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Natural coagulation performance for turbidity and iron removal from water using plant seeds

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Abstract: Access to clean and safe drinking water remains a critical challenge in many parts of the world, particularly in regions with limited resources and infrastructure. This research conducted a series of laboratory experiments to evaluate the coagulation performance of plant seeds treating Nile River water compared with chemical coagulants as Aluminum Sulphate. Also, the natural coagulants are examined to evaluate the adsorption process of free iron ions from groundwater using plant seeds. Moringa Oleifera and date seeds as natural coagulants achieved high efficiency for removing turbidity from Nile River water with a dosage of 150 and 60 mg/l, respectively, whereas date seeds as bio-sorbent coagulant approved after sedimentation and filtration stages about 65.7% and 87.25%, respectively for iron removal from groundwater with a dosage of 60 mg/l. In addition, life cycle assessment was studied to evaluate the damages to human health and ecosystem quality caused by carcinogenic substances, respiratory effects by inorganic substances, ecotoxic emissions, eutrophication, acidification and climate change effect due to natural coagulation compared with chemical coagulation. Furthermore, a cost analysis was studied to determine the economic cost of different plant seeds compared with chemical coagulant used for water purification. The cost-benefit value of coagulation using alum, Moringa Oleifera seeds and date seeds were estimated as 0.002, 0.01 and 0.0003 LE/%, respectively.

Keywords: chemical coagulation; date seeds; life cycle assessment; plant-based coagulant; water purification

1. INTRODUCTION

A healthy fresh water for drinking must be supplied without any pollutants as toxic metals, turbidity, organic and inorganic materials and pathogenic microorganisms. Moreover, it is important for drinking fresh water considering permissible aesthetic values. Organic materials in contaminant water might be established and formed from ecological, industrial and agricultural processes, which participate with other materials in increasing of pollution of water such as dichloromethane, fuel of vehicles, plant and animal wastes and pesticides [1]. In addition, undesirable quantities or high concentrations of soil constituents such as iron, manganese, nitrate and arsenic can contaminate groundwater that can be attributed to the flow of groundwater through sedimentary rocks and water infiltrating various soils [2]. Drinking water is a basic requirement for living creatures especially for human beings. Many developing countries have been facing drinking water problems due to the lack of facilities and financial resources. Many developing countries use untreated water for drinking purposes but untreated water contains heavy metals such as Cadmium, lead, chromium and iron that lead to human health risks [3]. Ammonia, nitrate and phosphorus as well as bio-organisms may also impact the human health due to release of inadequately treated wastewater into groundwater [4]. On the other hand, turbidity of surface water resulting from soil sediments transport and algae growth is a major environmental problem.

A coagulant is a key for turbidity removal in water purification processes, and improving practices relevant to water conservation. Coagulation mechanism can be classified into four types; double-layer compression, inter-particle polymer bridging, charge neutralization, and sweep coagulation [5, 6]. The mechanism of double-layer compression depends on adding salts in water so that the ionic strength increases in water and repulsion energy of colloids decreases. Whilst inter-particle polymer bridging mechanism is preceded by adsorption process where some parts of polymer attach itself to the colloidal particle's surface allowing other polymers parts to form loops that helps in polymer bridging and thus other colloidal particles are attached resulting in larger flocs. In addition, charge neutralization mechanism occurs by hydrolysis of inorganic coagulant in water and attraction of hydroxide negative ions by metal positive ions forming neutralized flocs. Regarding plant-based natural coagulation, charge coagulation occurs by extending polyelectrolytes (ionizable polymers) of coagulant on colloidal surfaces to form destabilized flocs that helps in flocs aggregation [5]. On the other hand, adsorption of colloids on the voluminous participate (insoluble) metal hydroxides is enmeshed in sweep coagulation.

