Effectiveness of alhagi maurorum as natural coagulant aid in grey wastewater treatment study

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Abstract. The Alhagi Maurorum (AM) is used as a coagulant aid to support the action of coagulant factor in grey water treatment; alum could be accounted as the mean chemical coagulant and Alhagi Maurorum (in two separated forms: powdered and extracted liquid) as the coagulant aid. A series of experiments were managed to find the optimum dosage of AM and optimum pH condition so as to achieve higher removal efficiencies for the contaminants such as turbidity, chemical oxygen demand (COD) and total suspended solids (TSS) originated in synthetic grey wastewater. Using AM as an extracted liquid was better than the powdered form. The results showed that the combination of 40 mg/l of alum and 1.0 ml/L of extracted liquid AM achieved reduction efficiency for (Turbidity, COD and TSS) by (98%, 92%, 95%) at pH=10. The results showed the possibility of the application of AM as natural coagulant. The positive impact or possibility of the application of AM as natural coagulant

Keywords: Coagulation, Alum, coagulant aid, Alhagi Maurorum, grey water

1. Introduction

Society extension, fast development and necessary styles of living, result in expanding of clean water consumption in everywhere. Grey water has impressed international consideration as a replacement water supply recently [1]. Grey water is the water accumulated from clothing washing machines, baths, sinks as showers, except effluent from water closets [2]. Grey water comprises several pollutants as black water, but they found in low levels than in sewage water. For grey water the BOD: COD ratio is generally 1: 4, so that the biologically treatment may be limited for grey water [3]. Coagulation using chemicals can be considered as one of the documented pre-treatment choices for grey water refinement.

Aluminum Sulfate (Alum), Ferric Chloride, Poly aluminum Chloride (PAC) & Aluminum Chloro Hydrate (ACH) are typical inorganic coagulant used in water and wastewater coagulation.

Many effective natural coagulants from plant have been used: Nirmali [4], Okra, red bean, sugar and red maize [5], Moringa oleifera seeds are also used as coagulants in wastewater treatment because of the presence of a water-soluble cationic coagulant protein can minimize the turbidity, chemical oxygen demand (COD), and total dissolved solids (TDS) of the wastewater treated [6]. One of the important parameter that limits coagulation process is pH, it acts an important part in determining the required coagulant dosage [7, 8]. Natural plant coagulants are further typical because of their effectiveness for large production and practicability for it. Natural coagulants are harmless, non-hazardous, imperishable, generate lower sludge, decomposable and relatively cost effective [9]. Alhagi Maurorum is a natural plant and an undershrub, glabrous, or pubescent that is 60–100 cm tall. This plant is an ideal food for camels, sheep and goats [10]. It is found in Russia, Turkey, Iran, Syria, Afghanistan, Pakistan, and North
Africa. It is adopted in conventional medical treatment as an antipasto, simulative, analeptic, anti-breathless, diuretic, antipyretic, emollient, and cough syrup [11]. The plant has been widely used as a purgative and in treating a variety of liver disturbances and several kinds of digestive and urinals tract confusions. The main objective of this study is to reduce the contaminants concentrations of synthetic grey water (turbidity, chemical oxygen demand and total suspended solids) using a natural plant (Alhagi Maurorum) as a coagulant aid into two forms: - the first as a powder and the second as an extracted liquid, and also to evaluate the coagulating efficiencies by varying pH environment.

2. Experimental Work

2.1. Formulation of synthetic grey wastewater

The composition and characteristics of adopted grey water are shown in Tables 1-3. All parameters were determined according to the procedures described in the Standard Methods (APHA 1998). Duplicate COD measurements were carried out using COD reactor; model (WTW CR 2200) and single-beam spectrophotometer (SpectroDirect – Lovibond). Turbidity measurement was done using portable turbidity meter model (Turb® 355 IR – WTW). For the determination of pH, WTW pH330 pH meter was used. TSS was calculated by drying filter sheets with a diameter of 0.45 microns, then placed in the oven at a temperature of 103-105 °C for one hour and cooled to room temperature in a glass bell, weighted with a sensitive balance. Flask 500 mL dried flasks and 250 ml of the sample filtered through it. The suspended solids are separated and settled on the filter paper. The paper is then re-inserted in the oven at the same temperature for one hour, weighed again and applied the following equation:

\[ \text{TSS (mg/l)} = (A-B) \times 1000/V \]

