

Optimization of the Preparation Conditions of Polyaluminum Chloride by Recycling of Cans

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Abstract

This study involved the preparation of polyaluminum chloride (PAC) from basic materials and elements, namely aluminum flakes (pure and impure), by dissolving them in hydrochloric acid diluted to 50%. The flakes were added gradually to ensure the formation of a PAC solution with high specifications and efficiency in treating turbid water and forming heavy flocs as one of the important applications for removing turbidity and some elements from drinking water and wastewater. This method was verified using a turbidity meter and the application mechanism using a jar-test apparatus. The analyses showed that the efficiency and sedimentation speed reached 95% for high turbidity levels and 98% for low turbidity levels. X-ray diffraction (XRD) analyses clarified the compounds present in both pure and impure materials, and the purity of the material was determined using a UV device. The results indicated the purity of the substance in the solution prepared from pure materials and the level of impurities in the solution prepared from impure materials (poly aluminum), as well as the efficiency variation according to the alkalinity of the solution. Additionally, Fourier Transformation Infrared spectrometer (FT-IR), an atomic absorption spectrometer, and a titration meter for chlorine measurement were used. The comparison between PAC and alum showed the potential of PAC as an ideal and highly efficient alternative.

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1. Introduction

Pollution is one of the most dangerous challenges humans face daily, directly impacting their lives. Among the most hazardous pollutants are sewage, oil wastewater and nuclear pollution, the latter pollution being particularly dangerous. [1]. In the process of purifying turbid waters, multiple criteria such as turbidity, color, infectious agents, and toxic compounds in raw water need to be removed. Coagulation is an effective technique for removing suspended solids from turbid water [2]. One significant coagulant in this process is polyaluminum chloride (PAC). The main component in polyaluminum chloride ($\text{Al}_2(\text{OH})_{6-x}\text{Cl}_x\text{YH}_2\text{O}$) is the Al^{13+7} ion, and the difference between it and aluminum sulfate lies in the type of aluminum structure they contain. A distinctive feature of PAC is that, in addition to chloride, it contains some hydroxide ions, formed by the creation of small polymer complexes of aluminum in PAC [3]. The use of chemicals in treating sewage water is a crucial stage in hybrid systems, with a focus on reducing turbidity before applying other treatment methods, such as membrane processes [4]. Additionally, employing electrochemical methods can contribute to reducing treatment time [5]. Based on these conditions, proposed methods for treating sewage water for reuse purposes require significant attention to electrochemical processes and the use of coagulants as a pretreatment or as a major part of the treatment process [6]. Generally, water contains suspended and dissolved particles from soil erosion, plant decomposition, microorganisms, and color-producing compounds [7]. This requires studying the effects of alkalinity/pH, acidity, and the types of inorganic polymers (pure and impure) [8]. PAC



has multiple names depending on its preparation method, such as PAC and aluminum chlorohydrate [9]. It is used to remove natural and synthetic organic matter and particulates from turbid and contaminated water while maintaining the pH within the allowable range due to its unique characteristics, including the presence of hydroxyl groups, a colloidal nucleus, and simple additives for water treatment and with a wider range of effectiveness compared to aluminum sulfate [10]. In drinking water, international standards have set permissible levels for dissolved substances criteria for human consumption. These substances, related to human life in terms of physical, chemical, and biological standards, determine water quality [11]. The most effective aluminum species for arsenate removal in PAC remain unknown, as well as whether the e-Al13 polycation, δ -Al30 polycation, or both are necessary for arsenate removal. It is believed that the optimal pH range for arsenate removal (pH 6-7) is the same range favorable for the formation of the e-Al13 polycation during coagulation. If arsenate could be removed at non-optimal pH, such as pH > 7.5, it would be beneficial to avoid raising the pH to control corrosion in water distribution networks [12]. In this study, PAC was prepared from pure aluminum flakes and aluminum scrap (aluminum cans), which were dissolved in hydrochloric acid using a heat-generating catalyst at high temperature and for an extended period. The resulting PAC contains a moderate base, allowing it to be applied to drinking water at an appropriate dosage for the removal of suspended particles, organic matter, phosphates, toxic metals, and general color, as well as specific turbidity [13].

This study aims to establish the optimal conditions for preparing PAC from beverage cans and utilizing it as a coagulant in water treatment, thereby contributing to environmental preservation through waste recycling. It is also considered an easy-to-prepare and low-cost method, with the possibility of local production and utilizing aluminum scrap, such as beverage cans and aluminum foil. These materials pose an environmental problem and create an uncivilized situation when discarded on streets and alleys. The preparation process also involved producing the material without using additional enhancing substances that would increase costs, while maintaining the same efficiency. This process is what distinguishes the preparation of the material.

2. Experimental

The following materials were used in the preparation of this compound: 37% concentration hydrochloric acid (locally produced in Ibn Sina factories), aluminum foil with 99% purity (German origin), aluminum cans (industrial aluminum foil), locally produced distilled water. Titropocessor, Metrohm, model: 686, was employed to measure pH, Cl, Basicity. Fourier transformer infrared spectrometer (FT-IR) (Shimadzu, Japan); an aluminum oxide percentage analyzer (Flame atomic absorption spectrometer) (Germany, model: NOVAA350); a turbidimeter (HACH, model:43900) a jar- test device to check sedimentation.

PAC was prepared by dissolving pure aluminum foil or aluminum scrap (aluminum cans) in 50% diluted hydrochloric acid, using a 3-liter glass beaker. To ensure complete dissolution of the foil, (150-160 g) of pure foil or scrap was added gradually to a 1-liter volume of the acid solution. The addition should be done at a rate of 0.5 g per minute, to avoid rapid acid evaporation and to control the reaction temperature (60-90°C°). The reaction must be conducted inside a hood to prevent exposure to harmful fumes and gases. Also, it is necessary to use safety measures, such as protective clothing, masks, and appropriate gloves during the addition process. When using an open reactor, which reduces manufacturing costs and eliminates the need for complex technical operations, such as condensing, recycling, and compressing the generated gases, as well as controlling the reaction rate by specifying the amount of aluminum scrap added at specific

time intervals. That's why the closed reactor was not employed. This control enables us to determine the volume and concentration of the resulting solution. The batches volume was fixed at 1000 ml. Although, this volume may change slightly with the speed of aluminum foil addition. Upon completing the gradual addition of aluminum foil (or scrap), the resulting solution was filtered using a filter paper to separate propylene material and dyes, obtaining a clear solution of PAC.

To establish the optimal conditions for the compound preparation to obtain the best product in terms of color, oxide percentage, concentration, density, alkalinity, and chlorine content, according to the approved specifications, the effects of reaction time, temperature, and concentration of acid were investigated. The volume of hydrochloric acid HCl was fixed to 1 liter and diluted to specific concentrations to determine the percentage of aluminum oxide (Al_2O_3) that meets the desired international standard. The optimal concentration of Al_2O_3 , when used as a coagulant, was determined with high specifications in terms of alkalinity, pH value, and the clarity of the resulting solution, which should not leave undissolved particles in the treated water, as shown in Table 1.