Many coagulants are widely used in conventional water purification processes. These materials can be classified into inorganic and organic coagulants [7]. Inorganic coagulant, such as Aluminum Sulphate (alum), is usually used in drinking water purification. However, many researches showed that chemical coagulation of water using alum can pose a potential risk to human health [8]. Regarding a study of Life Cycle Assessment (LCA) for the impact of using alum in global warming potential (GWP), about 12760.76 Kg CO_2-eq comes from flocculation producing flocs by the addition of chemicals. Meanwhile, the potential impact of eutrophication can be 268.55 $KgPO_4$-eq that is derived from mud generation. Recent researches reported on improving treatment performance by electrocoagulation process [9]. However, a comprehensive LCA and electrical energy consumed have to be studied for dissolution of electrode ions in water as a result of anode oxidation by electric current. The decision to optimize chemicals and search for eco-friendly alternative coagulants is of a top priority that can help reducing environmental impact at GWP and overcoming human health risks, then the second priority comes by recycling sludge, and finally making cost savings and energy alternatives are the last priority [10].

Organic coagulants can be used to purify the contaminated water that is considered to be environmentally friendly and non-harmful to human health [11]. Moringa Oleifera seeds are used as a primary coagulant in drinking water clarification due to the presence of cationic coagulant protein which is able to reduce turbidity of treated water [12]. The adsorption of metals using Moringa is limited to the adsorption surface. This is because Moringa is a cationic polyelectrolyte of short chain and low molecular weight [13]. Date seeds have special coagulant properties. Their composition includes polysaccharides and proteins, which aid in the aggregation of suspended particles. Date seeds have demonstrated effectiveness in reducing turbidity in water [14]. Also, these seeds are composed of lignin, hemicellulose, and cellulose which are effective bio-sorbents. The efficiency of this inexpensive bio-sorbent is due to oxygenated functional groups in the lignocellulosic materials such as cellulose and phenolic compounds [15]. Watermelon seeds are used as a coagulant for water treatment because it has high protein content and some authors considered their ability to have the active coagulating agents of cationic protein that exhibit isoelectric potentials [16].

In this study, the use of extracts of plant seeds as natural organic coagulants, such as Moringa (Moringa Oleifera), date (Phoenix dactylifera) and watermelon (Citrullus Lanatus) seeds, were tested for contaminant water purification. Water samples were experimentally tested for turbidity level and total suspended solids (TSS) concentration using alum and natural plant seeds. In addition, groundwater samples were experimentally tested for turbidity level, TSS concentration, and iron metal concentration using natural plant seeds. Also, a LCA was studied for both chemical and natural coagulation used for water purification. In addition, a cost-benefit analysis was performed in order to determine the economic cost associated with the treatment performance relevant to chemical and natural coagulation. The aim of this study is to (a) investigate the suitability of Moringa Oleifera seeds, date seeds and watermelon seeds for water purification, (b) compare the efficiency of plant-based coagulants with alum used for water treatment, (c) control and removal of metal pollution, (d) Reducing the amount of waste generated, (e) minimize human health risks by LCA study, and (f) achieve a low-cost treatment process as well as sustainable development goals using eco-friendly renewable materials.

2. Materials and Methods

The pilot system was established for the treatment of Nile River water samples by using alum, Moringa Oleifera seeds, date seeds and watermelon seeds, and for groundwater samples by Moringa Oleifera seeds and date seeds as coagulant in coagulation process as a first stage followed by filtration process as a second stage.

2.1. Water Samples

Nile River water samples were collected by using a plastic gallon from shore intake to Gezeret El-Dahab Water Plant located in Giza, Egypt, whereas groundwater was collected from a groundwater well with 1000 meters deep in the Bahariya Oasis at Giza, Egypt. Samples were collected and transferred to the National Research Centre for the experiments.

The characterization of raw water was determined to emphasize the testing conditions at the National Research Centre. The characteristics of Nile River water and groundwater are given in Tables 1 and 2. The water samples were tested at a temperature of 15 – 25 °C.