Where
- A=weight of filter paper after filtration
- B=weight of filter paper
- V= ml of sample

| Compound                  | Concentration (mg/l) |
|---------------------------|----------------------|
| Glucose                   | 300                  |
| Sodium acetate tri-hydrate| 400                  |
| Ammonium chloride         | 225                  |
| Disodium hydrogen phosphat| 150                  |
| Potassium dihydrogen phosphate| 75            |
| Magnesium sulphate        | 50                   |
| Cow dung                  | 225                  |

| Parameter            | Shower | Bath | Wash Basin |
|----------------------|--------|------|------------|
| BOD (mg/l)           | 146    | 129  | 155        |
| COD (mg/l)           | 420    | 367  | 587        |
| Turbidity (NTU)      | 84.5   | 59.8 | 99         |
| pH                   | 7.52   | 7.57 | 7.32       |
| PO4 (mg/l)           | 0.3    | 0.4  | 0.4        |
| TOC (mg/l)           | 65.3   | 59.8 | 99         |
Table 3. Characteristics of synthetic grey water (this study).

| Parameter | Unit | Value |
|-----------|------|-------|
| BOD       | mg/l | 280   |
| COD       | mg/l | 390   |
| Turbidity | NTU  | 75    |
| pH        | -    | 6.85  |
| TSS       | mg/l | 580   |
| TDS       | mg/l | 850   |

2.2 Chemical and Natural Coagulants

2.2.1. Chemical Coagulants. Alum was the chemical coagulant used in this study to improve the removal efficiency. Standard dissolvent of alum was prepared by dissolution 10g of Al₂(SO₄)₃.18H₂O into 1000 ml of purified water at 25˚C to make a homogenized solution of alum solution concentration of 1%. Thus, each 1 ml/l of stock solution included 10 mg/l of Al₂(SO₄)₃.18H₂O.

2.2.2. Natural Coagulant as a Powder. In this research (AM) as shown in Figure 1 was collected during spring from the field of Wasit governorate (Middle of Iraq). The plant was washed and dehydrated in an oven at 60° C for five hours. Then smashed and powdered using flour grinder and finally sieved through a 200µm sieve. Stocks solutions of this natural coagulant aid (powdered) were arranged for coagulation improvement, by adding as different masses 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 grams to each one litre of grey water. At last, this solution was filtered using 1 µm filter paper to get rid of any residual particles.

2.2.3. Natural Coagulant as a Liquid. The same plant AM was collected during spring from the field of Wasit governorate (Middle of Iraq), washed in tap water for several times, then the plant was squeezed using a fruit squeezing machine, to extract juice and liquids from leaves and stems. This extracted liquid was filtered using 1 µm filter paper to get rid of any residual particles. The extracted liquid of AM adopted as a coagulant aid using the following sequence volumes 0.25, 0.5, 0.75, 1.0, 1.25, and 1.50 ml for each litre of grey water.

2.3. Best Dose of Main Coagulant

Jar test is a method used to determine the coagulation performance and optimum coagulant dosage [14]. First of all the optimum dosage of alum as a coagulant was determined, each jar was loaded with grey water sample. pH was adjusted to the specified values by adding NaOH (1 N) and H₂SO₄ (1 N) to
synthetic grey water. In each jar, a diverse solution dose of alum was applied with different concentrations (10, 20, 30, 40, and 50 mg/l). The jars exposed to rapid mix 125 RPM for 2 min to disperse coagulant in all solution, and then slow mix 2 RPM for 30 min to form the flocs. The mixers is switched for 30 min for settling the flocs. At the end of settling period, samples were withdrew from a height 4-5 cm below the surface of each jar by syringe. These samples were examined for determination the removal of turbidity, COD and TSS.

2.4. The Combination Effect of Alum and AM
The AM is employed as a coagulant aid into two separated forms as a powder and as an extracted liquid to support the principal coagulant agent in coagulation purposes of grey water therefore, Alum would be treated as the main chemical coagulant and AM as the coagulant aid. A group of experiments were carried out on grey wastewater treatment by alum as explained in section 2.3 and finding the optimum dosage to remove turbidity, COD and TSS. So this optimum alum dose will be used as fixed main coagulant dose for all experiments. Adding AM powder as a coagulant aid to the optimum alum dose at separated different masses 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 grams to each one litre of grey. Then the same procedure was done by adding extracted liquid of AM as a coagulant aid to the optimum alum dose at separated different volumes 0.25, 0.5, 0.75, 1.0, 1.25 and 1.5 ml to each one litre of grey water. The same procedure of jar test as stated in section 2.3 was done for each combination to find the optimum mixed dosage to remove the pollutants turbidity, COD and TSS from grey water. The summery of the experimental mixing can be shown in Table 4.

| Alum and AM (Liquid) | Alum and AM (Liquid) |
|----------------------|----------------------|
| Alum AM (g/L)        | Alum AM (ml/L)       |
| Optimum Dose         | Optimum Dose         |
| 0.1                  | 0.25                 |
| 0.2                  | 0.5                  |
| 0.3                  | 0.75                 |
| 0.4                  | 1.0                  |
| 0.5                  | 1.25                 |
| 0.6                  | 1.50                 |

3. Results and Discussion

3.1. Alum as main coagulant
Figure 2 shows the effect of various alum doses, on grey water turbidity, COD and TSS at pH=7, it’s clear that alum dose of 40 mg/l resulted the maximum turbidity, COD and TSS reduction efficiency 83%, 75% and 79% respectively.

