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Coagulation of Synthetic Contaminated Water with Lead (II) Metal by Using Kaolin and Bentonite with Alum

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Abstract.

The present study examines the susceptibility of both bentonite clay and kaolin as coagulant aids with alum to the removal of lead metal from synthetic contaminated water two levels of lead(II) contamination were taken (10,20)mg/l by using lead nitrate .Use the Jar test to represent coagulation and flocculation after determining the optimum dose and medium for all coagulants different proportions of both clays were taken with alum the results were the best removal to lead (II) with 20 mg/l (75% bentonite : 25% alum) 94.1%, (40% kaolin : 60% alum) 91.2% and the best removal to lead (II) with 10 mg/l(40% bentonite : 60% alum) 92.02 % , (75% kaolin : 25% alum) 90% . After the treatment , the sludge for the best removal was taken and divided into three sections once used directly and again for regeneration using a base solution once and an acid solution for different periods. The best lead(II) removal was achieved when using the sludge directly, which does not deny that the regeneration of the sludge was also a good removal. The best removals were (85, 85.9, 84, 86)

Keywords: Bentonite, Kaolin , Regeneration , Lead(II) , Lead nitrate , Coagulation , Flocculation, Jar test

1- Introduction

Heavy metal buildup has resulted from a sharp rise in the amount of industrial waste being released into the environment, mostly into the soil and water, as a result of the expansion of industry, particularly in urban areas. The careless discharge of heavy metals into the earth and oceans poses a significant global health risk due to their irreversible toxicity and consequently enduring impact on the ecosystem.[1] Because of the hazardous impact that heavy metal ions have on living things, including humans, environmental pollution from these ions is a major concern. Heavy metals tend to accumulate in living organisms and do not break down into innocuous end products, which can lead to a variety of illnesses and disorders.[2], [3] The concentration of heavy metals in the environment is greatly increased by operations like metal castings, smelting and mining, wastewater treatment plants, and other agricultural tasks Although the issue of heavy metal contamination is not new, there is still concern worldwide for its management and prevention [4], [5]The World Health Organization (WHO) lists aluminum, chromium, manganese, iron, cobalt, nickel, copper, zinc, cadmium, mercury, and lead as the metals that should be taken into the greatest amount of immediate attention[6]. As a result, before being disposed of in the environment, these pollutants must be reduced to a level that is acceptable and in accordance with the limitations allowed by international rules and regulations of the World Health Organization (WHO)[7], [8].Lead pollution, in particular, has been linked to reproductive and neurological system damage, anemia, persistent headaches, diarrhea, cancer, mental retardation, and kidney problems[9]. coagulation-flocculation is a frequently employed physico-chemical approach in the treatment of metal-bearing industrial wastewater because it eliminates colloidal particles, certain soluble chemicals, and extremely fine solid suspensions that were initially present in the wastewater by destabilizing and forming flocculation[10]. traditional chemical-based coagulants, such as polyaluminum chloride (PAC), ferric chloride ($FeCl_3$), and alum ($AlCl_3$). The use of these coagulants, while beneficial, has drawbacks such as inefficiency in low-temperature water, comparatively high acquisition costs, negative health effects, large volumes of sludge produced, and a notable impact on the pH of treated water. Additionally, there is substantial evidence that coagulants based on aluminum contribute to the onset of Alzheimer's in people. The use of synthetic polymers as coagulants, such as acrylamide, raises concerns about their neurotoxicity and carcinogenicity. To prevent the disadvantage, it is therefore preferable to use clay minerals in place of these artificial coagulants. The safe use of sludge and reducing the cost of flocculants and coagulants are currently the top priorities for environmentalists[11], [12]. Conventional water treatment plants do not treat water from heavy metals, and because of the increasing proportion of heavy metals in surface waters due to the development of industry and the lack of control over the plants, new methods and techniques must be developed to treat water from the hazards of these metals. Some previous studies of the use of clays to remove lead from water[13] The maximum removal effectiveness of 85.1% was achieved with a pH of 5 and 2 grams of adsorbent weight and 10 mg/L of starting metal concentration. It turned out that kaolin clay is ideal for eliminating Pb^{+2} from wastewater.[14] That's where he found in this study that Bentonite-assisted pb(II) removal was 100% at room temperature and with light agitation (100 rpm); at 60°C and no agitation, it was only about 90%.