Table 1. The characteristics of raw Nile River water used in experimental runs

Parameters	Unit	Value
pH	------	6.8
Turbidity	NTU	8.47
TSS	mg/l	13
Total hardness	mg/l	126
Total alkalinity	mg/l	160
Chloride	mg/l	37.4
Fluoride	mg/l	N.D.
E. Coli	MPN-index/ 100 ml	750

Table 2. The characteristics of raw groundwater at Bahariya Oasis

Parameters	Unit	Value
Turbidity	NTU	270
TSS	mg/l	22.4
pH	------	6.24
Copper	mg/l	<0.01
Cadmium	mg/l	<0.001
Lead	mg/l	<0.001
Iron	mg/l	10.2

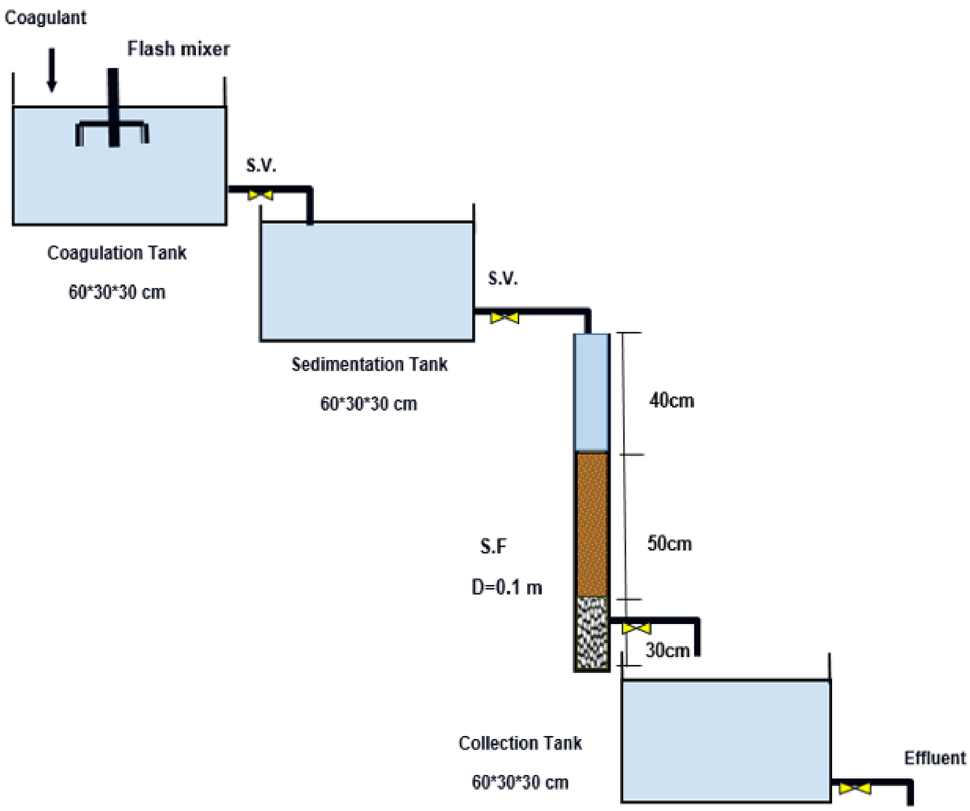


Fig.1. Experimental lab-scale model setup

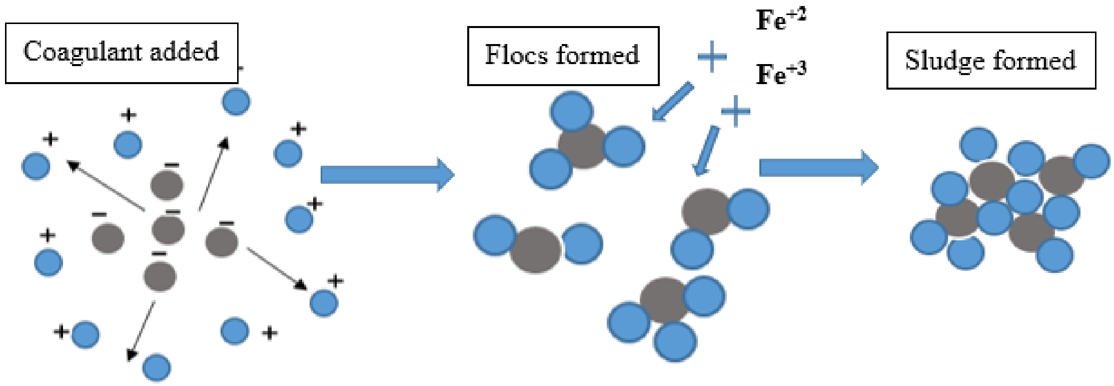


Fig.2. Coagulation-adsorption mechanism

2.2. Experimental set-up

An experimental model was set up consisting of mixing, sedimentation, and filtration to purify the water samples in two-stage process (see Fig.1).

2.2.1. Coagulation-Sedimentation stage

In this stage, we added the coagulants to raw water where the coagulants positive charges neutralize the negative charges of suspended contaminants as shown in Fig.2. A flash mixer was used to mix the coagulant with raw water in a coagulation-flocculation tank of dimensions 60 x 30 x 30 cm, whereas gentle mixing is applied to allow for neutralized flocs to coalesce in the coagulation-flocculation tank. Simultaneously, the adsorption of dissolved iron ions from water on coagulant-floc particles occurs prior to physical treatment for floc settling in sedimentation tank with retention time 2.0 hours. In this stage, turbidity levels and TSS concentrations were measured for Nile water and groundwater, whereas iron concentrations were measured for groundwater samples.

2.2.2. Filtration stage

In this stage, a sand filter was designed to purify water after decreasing turbidity in the first stage. The sand filter consists of UPVC pipe with 1.20 m and 0.1 m diameter. The filter media consist of layer of sand 50 cm thickness similar to that used in filter of (Gezeret El-Dahab Water Plant). The sand particles diameter fluctuates between 0.8 – 