At a fixed acid solution concentration, and the scrap amount added, the reaction time was varied 1, 2, 4, 6, 8, 24 hrs. Upon comparison with the approved specifications, the optimal time to prepare 1 liter of the compound was found to be 4 hrs. With a fixed reaction time of 4 hrs, the effect of temperature (25 and 100°C) on the quality of the prepared solution and the degree of alkalinity was determined, as shown in Table 2. It was found that room temperature (25°C) is optimal for obtaining a compound that meets the required specifications. After that, the concentration of the acid solution was fixed, as shown in Table 3. The concentration of hydrochloric acid was varied by dilution with distilled water while keeping the amount of aluminum scrap constant, to determine the optimal acid concentration that leads to the best specification of aluminum chloride polymer, as shown in Table 3, and the results showed that a 50% acid concentration produced the best compound, meeting the approved specifications. Conversely, the dissolution of iron hydrochloric acid in aluminum scrap into Fe^{2+} and Fe^{3+} ions ultimately leads to the formation of $\text{Fe}(\text{OH})_3$ and FeCl_2 , their proportion in the PAC composition is very low, and this percentage decreases further upon the addition of 20 $\mu\text{m}/\text{l}$, ensuring that the final iron concentration in the treated water complies with safe drinking water standards; these impurities have no environmental impact as shown in Table 4., To ensure efficient dissolution of iron in the aluminum scrap in the acid leaching process, a mixture of synthetic hydrochloric acid was suggested for the dissolution of aluminum scrap.

After establishing the optimal conditions (reaction time of 24 hrs, reaction temperature of 25°C and 50% acid concentration) six experiments were conducted three for pure materials (M4, M5, M6), and three for impure materials (M1, M2, M3) for impure materials, and solid PAC (M7). The results are shown in Tables 5 and 6.

X-ray diffraction (XRD) results of the crystal obtained from the dried leaching solution indicated that the main components of this crystal were Si, $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$, $\text{Sn}(\text{OH})_3$, and $\text{Fe}(\text{OH})_3$. Therefore, it was evident that the PAC prepared from the resulting solution, whether it used aluminum scrap or pure aluminum, was significantly different from industrial-grade PAC. Instead, it consisted of multiple crystalline phases and components, including AlCl_3 , FeCl_3 , SiF_4 , and H_2SiO_3 . The plural gel formed by the polymerization of these components might exhibit a synergistic effect on the coagulation characteristics of PAC.

3. Results and Discussion

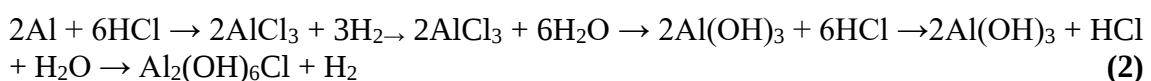
The final results indicated a significant relationship between the density of the resulting solution PAC and the concentration of Al_2O_3 , with their variation in acidic and basic functions [14]. It is clear that basicity is a critical factor in interpreting sedimentation

rates and final turbidity levels after adding PAC (PAC efficiency). For example, when using a pure PAC solution with low basicity, its efficiency was lower than an impure solution with higher basicity. Higher basicity determines sedimentation efficiency, correlating somewhat with the concentration of aluminum oxide, a complex compound in water that forms dense aggregates, leading to the sedimentation of suspended particles in turbid water [15,16]. PAC is distinguished by hydroxyl groups in its polymer structure, which confer flocculation properties distinguishing it from other coagulants, as in the case of the impure sample (M₃) with a basicity of (32.5%) and an aluminum oxide content of (17.1%), compared to the pure sample (M₅) with a basicity of (31.75%) and an aluminum oxide content of (17.5%), where the sedimentation efficiency of the impure sample was higher than that of the pure sample. These samples were selected from many others that were tested using a sedimentation rate measurement device (Jar-test), as shown in Table 7 [17].

X-ray diffraction (XRD) examinations confirmed the presence of hydroxyl in the crystalline structure of the prepared PAC. It was found that there is variation and disparity in the peaks and its intensities, where the most prominent peaks appear at specific 2θ indicating the regions with highly ordered crystals of the compound. As for the intensity, the narrower the spectral lines, the more crystalline the material is, and the wider the lines, the less crystalline it is. On the other hand, the spaces between the peaks indicate the absence of crystalline compounds in those regions. This suggests that we are dealing with a multi-component mixture, as mentioned earlier, containing multi-aluminum compounds. Although the percentage is minimal, it is somewhat beneficial. Analysis was conducted on three pure and three impure samples (Figs. 1-6), showing crystalline properties matching the $\text{gl-}\epsilon\text{-Al Al13}$ formula for non-crystalline Keggin-type PAC [18]. The compound structure PAC is identified as $[\text{Al}_2(\text{OH})_n\text{Cl}_{6-n}]_m$, where m ranges from 4 to 10, indicating the number of linked polymer units, n ranges from 2 to 5 representing hydroxyl bonds that enhance PAC structure [19,20]. The main peak of PAC was found at $2\theta = 27$. The elemental composition of PAC differed between pure and impure samples due to the variation in impurity levels, yet the formula $2\theta = 27.054$ appeared consistent across all characterized samples in the XRD device [21]. Solid PAC (powder) was also characterized on the same device (Fig. 7), showing surface crystalline features consistent with Boehmite ($\gamma\text{-AlOOH}$) [22], as seen in the XRD pattern with peaks at 2θ of 14.2, 28.2, 38.4, 49.2, 64.1. Additionally, hydroxyl group types were identified as pyrite type ($\alpha\text{-Al}(\text{OH})_3$) at 2θ of (18.6, 20.3, 40.6), consistent with the Keggin-Al13 formula of the prepared PAC [23]. According to the Brønsted-Lowry theory, for example, in a reaction between an acid like HCl (hydrochloric acid) and water (H_2O), HCl donates a hydrogen ion to become a chloride ion (Cl^-). Water accepts this ion to become a hydronium ion (H_3O^+), as in Eq. (1).



In PAC preparation, aluminum exhibits amphoteric behavior, as does water according to the theory. Both of them are critical in PAC preparation with desired specifications. As for the reactions occurring instantly in the reactor under ideal conditions for the gradual polymerization process are [24,25]



Despite using pure and impure materials, trace amounts of other elements appeared in the substance's composition due to impurities in raw materials, (Figs. 8-14), specifically hydrochloric acid and aluminum foil at a ratio of 0.5%. These include other elements (such as magnesium, manganese, iron, lead, zinc, cadmium, chromium, arsenic). However, these ratios do not affect drinking water specifications when appropriate doses are added to treat water, as shown in Table 4. Standard-grade PAC was used at a concentration of 20 mg/L for both pure and impure cases (M3, M5) at varying doses. The treated water matched drinking water as shown in Table 8, moreover, some of these impurities contribute, in one way or another, to forming a multi-polymer compound and enhancing its efficiency. Many studies indicated that adding small amounts of materials, such as silicon, calcium oxide, and sodium hydroxide can lead to the formation of a multi-polymer compound. Most of these element's precipitate with sludge after forming a complex compound during treatment [26].