The objective of this study is to treat water from the effects of lead metal by conventional treatment using clay as an adjuvant with alum and the possibility of reusing sedimentation process sludge in coagulation.

2- Experimental Work

1- Preparing of coagulant

Alum stock:

To prepare alum stock Ten grams of $Al_2(SO_4)_3.18H_2O$ were dissolved in one liter of distilled water, and the mixture was vigorously stirred to produce a 1% solution concentration. Thus, 10 mg of alum are included in 1 milliliter of this solution.[15]

2- Preparing of coagulant aids

Bentonite and kaolin clay were used as coagulation aids with alum; these are natural, environmentally friendly Iraqi clays. The samples were ground using an electric grinder for 15

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minutes to obtain a very fine powder. The cation exchange capacity of clay (Bentonite and Kaolin) with respect to heavy metal removal is well documented.[16]

3- Preparing of stock solution lead (II)

In order to create 1000 mL of 1000 ppm lead stock solution, 1598 mg of lead nitrate pb(NO3)2 will be dissolved in 1000 mL of distilled water in a 1000 mL beaker.[17]

4- Jar test : A Jar test apparatus was used to simulate the treating processes of coagulation, flocculation and sedimentation. The test Jar test consists of six glass beakers with a usable capacity of 1 L and stirrers that can be adjusted to the same mixing conditions for all beakers.[18] The experiments were performed on Sanitary engineering lab in Collage of Engineering in Al-Qadisiyah University Al-Diwaniya /Iraq,

After adding coagulants, mixing time and strength are of great importance for the success of the processing steps. The mixing process after the addition of coagulants generally includes two successive phases [19]:

1- The short and dense mixing phase is intended to optimize the interaction conditions of the coagulation particles.
2- A longer, less intense phase aims to flocculate the activated particles to produce strong, large, separable flocs.

Section I of experminent included Determine the best dose to remove lead at low concentration (10 mg/l) with concentrations (10, 15, 20, 25, 30) for alum, bentonite, and kaolin, and at high concentration (20 mg/L) with concentrations (30, 35, 40, 45, 50, 55) mg/L for alum, bentonite, and kaolin.fig (1)

After determining the best dosage for alum, bentonite, and kaolin, pH was adjusted between 5 and 9 using NaOH and HCl [17]. Constant is the is the best dose for three materials. The surface charge of suspended colloids is altered by pH, which can significantly affect the dosage and application of coagulants. This makes pH an important factor in coagulation [20], [21].

In Section II of the coagulation and flocculation experiments, different proportions of clay and alum were taken from the optimum dosage, and the best lead (II) demineralization ratio was calculated. Experiments conducted under neutral-to-base conditions were controlled by the addition of NaOH.

TABLE1. The Operating conditions of the jar test experiment used in this study

Characteristic	Description
Coagulants	Alum (Al2(SO4)3.18H2O)
Coagulants aid	Bentonite , kaolin
pb (II) concentration	10mg/l , 20mg/l
Quick mixing	1 minute at 150 rpm
Slow mixing	20 minutes at 40 rpm
Time of setting	30 minutes
Temperature	Room condition
pH value	7.3 – 7.8
The Optimum dose for alum	((55,25)mg/l
The Optimum dose for bentonite	(55, 20)mg/l
The Optimum dose for kaolin	(55 ,15)mg/l

3-Result And Discussion

1- Optimum dose: The optimum dosage with 10mg/l of lead(II) for alum was 25 mg/l , bentonite clay 30 mg/l and kaolin clay 10 mg/l fig(1-a) . The optimum dosage with 20 mg/l of lead (II) for three material was (55 mg/l),fig (1-b)

2- pH effect: experiments have shown that the best lead (II) removal is between 7-8. The outcomes are consistent with those documented in the literature[20] .The removal rate of lead increased significantly with bentonite clay and kaolin at baseline conditions, but with alum the increase was slow fig (2)