1.4 mm. The texture of sand grains varies between medium and coarse-grained type. The composition of sand grains is comprised of a high percentage of silica. This sand column is supported by a 30 cm thick of gravel at bottom of the column with size from 3 to 5 mm as shown in Fig.3. The water flow was directed downward in rapid sand filter with a rate of filtration of 150 m^3/m^2/day. An effluent pipe is installed in the filter gravel layer to direct filtered water into a collection tank.

(a) (b)

Fig.3. (a) Sand and (b) gravel media in filter unit

2.3. Preparation of plant seeds

Dry Moringa Oleifera seeds were purchased from National Research Centre outlet. Matured Pod shells were removed manually by using a knife; kernels were grounded in a domestic blender and sieved through 600-micron stainless steel sieve [17]. Agwa dates were purchased from local market stores in Cairo, Egypt. The seeds were separated from their original date fruits. The separated seeds were rinsed several times with clean tap water and then with distilled water to eliminate any traces of consumable parts, dirt and dust from them. Then, the clean seeds were dried in oven at 80 °C for 2 h, the dried seeds were taken out from the oven and crushed using hammering and blending to powder form. Further, the powder was crushed with Mixer grinder to prepare fine powder of homogeneous size. Finally, the powder was sieved through 120 µM size sieve to get fine powder and stored in clean and dry glass bottles [18]. Dried seeds of watermelon were purchase from Amazon site. The seeds sorted to remove bad ones and shelled. The dried seeds were ground to fine powder by domestic blender. This powder was sieved through 450 µm sieve. The 10 g of fine powder was mixed well with 100 ml distilled water solution and the suspension was stirred using a magnetic stirrer for 10 minutes for homogeneous mixing. The solution was prepared fresh before each set of experiment. The seed solution was then used as the coagulant [19].