Table 1: Time, HCl, H₂O, Volume, Al, density, Al₂O₃, pH, Cl, Basicity of PAC.

Reaction Time hr.	HCl ml	H ₂ O ml	Volume ml	Al g	Color of the resulting solution	Density g/cm ³	Al ₂ O ₃ %	pH	Cl %	Basicity %
1	1000	1000	1000	150	White	1.44	19.8	1.06	23.9	25
2	1000	1000	1000	150	Gray	1.4	18.5	1.33	23.8	26
4	1000	1000	1000	150	Black	1.38	17.4	1.6	23.6	29
6	1000	1000	1000	150	Black	1.37	17	1.06	21.6	29.5
8	1000	1000	1000	150	Brown"	1.365	17.16	0.45	21.8	30
24	1000	1000	1000	150	Brown"	1.36	16.8	0.4	21.4	36.6

Table 2: Time, HCl, H₂O, Volume, Al, color, density, Al₂O₃, pH, Cl, Basicity of PAC.

Temp. °C	HCl ml	H ₂ O ml	Volume ml	Al g	Color of the resulting solution	Density g/cm ³	Al ₂ O ₃ %	pH	Cl %	Basicity %
25	1000	1000	1000	150	Brown	1.32	16.94	1.17	21.2	42.52
100	1000	1000	1000	150	Brown	1.37	16.44	1.11	18.46	42.13

Table 3: Time, HCl, H₂O, Volume, Al, color, density, Al₂O₃, pH, Cl, Basicity of the used aluminum cans.

HCl ml	H ₂ O ml	Volume ml	Al g	Color of the resulting solution	Density gm/cm ³	Al ₂ O ₃ %	pH	Cl %	Basicity %
1000	-----	500	60	Yellow	1.25	8.68	-1.094	27	25
1000	330	700	120	Black	1.29	16.8	1.6	23.8	37
1000	330	600	140	Black	1.36	16.86	1.3	22.9	38
1000	1000	1000	150	Brown	1.32	18.12	1.33	21.8	38.5
1000	1000	1000	150	Brown	1.36	17	1.06	19.6	38.5
1000	1000	980	160	Brown	1.37	16.8	0.83	20	37

Table 4: The percentage of elements in the prepared PAC sample, the added dosage of PAC, and the percentage of elements in the treated water.

Element	water Specification mg/l	Elements in the pure bulk sample mg/l	The added dose of PAC mg/l	Elements in the treated water in PAC mg/l
AL	0.2	0.90000	20	0.18
CN	0.1	nil	20	nil
AS	0.05	0.59	20	nil
Br	zero	zero	20	nil
Cd	0.05	0.8	20	nil
Fe	0.3	0.2	20	nil
Pb	0.05	1.56	20	nil
Mg	0.1	1.33	20	nil
Mn	5-0	1.32	20	nil
Zn	5	0.98	20	nil
Cr	0.05	0.8	20	nil

Table 5: Volume, Basicity, pH, density of used aluminum waste.

Name Sample	Al gm	HCl ml	Volume ml	Al ₂ O ₃ %	Density gm/cm ³	pH	Basicity %
M1	30	250	270	13.47	1.336	0.45	18.5
M2	25	250	272	13.41	1.319	0.82	30
M3	40	250	260	17.1	1.392	0.48	33.5

"Where (M1, M2, M3) are samples of pure aluminum chloride prepared from aluminum scrap (aluminum cans).

Table 6: Volume, Basicity, pH, density of used pure aluminum.

Name Sample	Al g	HCl ml	Volume ml	Al ₂ O ₃ %	Density gm/cm ³	pH	Basicity %
M4	30	250	240	16.856	1.3965	0.60	34.5
M5	40	250	275	17.510	1.3693	0.78	31.75
M6	40	250	345	15.513	1.2882	0.91	10.5

where (M4, M5, M6) are samples of pure aluminum chloride prepared from pure aluminum.

Table 7: The turbid in and turbid out of aluminum cans for the addition of pure and impure aluminum.

Name sample	Al ₂ O ₃ %	The amount of turbidity in	PAC	The amount of turbidity coming out	The conductivity of the water after treatment.	pH	The floating aluminum in external water Al mg/l
M ₃	16.454	950	20μ	5.5	190	7.8	0.17
M ₃	16.454	110	20μ	0.95	190	8	0.18
M ₅	15.730	950	20μ	5.7	190	7.8	0.18
M ₅	15.730	110	20μ	1	190	7.6	0.17

**Table 8: Natural Characteristics of Drinking Water: Sulphates: between 25 to 250 mg/l.
Nitrates: between 25 to 50 mg/l.**

Element	Water Specification mg/l
AL	0.2
CN	0.1
AS	0.05
Br	zero
Cd	0.05
Fe	0.3
Pb	0.05
Mg	0.1
Mn	5-0
Zn	5
Cr	0.05

Fig. 1 provides information about the composition of PAC and identifies the peaks related to the presence of iron impurity in the compound structure. The open upward triangle represents the peaks resulting from XRD of iron at 14.9 and 24.4, while the open downward triangle represents the XRD peaks of aluminum at 27, 34.9, 39, 44, 53 and 63.4.

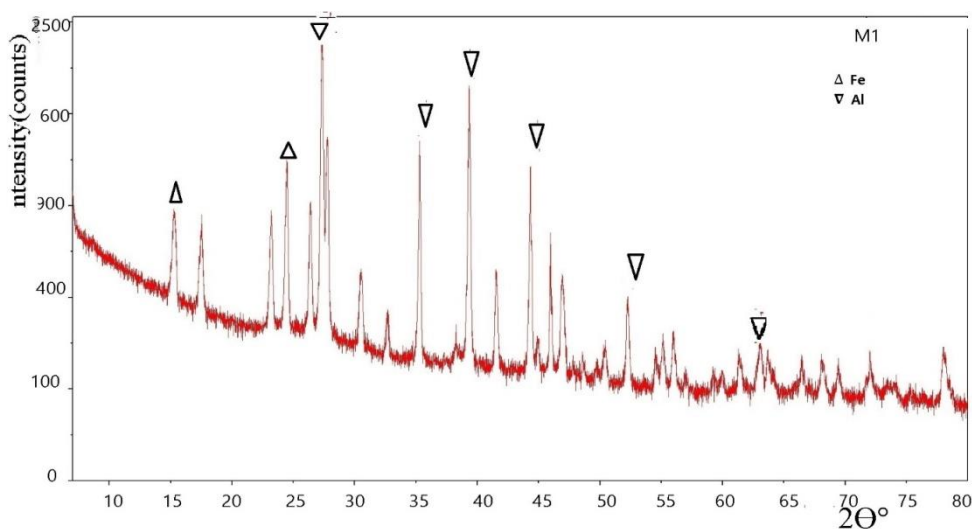


Figure 1: XRD spectra of PAC (Sample M₁) generated from polymerization induced by (aluminum cans).