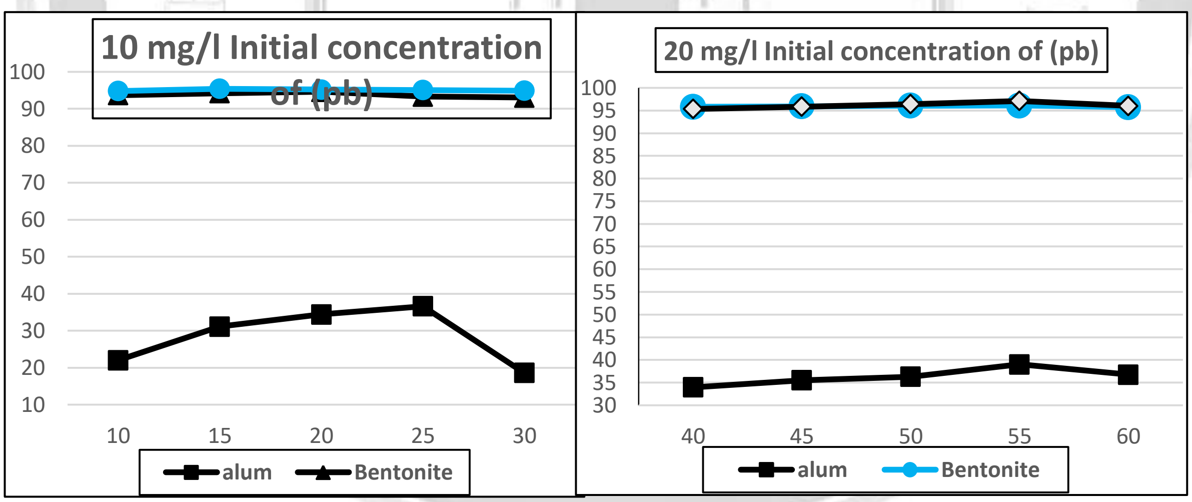

FIGURE 1. the best remover for alum, bentonite clay, and Kaolin (a) with (10 mg/l) and (b) with (20 mg/l)

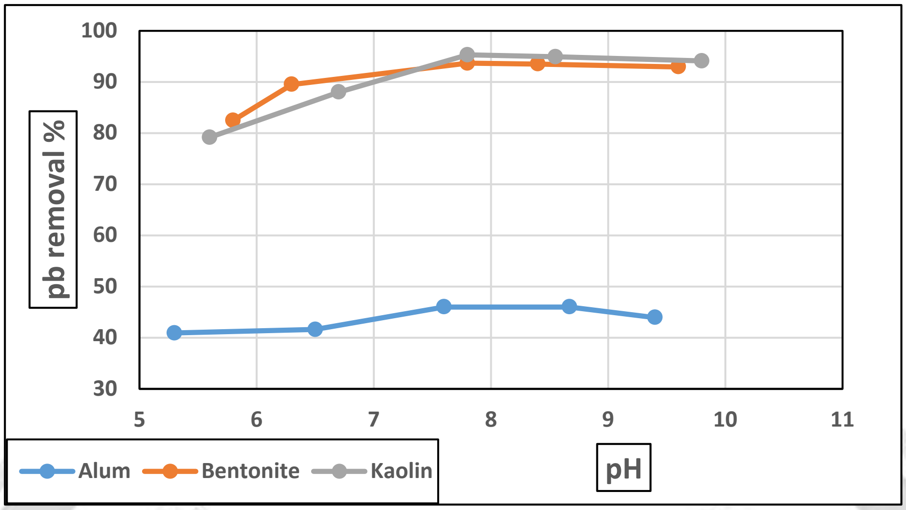

FIGURE 2. showing the pH effect

3- Lead (II) removal for a mixture alum and clay (Bentonite and Kaolin)

With the results, the best removal to lead (II) with 20 mg/l (75% bentonite, 25% alum) was 94.1%, (40% kaolin, 60% alum) was 91.2%, and the best removal to lead (II) was 10 mg/l(40% bentonite, 60% alum). 92.02% (75% kaolin, 25% alum) 90% The high efficiency of bentonite clay in removing. The increase in the removal rate is due to the positively charged edges present on the surface of the bentonite clay particle, which are caused by some broken bonds in the lattice structure of the bentonite clay. The particles are also attracted and clumped together when negatively charged faces collide with positively charged particles. Kaolin clay is considered to have a weak ability for ion exchange, estimated at 15–5 meq/100 g, when compared with the ion exchange ability of bentonite, which may reach 60–100 meq/100 g. The adsorption process in kaolin is also considered less than in the rest of the clays due to the strong bonding between its layers. This force prevents contaminants from entering between surfaces.[21], [22] The outcomes are shown in Fig. 3.

$$\text{Removal (\%)} = \left(\frac{C_0 - C}{C_0}\right) * 100 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \;(1)$$