2.4. Sampling collection and testing

Samples were taken directly from Nile River and groundwater well as shown in Fig.4; each was collected in a disinfected plastic bottle with one litter in capacity to perform the required physical tests. In addition, two samples for each were taken from the outlet of the sedimentation and filtration units after treating water using alum with dose 30 mg/l [20], Moringa Oleifera seeds with dose 150 mg/l according to jar test [21] as shown in Table 3, date seeds with dose 60 mg/l as reported by Al-Sameraiy [7], and watermelon seeds with dose 200 mg/l according to Shashank et al. [19]. The physical characteristics were carried out for the following parameters according to standard methods for water and wastewater examination, American Public Health Association (APHA 2023):

- Turbidity measurements were carried out by turbidity-meter, Model (Turbicheck) according to (SMWW 2130:2023).
- TSS measured by using oven drying and weighing solids according to (SMWW 2540D: 2023).
- Iron was measured using the atomic absorption spectrometer, Model (240FS) according to (SMWW 3111B:2023).

Fig.4. Collection of the groundwater samples and well location.

In addition, a comparison was performed among experimental runs using different doses of natural coagulants to approach the optimum dose of each coagulant for Nile River water purification as shown in Table 4. Accordingly, groundwater was tested using optimum doses as shown in Table 5.

Table 3. Jar tests for Nile water using various dosages of Moringa Oleifera seeds coagulant

Parameters	Unit	Nile River water (raw water)	Coagulant dose 50 mg/l	Coagulant dose 100 mg/l	Coagulant dose 150 mg/l
pH	------	6.8	6.98	7.4	7.6
Turbidity	NTU	8.47	3.41	2.66	1.1
TSS	mg/l	13	1.8	0.73	0.18
Total hardness	mg/l	126	57.8	17.8	4.37
Total alkalinity	mg/l	160	132	84	36.4
Chloride	mg/l	37.4	3.12	0.76	0.03
Fluoride	mg/l	N.D.	0	0	0
E. Coli	MPN-index/ 100 ml	750	276.6	199.8	123

Table 4. Experimental runs for testing Nile water samples using different coagulant dosages

Coagulant dosage		Raw Nile Water		After Sedimentation		After Filtration	
		Turbidity (NTU)	**TSS (mg/l)**	**Turbidity (NTU)**	**TSS (mg/l)**	**Turbidity (NTU)**	**TSS (mg/l)**
Alum	30 mg/l	8.47	13	2.83	3	0.33	0.7
	Removal % (Run 1)			66.6	76.92	96.1	94.61
Moringa Oleifera Seeds	150 mg/l	8.47	13	5.84	6.89	0.61	0
	Removal % (Run 2)			31	47	92.8	100
	100 mg/l	8.47	13	7.6	9.6	0.63	0.5
	Removal % (Run 3)			10.27	26.15	92.6	96.15
Date Seeds	20 mg/l	8.47	13	5.33	5.6	0.73	1
	Removal % (Run 4)			37.1	56.92	91.4	92.3
	30 mg/l	8.47	13	5.9	6.1	0.82	1
	Removal % (Run 5)			30.34	53.1	90.32	92.3
	60 mg/l	8.47	13	3.81	3.25	0.49	0.7
	Removal % (Run 6)			55	75	94.2	94.6
Watermelon Seeds	200 mg/l	8.47	13	5.76	7.67	1.86	2.6
	Removal % (Run 7)			32	41	78	80

Table 5. Experimental runs for testing groundwater samples using different coagulants

Bio-sorbent dosage		Raw Groundwater			After Sedimentation			After Filtration		
		Turbidity (NTU)	**TSS (mg/l)**	**Iron (mg/l)**	**Turbidity (NTU)**	**TSS (mg/l)**	**Iron (mg/l)**	**Turbidity (NTU)**	**TSS (mg/l)**	**Iron (mg/l)**
Moringa Oleifera Seeds	150 mg/l	270	22.4	10.2	161	19.8	6	2.9	0.5	0.6
	Removal % (Run 8)				40.37	11.61	41.2	98.92	97.8	94.12
Date Seeds	60 mg/l	270	22.4	10.2	29.1	10.5	3.5	1.5	1	1.3
	Removal % (Run 9)				89.2	53.12	65.7	99.4	95.53	87.25