Fig. 2 provides information through XRD and diffraction regions of the elements, indicating the presence of other elements in the composition of PAC. The number (1) represents the diffraction peak of the aluminum chloride compound AlCl_3 , and diffraction peaks appear at 2θ 41.27 and 53, indicating the presence of the compound in the polyaluminum composition. The number (2) represents the different locations of magnesium-silicon components at 2θ 32.3, 34, 41.27 and 53, and the number (3) identifies the peaks of tin-manganese crystals at 2θ 14.9, 17 and 22. Through these peaks, it was determined that the crystalline structure of the prepared compound, which contains other elements in the specific proportions, making it a polyaluminum compound.

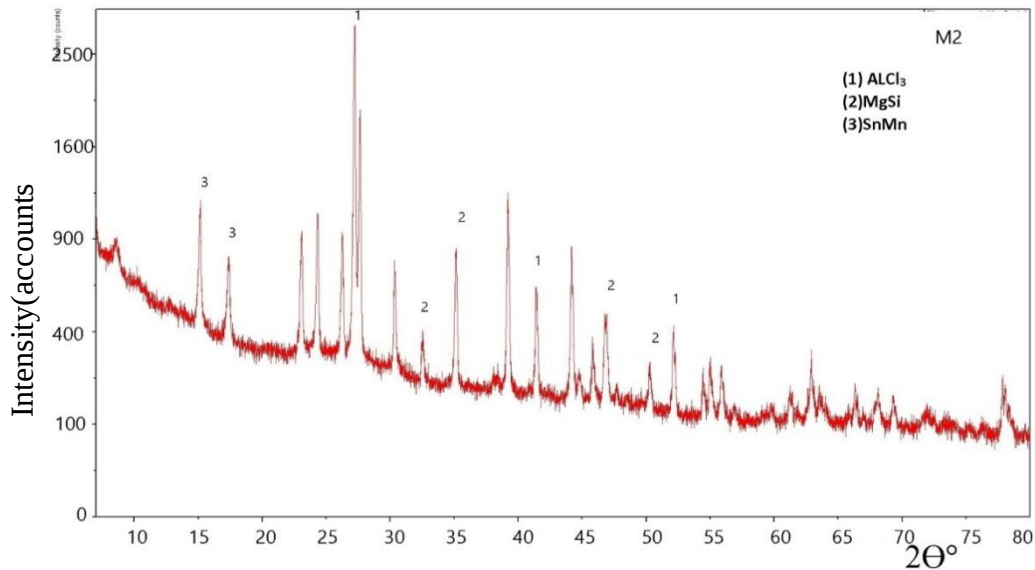


Figure 2: XRD spectra of PAC (Sample M₂) generated from polymerization induced by (aluminum cans).

In Fig. 3, the horizontal axis represents (2θ), and the vertical axis represents the intensity of the X-rays, giving an idea of the density of the crystal structure of the elements contributing to the crystalline composition of PAC. The symbol (*) represents the diffraction peaks of the magnesium-silicon compound (Mg_2Si) at 2θ 41.25, 62.8 and 63.5, while the symbol (#) represents the diffraction peaks of the hydrated aluminum chloride compound ($\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$) at 2θ 14.9, 27.05, 39 and 44. The symbol (^) represents the diffraction peaks of the tin-aluminum oxide compound ($\text{SnAl}_{22}\text{O}_{23}$) at the angle 2θ 17.25, 22.9 and 26.1. These elements contribute to the crystalline structure, and their presence at different locations in the crystal structure of PAC classifies the compound as polyaluminum.

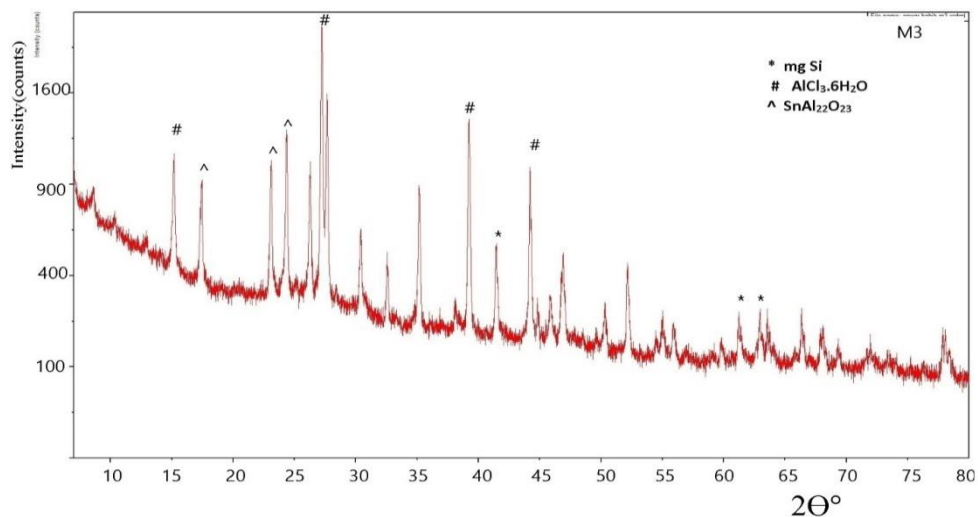


Figure 3: XRD spectra of PAC (Sample M₃) generated from polymerization induced by (aluminum cans).

Fig. 4 provides information about the composition of PAC and identifies the peaks related to the presence of iron in the compound structure. The open upward triangle represents the diffraction peak locations of iron at 9.8, 14.9 and 24.4, while the open downward triangle represents the diffraction peaks of aluminum at 17, 2, 27, 34.9, 39, 44, 53 and 63.4.