Where Co and C represent the initial and final lead (II) cocentration

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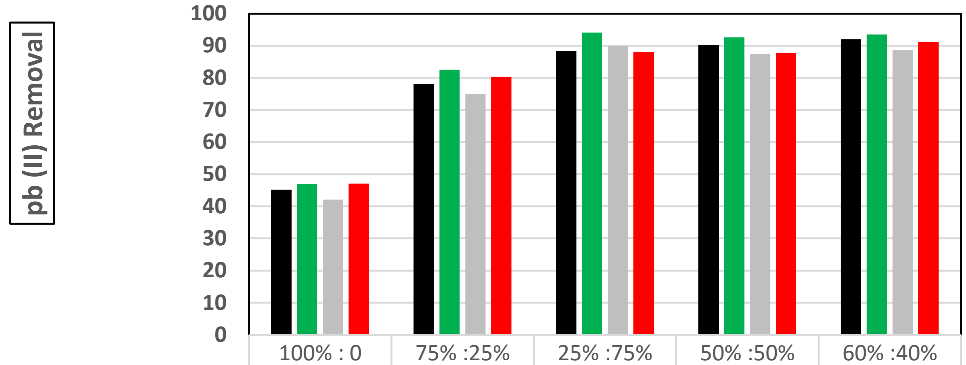

	100% : 0	75% :25%	25% :75%	50% :50%	60% :40%
ratio alum to bentonite with 10 mg/l	45.2	78.2	88.3	90.24	92.02
ratio alum to bentonite with 20 mg/l	46.9	82.5	94.1	92.64	93.5
ratio alum to kaolin with 10 mg/l	42.14	75	90	87.43	88.57
ratio alum to kaolin with 20 mg/l	47.1	80.35	88.07	87.85	91.2

FIGURE 3. showing the results of lead (II) removal

4- pH effect for a mixture alum with clay (Bentonite and Kaolin)

The pH of the samples was determined using an electronic pH meter.

The change in pH values after treatment ranged from (7.5–10), with the highest value being 9.78 and the lowest value being 7.52. The pH (10 mg/l) starts at 7.52 (100% alum) and reaches 9.5 (25% alum). The pH with 20 mg/l starts at 9.51 (100% alum) and reaches 7.5 at (25% alum, 75% kaolin) and 8 at (25% alum, 75% bentonite). The outcomes are shown in Fig(4).

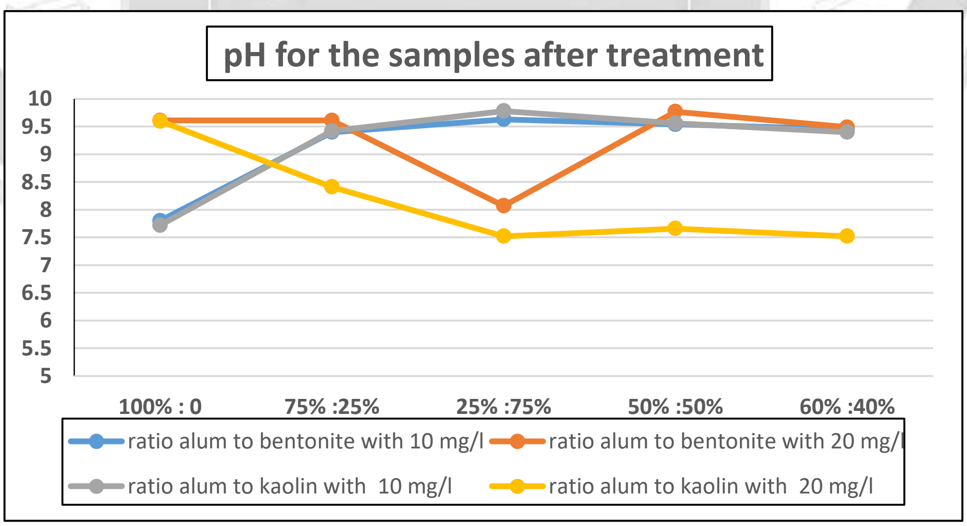

FIGURE 4. showing the results of pH

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5- Electrical conductivity (EC) for a mixture alum and clay (Bentonite and Kaolin)