2.5. Life Cycle Inventory study

Life cycle inventory (LCI) is presented as shown in Fig.5. The inputs and outputs of inventory are proposed for the two-stage purification process. The first stage includes a step of coagulation-flocculation followed by sedimentation, whereas the second stage is relevant to a filtration step. The input of LCI can be attributed to the type of coagulant used, the characteristics of raw water, and the type of filter media. The output of LCI is classified to human health impact and ecosystem quality. The human health risks are studied concerning damages caused by carcinogenic or toxic substances and respiratory effect of inorganic substances. The environmental impact is assessed by evaluating the ecotoxicity and eutrophication of dissolved emissions or participated particles in water streams as well as the climate change due to global warming potential (GWP) and acidification effect as air emissions.

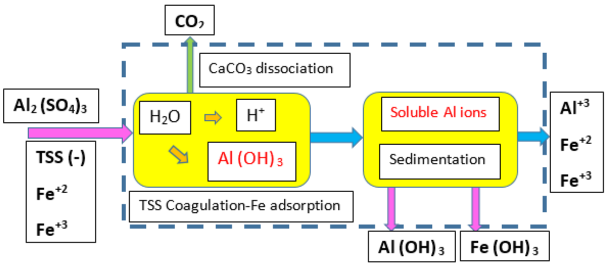


Fig.5. LCI inputs and outputs for coagulation-sedimentation process using alum in water

3. Results and Discussion

River water samples were collected from different steps in the semi-pilot treatment system using alum with dose 30 mg/l and plant seeds (Moringa seeds, date seeds and watermelon seeds) with doses of 150, 60 and 200 mg/l respectively, whereas groundwater samples were tested using Moringa seeds and date seeds with doses of 150 and 60 mg/l respectively. The samples include influent raw water, effluent water after sedimentation, and effluent water after sand filter.

3.1. Turbidity level

Turbidity levels are 8.47 NTU and 270 NTU for raw samples of Nile water and groundwater respectively. The high turbidity of groundwater can be attributed to high iron concentration. The turbidity measurement must be less than 5 NTU for drinking water according to the World Health Organization. According to the result obtained for Nile River and groundwater turbidity, Moringa seeds have decreased the turbidity by 31% and 40.37% respectively after sedimentation stage, and by 92.8% and 98.9% respectively after filtration stage. The increase of turbidity removal may owe to the rate of filtration and the ability of grains size to retain suspended solids in sand filter [22]. Notably, the ability of silica sand to adsorb metal ions from groundwater can significantly reduce water turbidity. Concerning another study, Madsen et al. [23] reported that about 90 – 99% of turbidity was removed using Moringa seed powder. Date seeds have also decreased the turbidity for Nile water and groundwater by 55% and 89.2% respectively after sedimentation stage, and by 94.2% and 99.4% respectively after filtration stage. In other study, Al-Sameraiy [7] found that date seeds achieved turbidity removal of 90% for the same dose. In addition, watermelon seeds have decreased the turbidity for Nile water by 32% after sedimentation stage and by 78% after filtration stage. In other studies, there was almost the same removal efficiency for turbidity using watermelon seeds of about 86% for initial turbidity 63.5 NTU [16]. However, watermelon seeds achieved turbidity removal of 94.7% for initial turbidity 114 NTU at the same dose according to Shashank et al. [19]. It is clear that watermelon seeds have a higher efficiency removal with initial high turbidity. Among these three seeds, date seed has caused significant reduction in turbidity approaching that of alum (66.6%) after sedimentation that can be attributed to the ability of date seeds to neutralize the negatively charged suspended solids in water (Fig.6 (a)), whereas Moringa and date seeds have caused significant reduction in turbidity compared with that of alum (96.1%) after filtration (Fig.6 (b)) that can be attributed to distribution of grains size in sand filter.