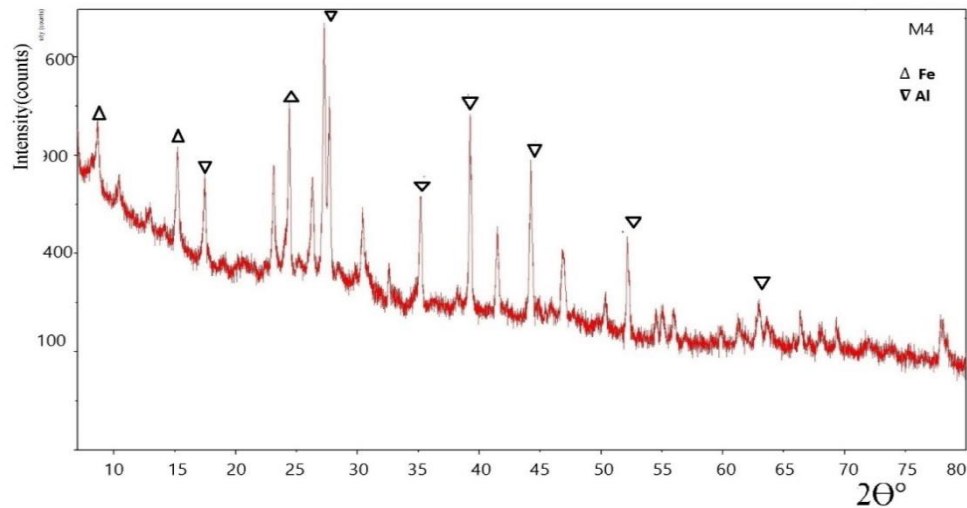


Figure 4: XRD spectra of PAC (Sample M_4) generated from polymerization induced by (pure aluminum).

In the composition of PAC, Fig. 5, the number (1) represents the XRD peaks of the aluminum chloride compound (AlCl_3), with peaks appearing through diffraction at 2θ 24.4, 39, 47 and 53, indicating the presence of the compound in the polyaluminum composition. The number (2) represents the different locations of the magnesium-silicon components at 2θ 32.3, 34, 44.27 and 53, and the number (3) identifies the peaks of tin-manganese crystals at 2θ 5.1 and 9.8. Through these peaks, it was determined that the crystalline structure of the prepared compound, which contains other elements in the specific proportions, making it a polyaluminum compound.

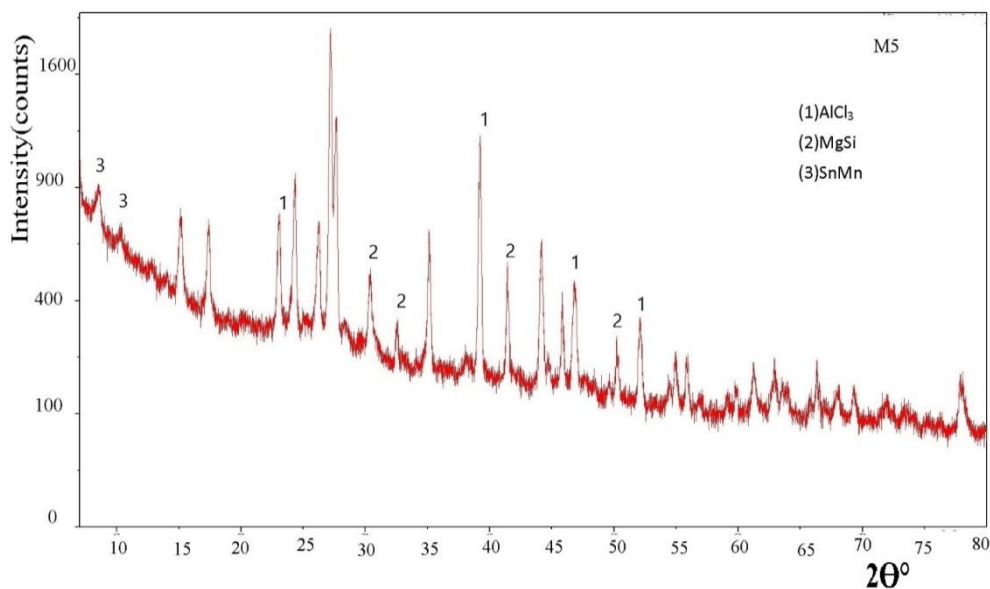


Figure 5: XRD spectra of PAC (Sample M_5) generated from polymerization induced by (pure aluminum).

In Figs. 1-6, the composition of the liquid PAC samples represents (M_1 , M_2 , M_3 , M_4 , M_5 and M_6) under XRD analysis and showing the crystalline properties matching) $\text{gl-}\epsilon\text{-Al Al}_{13}$ formula for non-crystalline keggung-type PAC. The compound structure of PAC is identified as $[\text{Al}_2(\text{OH})_n \text{Cl}_{6-n}]_m$, where (m) ranges from 4 to 10, indicating the number of linked polymer units, (n) ranges from 2 to 5 representing hydroxyl bonds that enhance PAC structure and positioned at $2\theta = 27.054$. The elemental composition of

PAC varied between pure and impure samples, yet the formula $2\theta = 27.054$ appeared consistent across all the characterized samples in the XRD device. The solid PAC (powder) was also characterized on the same device (Fig 7).

Figs. 1-6 illustrates the XRD patterns PAC samples (M1, M2, M3, M4, M5, M6) induced by pure aluminum. The intensity of the XRD device also indicated the presence of other elements in small proportions in the composition to the PAC. Figs. 1-6 illustrates the surface crystalline features that consistent with Boehmite ($\gamma - \text{AlOOH}$), where the X-ray diffraction pattern, shows the peaks at 2θ (14.958, 27.12, 39.01, 51.97 and 63.45). Additionally, the hydroxyl group types were identified as pyrite type ($\alpha\text{-Al}(\text{OH})_3$) at 2θ 17.27, 22.9, 24.14 and 44.11, that consistent with the Keggin- Al_{13} formula of the prepared PAC. When measuring the absorption spectrum of the prepared samples using an infrared spectrometer, similar absorption spectra appeared between the samples, with relative differences due to the varying amounts of impurities from which the sample was prepared.

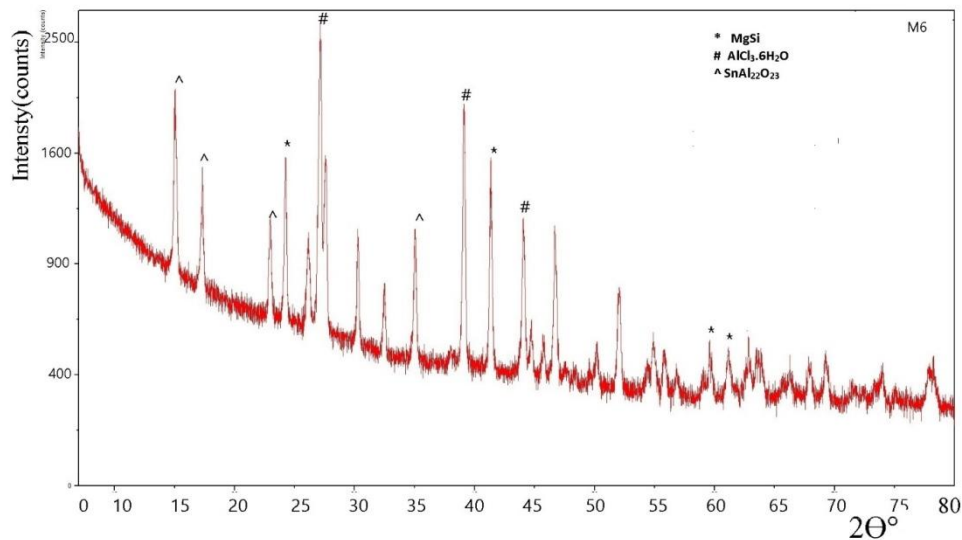


Figure 6: XRD pattern of PAC (Sample M₆) generated from polymerization induced by (pure aluminum).

