theresults obtained from this research are as follow:

- The wood ash is a good adsorbent that can remove toxic heavy metals from mine water.
- The optimum adsorption capacity of the dosage, pH and contact time is 1.5 g, 6.00, and 60 minutes respectively.
- Similar trend was observed for all the treatment conditions (dosage, pH, and contact time) as they are increased the removal rate was also increased.
- The wood ash adsorbent was found to be a good material for removal of toxic heavy metals in wastewater.

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