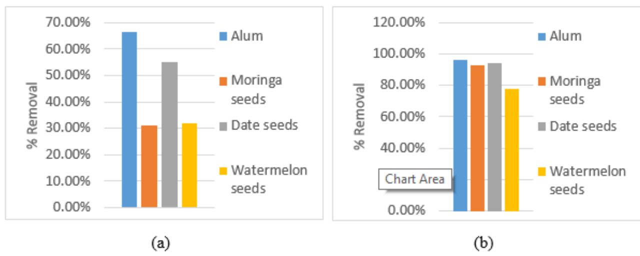
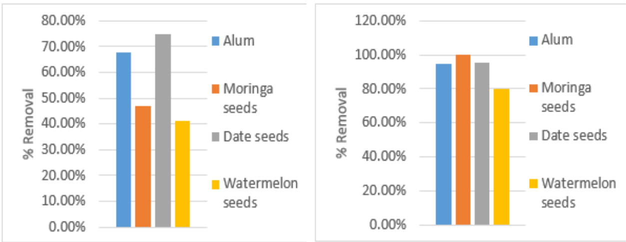


Fig.6. Effect on the change of turbidity for Nile using alum and natural seeds (a) after sedimentation and (b) after filtration.

3.2. TSS concentration

TSS concentrations are 10.8 mg/L and 22.4 mg/l for raw samples of Nile water and groundwater respectively. Sedimentation process is often used to water clarification by separating suspended solids to be removed in water treatment because they are usually relatively large particles. Based on the obtained results, Moringa seeds have decreased TSS by 47% and 11.61% for Nile water and groundwater respectively after sedimentation stage. In other studies, a removal efficiency reached about 49.5% at the same dose after sedimentation [24], whereas TSS removal reached about 100% and 97.8% for both water resources respectively after filtration. The high removal efficiency can be attributed to rate of filtration and grains size in sand filter. Moreover, date seeds have reduced TSS by 75% and 53.12% for Nile water and groundwater respectively after sedimentation stage, and by 95% and 95.5% respectively after filtration. Throughout the tests performed by Abu Amra et al. (2023), TSS removal performance was shown to be consistent at 99% at all doses. Watermelon seeds have also decreased the TSS by 41% for Nile water after sedimentation, and 80% after filtration. Among these three seeds, date seeds have caused better reduction in TSS than alum (67.9%) after sedimentation (Fig.7 (a)) that may owe to the ability of date seeds to neutralize the negatively charged suspended solids in water, moringa and date seeds have caused significant reduction in TSS similar to that of alum (94.6 %) after filtration (Fig.7 (b)).

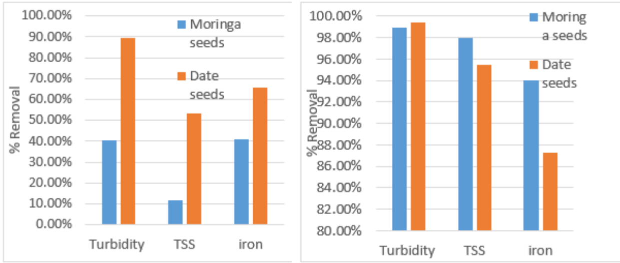


(a) (b)

Fig.7. Effect on the change of TSS for Nile using alum and natural seeds (a) after sedimentation and (b) after filtration