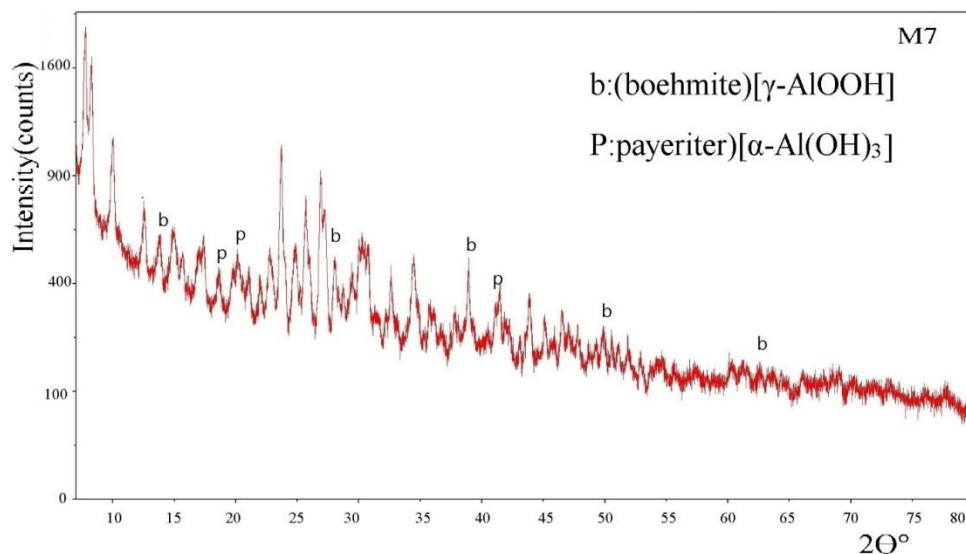


Figure 7: The characteristic patterns of PAC powder.

Fig. 8 shows the structure of PAC, which contains elements in its crystalline structure as represented by XRD. The upward triangle represents magnesium (α) in XRD at 2θ 14.9, 17.22, while the downward triangle represents the XRD of manganese when 2θ 26.07, 32.2, 34.97, 45, 47.5, 47.5, 48.6, 55.9, 59.6, 63.9, 65.6, 67.7, 68.2, 69.13, 71.80, 71.88, 72.3, 79.8. The circle symbol represents type (β) manganese aluminum at diffraction 2θ 38.2, 66.9, and the upward arrow symbol represents manganese tin at diffraction 2θ 44.11, 68.2, 72.3.

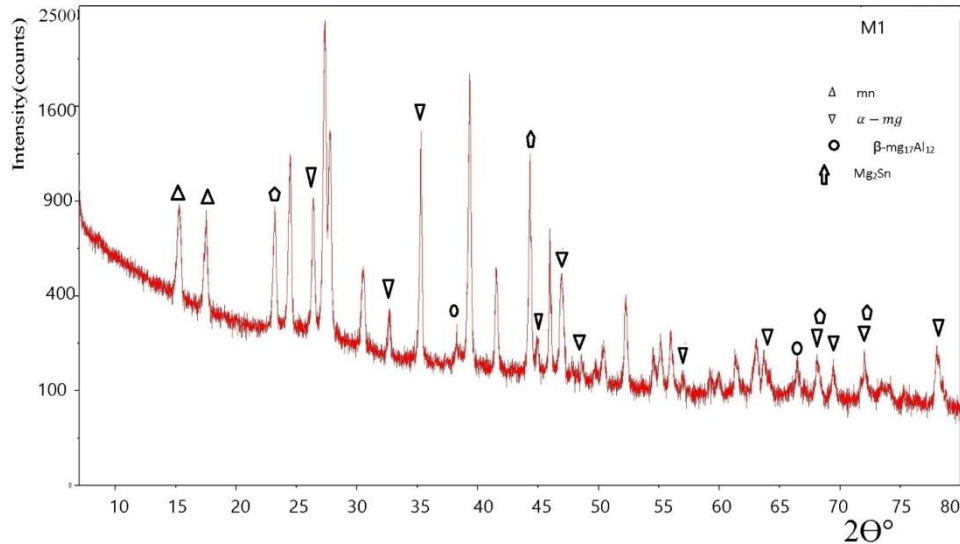


Figure 8: XRD spectra of PAC (Sample M₁) generated from polymerization induced by (aluminum cans).

Fig. 9 shows the structure of PAC, which contains elements in its crystalline structure as represented by XRD. The upward triangle represents magnesium (α) at X-ray diffraction 2θ 14.9, 17.22, while the downward triangle represents the XRD of manganese when 2θ 26.05, 32.2, 34.97, 47.5, 56.75, 67.7, 68.2, 69.13, 79.8. The circle symbol represents type (β) manganese aluminum at diffraction 2θ 41.2, 66.9, and the upward arrow symbol represents manganese tin at diffraction 2θ 24.14, 68.2.

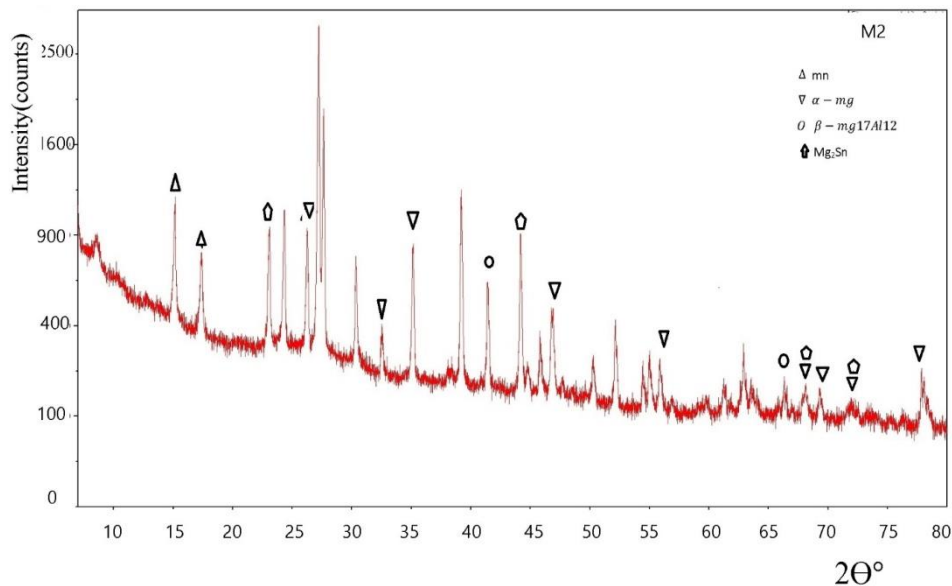


Figure 9: XRD spectra of PAC (Sample M₂) generated from polymerization induced by (aluminum cans).