Using lead nitrate to pollute the water with lead metal also caused the nitrate to be thrown into the water, which increased the salts in the water, which also increased electrical conductivity. The use of(NaOH) to increase removal efficiency also resulted in the excretion of Na into the water, in addition to the use of alum, thus increasing salts and conductivity. The electrical conductivity at 20 mg/l lead started a little bit (110.3, 111) µs/cm at (100% alum), and the maximum conductivity for (25% bentonite and 75% alum) was (417) ms/cm, and the (60% alum and 40% kaolin) was (399) µs/cm. The electrical conductivity at 10 mg/l led to the minimum conductivity for (50% bentonite and 50% alum) being 191 µs/cm, and the minimum conductivity for 60% alum and 40% kaolin was 110.3 µs/cm. The maximum conductivity for 40% bentonite and 60% alum was (693) µs/cm, and for 100% alum, it was (336) µs/cm. The outcomes are shown in fig (5)

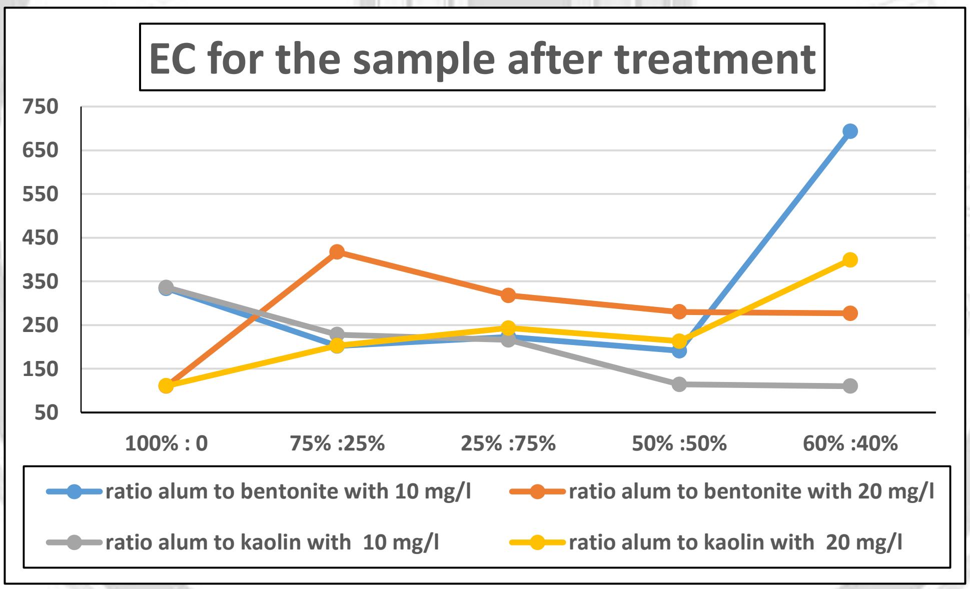


FIGURE 5 . showing the results of Ec

Sludge Regeneration

Two solutions were prepared with adjusted pH values at 9.5 and 5.5 The pH of the solutions was adjusted by adding either hydrochloric acid (Hcl) or sodium hydroxide (NaOH). Samples immersing for 30min , 60min and 120min , to regeneration Then reused it as a coagulant. Experiments (at same previous experimental conditions except stay natural pH for samples 5-6) [23]

6- Lead (II) removal after the sludge has been used as a coagulant

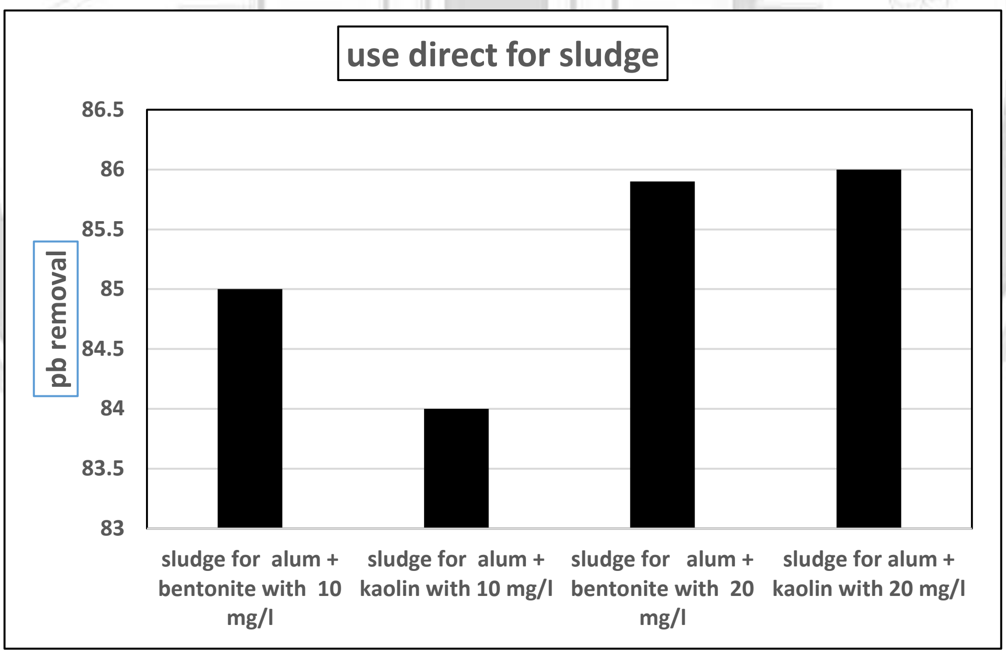
a- The best lead (II) removal was achieved when using the sludge directly, which does not deny that the regeneration of the sludge was also a good removal. The best removals were (85, 85.9, 84, and 86) . The outcomes are shown in Fig(6-a).