3.2. Effect of AM powder as a coagulant aid
The AM powder is utilized as a coagulant aid to enhance the objective of coagulant agent in grey water treatment. Consequently, alum will be advised as the major chemical coagulant and AM powder as the coagulant aid. A group of tests were implemented at an optimum dose 40 mg/l and addition AM powder in a separated consequence dosages starting from 0.1 g/L to 0.6 g/L by using an increase of 0.1 g/L. As shown in Figure 3 a mass of 0.3 g/L of AM achieved maximum removal efficiency for turbidity, COD, and TSS of 90%, 84% and 88% at environment pH=7.
3.3. Effect of AM extracted liquid as a coagulant aid
In this section the AM extracted liquid is utilized as a coagulant aid to enhance the objective of coagulant agent in grey water treatment. Consequently, alum will be advised as the major chemical coagulant and AM extracted liquid as the coagulant aid. A group of tests were implemented using a combination of alum and AM extracted liquid. At each time alum dosage was fixed 40 mg/l while AM extracted liquid dosages varied starting from 0.25 ml/L to 1.5 ml/L by using an increase of 0.25 ml/L. As shown in Figure 4 a volume of 1.0 ml/L of AM achieved maximum removal efficiency for turbidity, COD, and TSS of 93%, 88% and 92% at environment pH=7.
3.4. Influence of pH on coagulation process

One of the important parameters that limits the coagulation process and colloidal reduction is the pH of solution, so as to investigate the best pH values, laboratory tests were implemented on pH values ranging from 4-10.

**Figure 4.** Effect of AM liquid on turbidity, COD and TSS reduction.

**Figure 5.** Influence of pH on turbidity reduction using AM powder.
3.4.1. Influence of pH on AM powder as a coagulant aid. A group of tests were implemented adopting the optimum dosage of alum 40 mg/l and optimum dosage of AM as a coagulant aid 0.3 g/L with varying the environment at different pH values (4, 6, 8 and 10) to obtain the optimum pH value that leads to the optimum removals for turbidity, COD, and TSS. As shown in Figures 5-7 the optimum pH value was 10 that leads to maximum removal efficiencies for turbidity, COD and TSS (94%, 88% and 91%) respectively.

3.4.2. Effect of pH on AM extracted liquid as a coagulant aid. A group of tests were implemented adopting the optimum dosage of alum 40 mg/l and optimum dosage of AM as a coagulant aid 1.0 ml/L with varying the environment at different pH values (4, 6, 8 and 10) so as to obtain the optimum pH value that produces the optimum removals for turbidity, COD, and TSS. As shown in Figures 8-10 the
The optimum pH value was also 10 that produces maximum removal efficiencies for turbidity, COD and TSS (98%, 92% and 95%) respectively.

![Figure 8](image_url1)

**Figure 8.** Influence of pH on turbidity reduction using AM powder.

![Figure 9](image_url2)

**Figure 9.** Influence of pH on COD reduction using AM powder.
Figure 10. Influence of pH on TSS reduction using AM powder

4. Conclusions
1- Turbidity, COD and TSS removals by 83%, 75%, 79% 66% respectively could be achieved using 40 mg/L alum solution at pH=7.

2- The combination of alum and powdered AM as a coagulant aid improved pollutants reduction performance for Turbidity, COD and TSS by 90%, 84%, 88% respectively at optimum dosage of alum 40 mg/l and optimum dosage of AM 0.3 g/L at pH=7.

3- The combination of alum and extracted liquid AM as a coagulant aid improved pollutants reduction performance for Turbidity, COD and TSS by 93%, 88%, 92% respectively at optimum dosage of alum 40 mg/l and optimum dosage of AM 1.0 ml/L at pH=7.

4- Using AM as an extracted liquid was more efficient than powdered AM. The efficiency increased when the pH increased to optimum value pH=10, the results for pollutants removal efficiency from grey water for Turbidity, COD and TSS by 98%, 92%, 95% respectively at optimum dosage of alum 40 mg/l and optimum dosage of AM 1.0 ml/L at pH=10.

5- All the obtained results showed the possibility of using of natural plant Alhagi Maurorum as a coagulant aid in removing several pollutants from grey water.

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