Fig. 10 shows the structure of PAC chloride, which contains elements in its crystalline structure as represented by XRD. The upward triangle represents magnesium (α) at XRD diffraction 2θ 14.9, 17.22, while the downward triangle represents the XRD of manganese when 2θ 26.05, 32.2, 34.97, 46.8, 63.9, 68.2, 69.13, 79.8. The circle symbol represents type (β) manganese aluminum at diffraction 2θ 41.2, 66.9 and the upward arrow symbol represents manganese tin at diffraction 2θ 24.14, 68.2.

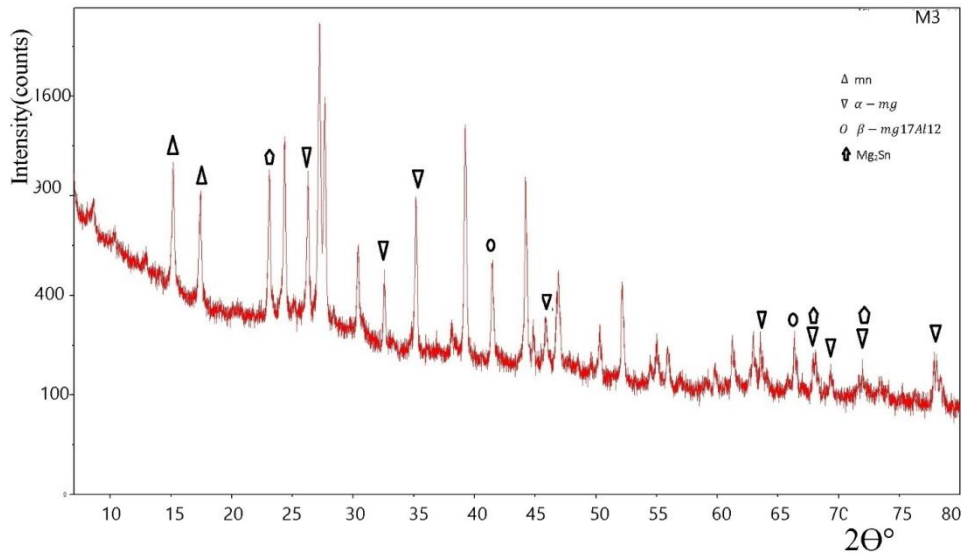


Figure 10: XRD spectra of PAC (Sample M_3) generated from polymerization induced by (aluminum cans).

Fig. 11 shows the structure of PAC, which contains elements in its crystalline structure as represented by XRD. The upward triangle represents magnesium (α) at XRD 2θ 5, 11.9, 14.9, 17.22, while the downward triangle represents the XRD of manganese when 2θ 26.05, 32.2, 34.97, 46.8, 56.75, 67.7, 68.2, 69.13, 79.8. The circle symbol represents type (β) symbol when manganese tin at diffraction 2θ 24.14, 68.2.

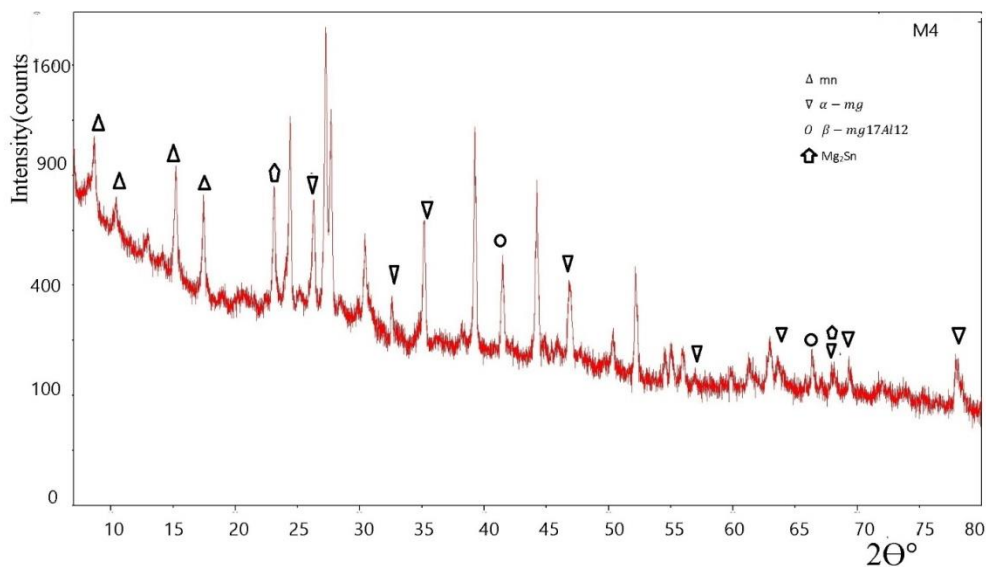


Figure 11: XRD spectra of PAC (Sample M_4) generated from polymerization induced by (pure aluminum).

Fig. 12 shows the structure of PAC, which contains elements in its crystalline structure as represented by XRD. The upward triangle represents magnesium (α) at XRD 2θ 14.9, 17.22 while the downward triangle represents the XRD of manganese when 2θ 26.05, 32.2, 34.97, 47.5, 56.75, 67.7, 68.2, 69.13, 79.8. The circle symbol represents type (β) manganese aluminum at diffraction 2θ 38.2, 41.2, and the upward arrow symbol represents manganese tin at diffraction 2θ 24.14, 44.1, 67.7, 73.6.

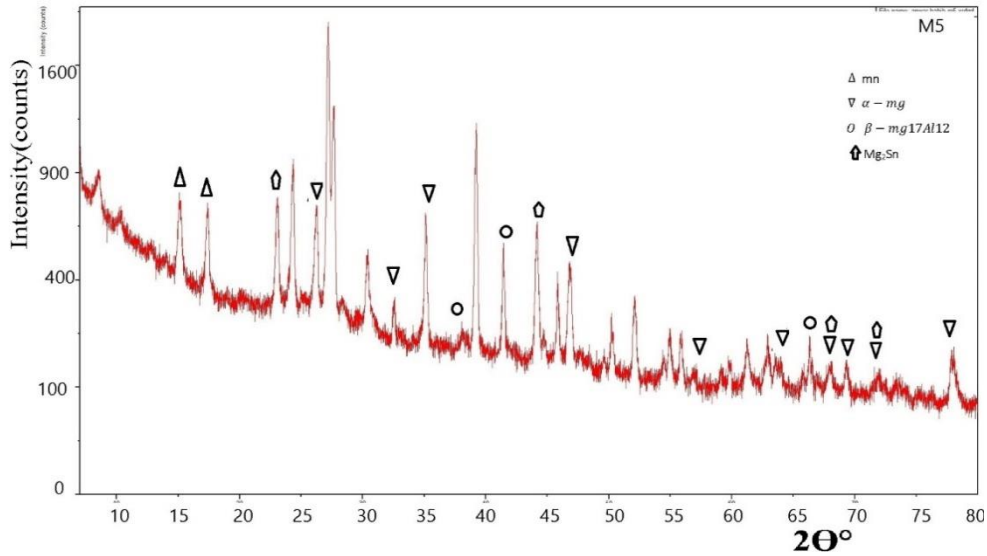


Figure 12: XRD spectra of PAC (Sample M_5) generated from polymerization induced by (pure aluminum).