b- Effect time with an acidic condition:

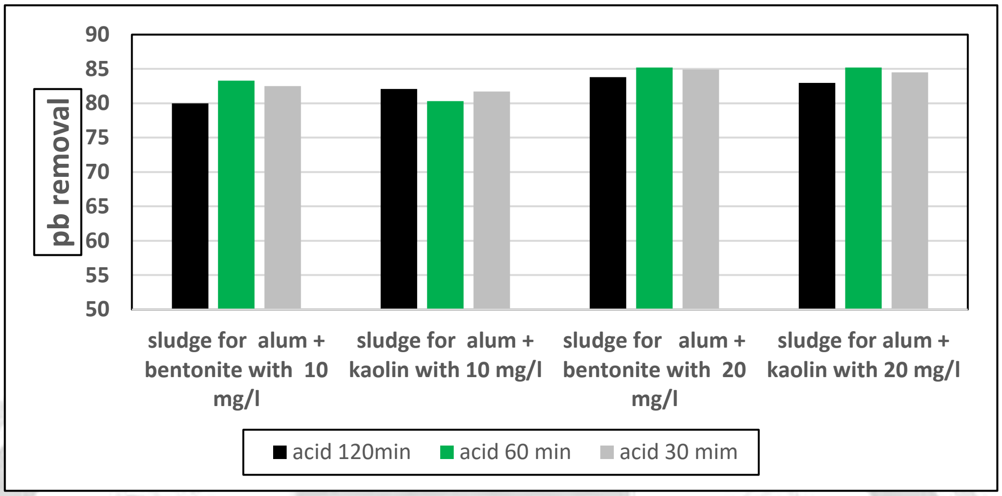
The results shown when the sludge is immersed in an acidic medium for 60 min that has the best removal for lead (II) when used (alum + bentonite with 10 mg/l and 20 mg/l) and (alum +kaolin with 20 mg/l) (83.2, 85.2,85.2,85.2). the best removal for lead (II) when using alum and kaolin with 10 mg/l (82.1) when the sludge is immersed in an acidic medium for 120 min. The outcomes are shown in fig (6-b)

c- Effect time with the basic condition:

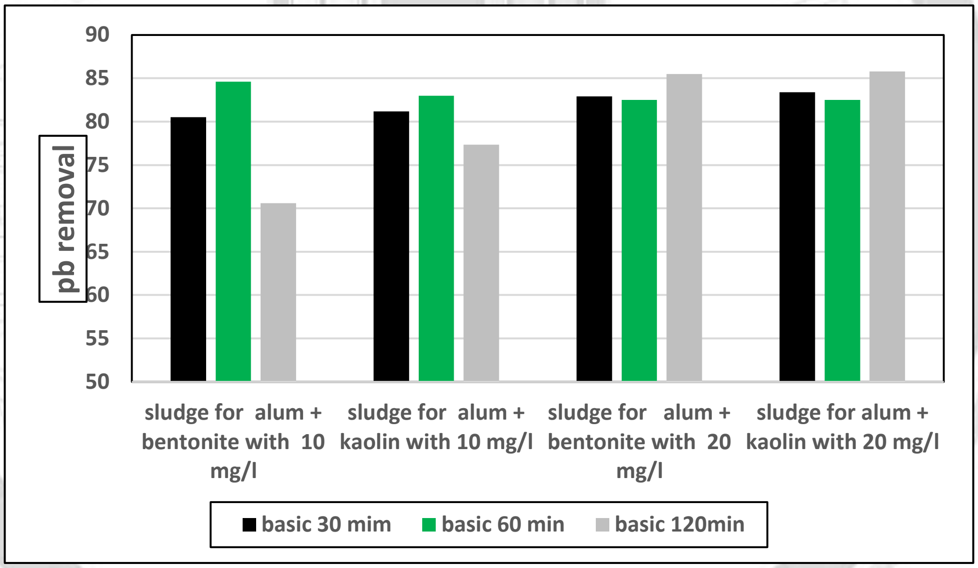
The results shown when the sludge is immersing in the basic medium for 60 min that has the best removal for lead (II) when used (alum + bentonite and alum +kaolin with 10 mg/). (84.6, 83). the best removal for lead (II) when used (alum + bentonite and alum +kaolin with 20 mg/) (85 5, 85.8) . when the sludge is immersing in the basic medium for 120 min The outcomes are shown in fig (6-c)



(a)



(b)



(c)

FIGURE 6. Showing the results of lead (II) removal after the sludge has been used as a coagulant

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7- pH effect after the sludge has been used as a coagulant

In this part of the experiments, (NaOH) was not added in the experiments, so we noticed that the values of pH were acidic because of lead nitrate and ranged from (5 to 6) with a small increase when the sludge was immersing with a base solution. The outcomes are shown in fig (7)

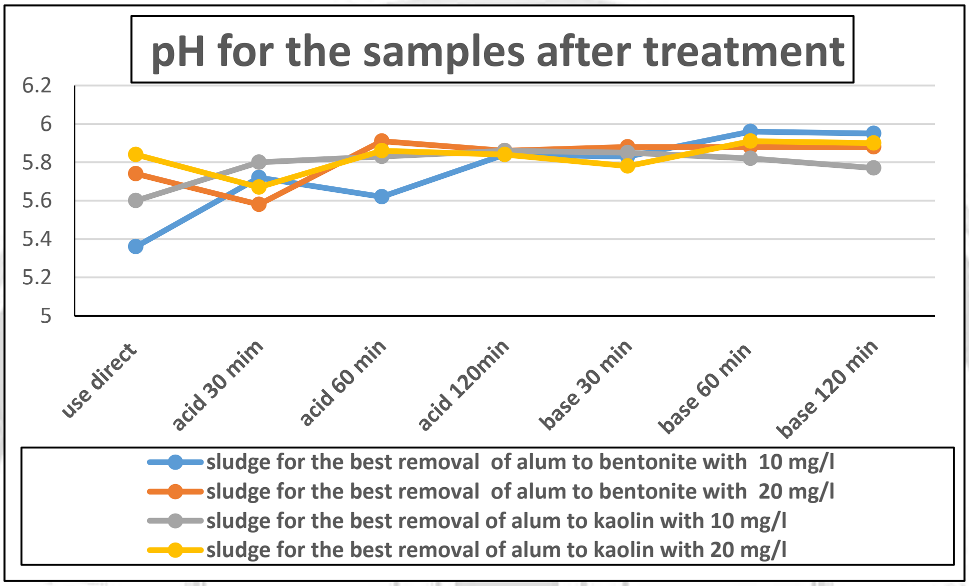

FIGURE 7. showing the results of pH after the sludge has been used as a coagulant

8- Electrical conductivity (EC) after the sludge has been used as a coagulant

The effect of not using alum and (NaOH) was to reduce the conductivity by 30 compared to the conductivity before the sludge was used The maximum conductivity was (149) µs/cm for the alum and kaolin sludge immersed for two hours in a basic solution. The outcomes are shown in fig (8)