Fig. 13 shows the structure of PAC, which contains elements in its crystalline structure as represented by XRD. The upward triangle represents magnesium (α) at XRD 2θ 14.9, 17.22, while the downward triangle represents the XRD of manganese when 2θ 26.05, 32.2, 34.97, 46.84, 51.97, 55.9, 63.9, 67.7, 74.3, 79.8. The circle symbol represents type (β) manganese aluminum at diffraction 2θ 41.2, 66.9 and the upward arrow symbol represents manganese tin at diffraction 2θ 24.14, 44.11, 68.2. The significant difference is the variation in the distribution of impurities in the prepared compound and its polymerization, as evident at the angle 2θ .

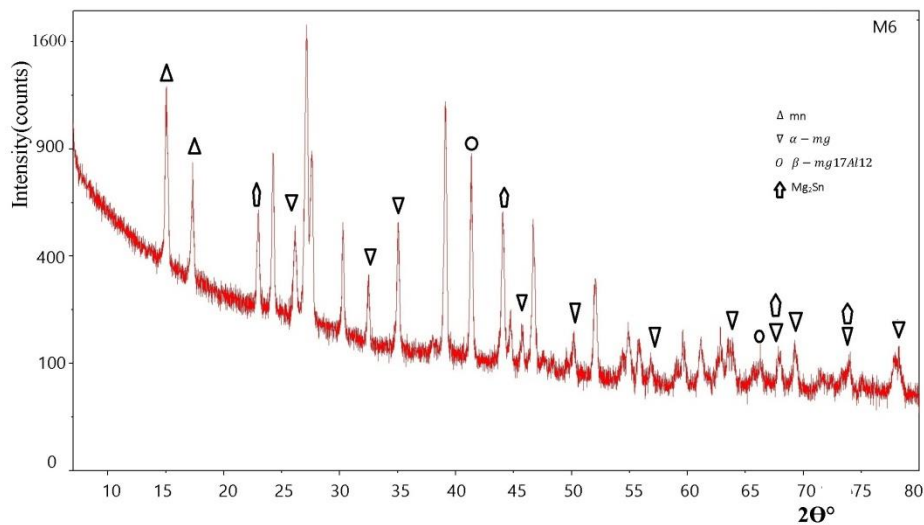


Figure 13: XRD spectra of PAC (Sample M_6) generated from polymerization induced by (pure aluminum).

4. Conclusions

The following conclusions can be drawn: based on the reaction of pure aluminum and aluminum scrap with hydrochloric acid in two distinct reactions and at different concentrations, the laboratory-produced sample of PAC performed well in treating turbid water compared to aluminum, as shown in Table 9. It was found that the appropriate PAC dosage at turbidities of 95–110 was approximately 20 μm . Increasing the dosage caused aluminum to float in the treated water, which may lead to future health problems for living organisms. Additionally, it increased acidity, thereby reducing sedimentation efficiency. Similarly, in the case of using aluminum, excessive dosage also caused aluminum to float, leading to potential future health issues and increased acidity in the treated water. Therefore, it is necessary to determine the dosage based on the turbidity levels of the treated water. PAC application reduced residual turbidity in the treated water. Experimental results indicated that the dosage of PAC required for treating turbid water was 98% less than that of aluminum when turbidity was low and 90% less at higher levels of turbidity. Treatment operations using PAC yielded excellent results in rapid and dense floc formation, as well as shorter settling times. PAC also offers a wide range of dosages and may be well-suited for various turbidity levels. Preparing PAC from aluminum scrap is an excellent recycling method for maintaining a clean environment, and the preparation process is economical, cost-effective, and employs a basic technique. Preparing liquid PAC and stabilizing its conditions serves as the foundation for establishing the operational conditions necessary to prepare solid PAC, which possesses superior characteristics compared to liquid PAC.

Table 9: The turbid in, turbid out, amount of PAC and alum addition, conductivity, aluminum out, of use of PAC and alum.

Influent Turbidity N.T.U	Alum % mg/l	Effluent Turbidity N.T.U	pH	PAC mg/l	Effluent Turbidity N.T.U	pH
90	30	22.0	7.26	20	0,95	7.8
130	40	13.00	7.10	20	1	7.76
240	50	11,60	7.06	20	6.4	7.67
500	60	10.3	6.96	20	4,2	7.75
750	80	30	6.93	20	3.5	7.70

Conflict of Interest

Authors declare that they have no conflict of interest.

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تحسين شروط تحضير بولي كلوريد الألمنيوم عن طريق إعادة تدوير العلب

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الخلاصة

تضمنت هذه الدراسة تحضير بولي كلوريد الألمنيوم من مواد وعناصر أساسية، وهي رقائق الألمنيوم (النقية وغير النقية) وذلك عن طريق إذابتها في حمض الهيدروكلوريك المخفف بنسبة 50%. تم إضافة الرقائق بشكل تدريجي لضمان تكوين محلول بولي كلوريد الألمنيوم بمواصفات عالية وكفاءة في معالجة المياه العكرة وتكوين كتل ثقيلة. كأحد التطبيقات الهامة لإزالة العكارة وبعض العناصر من مياه الشرب ومياه الصرف الصحي. تم التحقق من ذلك باستخدام جهاز العكارة والية تطبيقه باستخدام جهاز اختبار الجرة وأظهرت التحليلات ان الكفاءة وسرعة الترسيب وصلت الى 95% في مستويات العكارة العالية و98% في مستويات العكارة المنخفضة. أوضحت تحليلات الأشعة السينية المركبات الموجودة في المواد النقية، وتم تحديد نقاوة المادة باستخدام جهاز الأشعة فوق البنفسجية. أشارت النتائج الى نقاوة المادة في المحلول المحضر من المواد النقية ومستوى الشوائب في المحلول المحضر من المواد غير النقية (بولي المنيوم) وكذلك تفاوتت الكفاءة حسب قلوية المحلول بالإضافة الى ذلك، تم استخدام جهاز الأشعة تحت الحمراء وجهاز الامتصاص الذري، وجهاز المعايرة لقياس الكلور. أظهرت المقارنة بين البولي كلوريد الألمنيوم والشب، ان الباك يعتبر بديلاً مثالياً وفعالاً للغاية.

الكلمات المفتاحية: كلوريد البولي المنيوم، معالجة المياه، التلبد، إعادة تدوير النفايات، كفاءة التلبد.