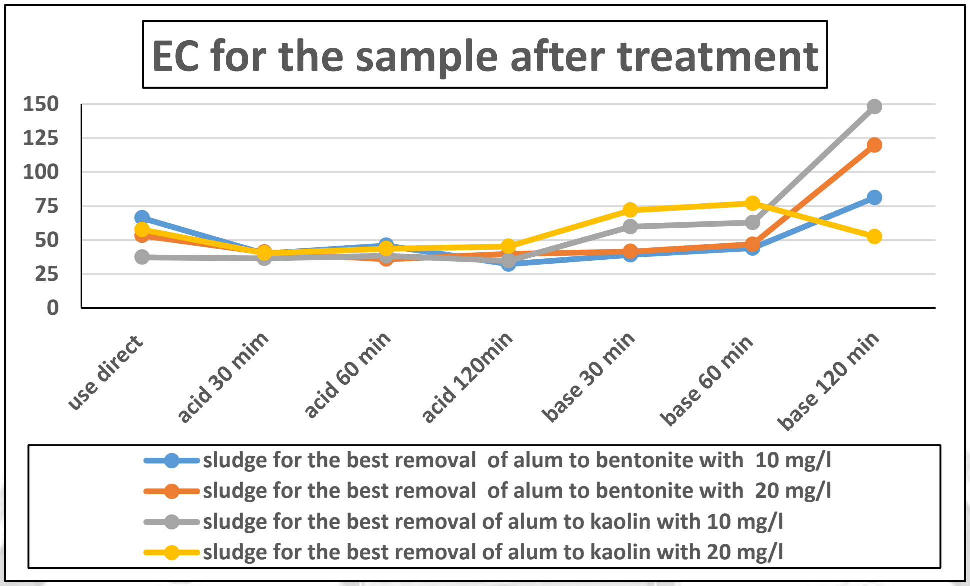

FIGURE 8. showing the results of Ec after the sludge has been used as a coagulant

4- Conclusion

Industrial development and the increased use of fossil fuel-based vehicles have led to an increase in the dumping of heavy metals in soil and water. Alternative, cheap, and environmentally friendly methods that reduce the risk of these metals, especially lead (II), need to be found because of their direct association with cancer and their impact on the human nervous system. The World Health Organization (WHO) recommends that the lead (II) level in water be below 0.01 mg/l.

The results prove that clays are more effective at demineralizing lead from alum due to their catonic nature, ion exchange, and negative charge.

The results were the best removal to lead (II) with 20 mg/l (75% bentonite : 25% alum) 94.1%, (40% kaolin : 60% alum) 91.2% and the best removal to lead (II) with 10 mg/l(40% bentonite : 60% alum) 92.02 % , (75% kaolin : 25% alum) 90% .

When recycled sludge is used, it has been observed that lead may be effectively removed from synthetic wastewater. The best removals were (85, 85.9, 84, 86).

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تخثير المياه الملوثة اصطناعيا بمعدن الرصاص بأستخدام طيني (البنتونايت و الكاؤلين) مع الشب

اخلاص جاسم حسين[1] ( ) انتصار كريم حسين[1]

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الخلاصة

تناولت الدراسة الحالية قابلية كلا من طين البنتونيت والكاؤلين كمادة تخثير مع الشب لأزالة معدن الرصاص من المياه الملوثة اصطناعيا وتم أخذ مستويين من التلوث بالرصاص (10,20 ملغرام / لتر) بأستخدام نترات الرصاص . استخدم جهاز اختبار الجرة لتمثيل التخثير والتلبيد .بعد تحديد الجرعة المثالية والوسط الامثل لجميع المواد المستعملة للأزالة تم دمج كل من طيني (البنتونايت و الكاؤلين) كل على حدا مع الشب بنسب مختلفة .كانت النتائج افضل أزالة لمعدن الرصاص مع 20ملغرام/لتر (75%بنتونايت ،25% شب)بنسبة 94.1 و(40%كاؤلين ، 60%شب)بسبة 91.2 ومع 10ملغرام/لتر (40%بنتونايت ،75% شب)بنسبة92.02 و(75%كاؤلين ، 25%شب)بسبة 90 بعد المعالجة تم أخذ الحماة لأفضل ازالة وتم تقسيم الراسب الى ثلاثة اقسام مرة استخدم مباشرتا ومرة تم غمره بمحلول حامضي مره ومحلول قاعدي مره اخرى ولأوقات مختلفة لغرض اعادة التنشيط وكانت النتائج أن افضل ازالة تحقق عند استخدام الراسب مباشرتا وهذا لاينكر ان عند غمر الراسب بمحلول حامضي وقاعدي حقق ازالة جيدة ايضا وكانت النتائج لأفضل ازالة كالأتي (85,85.9,84,86)

الكلمات الدالة : البنتونايت الكاؤلين، اعأدة التنشيط، معدن الرصاص ،نترات الرصاص، التخثير، التلبيد، الجارتست .