3.3. Iron concentration

Iron concentration for groundwater sample is 10.2 mg/l. The permissible concentration of iron in drinking water is less than 0.3 mg/L according to the World Health Organization. When iron is oxidized, its chemical composition changes into particles that cause the color and odor of the water. This is the reason why groundwater changes color after it leaves the well until it is used in the treatment process. The results showed the removal efficiency of Iron metal using Moringa Oleifera seeds declined by 41.2% after sedimentation stage (Fig.8 (a)), and 94.12% after filtration (Fig.8 (b)). The increase in iron removal after filtration may owe to the ability of silica sand grains to adsorb iron from water accompanied by a high TSS removal in sand filter. In other studies, by applying moringa seeds for treating water, the iron level was reduced by 75.1%. [25]. On the other hand, the removal efficiency of iron metal using date seeds was reduced by 65.7% after sedimentation stage (Fig.8 (a)), and 87.25 % after filtration (Fig.8 (b)) that strictly ensures the ability of date seeds to adsorb iron from water. The efficiency removal of iron was about 97.9% as mentioned in other studies using date seeds as bio-sorbent [26]. The difference in removal percentage is due to the variation of the concentration of iron in the raw groundwater and variation of the date seeds doses. Although iron can be efficacy removed using Moringa seeds after the filtration stage, date seeds are a good adsorbent for iron removal compared with Moringa seeds in sedimentation process that can be attributed to the variation of removal efficiency of TSS.



(a) (b)

Fig.8. Removal efficiency for turbidity, TSS and iron concentrations in groundwater using Moringa Oleifera and date seeds (a) after sedimentation and (b) after filtration

3.4. LCA using natural and chemical coagulant

This research indicates that using extracts of plant seeds in water purification is considered as a sustainable process that can have a positive life cycle impact compared to conventional chemical treatments. Using plant seeds in water purification achieves the goal of LCA compared with that of using alum. Regarding the human health risks, plant-based coagulants have no effect on health except for use after long-term storage that helps in organic decomposition by bacteria. Also, natural coagulation has no harmful environmental impact except for excessive use at high doses that helps in fat decomposition and nutrient release [27]. However, Ang et al. [28] reported on efficiently clean processes so that the active coagulant agent as purified proteins can be extracted for water purification by removing lipids, organic and anionic contaminants from plant-based coagulants. On the other hand, using alum causes Alzheimer's disease [28]. Carcinogenic and toxic substances may release if inadequate doses of chemical coagulant are used in water. Besides, using alum causes pollution of the environment with high amounts of participated aluminium flocs which are degradable. CO_2 emissions are produced by reducing alkalinity as $CaCO_3$ and dissociation of bicarbonate ion as a result of adding alum generating carbon dioxide gas which causes global warming. Increase acidity of water by attracting hydroxide ions to aluminium metal ion and leaving hydrogen ion in water is another drawback of using alum as a coagulant forming neutralized floc and thus pH of treated water decreases. Regarding recycling sludge, using plants seeds as coagulant results in biodegradable sludge that can be used in agriculture as compost but using alum leaves harmful residues in water where inorganic sludge results in eutrophication impact, requiring more complex waste management solutions. Beyond, availability of plant seeds is relevant to local availability and cultivation. In regions where these plants grow naturally, the approach is more practical and cost-effective. But for alum, the cost is derived from bauxite ore which is mined and refined to produce aluminium sulphate, this makes it expensive to obtain. Saving energy with eco-friendly and low costly process is the main advantage of using natural seeds in water purification as compared with alum.

3.5. Cost analysis

The results showed that the purchase prices of coagulants as alum, Moringa Oleifera seeds, date seeds and watermelon seeds were 0.17 LE/g, 0.2 LE/g, 0.011 LE/g and 0.28 LE/g, respectively (Table 6). Notably, watermelon seeds coagulant was 64.7% more expensive compared with alum, Moringa Oleifera seeds coagulant was 17.64% more expensive compared with alum, but alum was 1445.5% more expensive compared with date seeds coagulant. Based on the amount of coagulant per day, the cost of water treatment using alum, Moringa Oleifera seeds, date seeds and watermelon seeds can be obtained as 0.23 LE/day, 1.35 LE/day, 0.03 LE/day and 2.52 LE/day, respectively. At average, the removal efficiencies of Nile water turbidity during the use of coagulants as alum, Moringa Oleifera seeds, date seeds and watermelon seeds were 96.1%, 92.8%, 94.2% and 78%, respectively. The daily cost-benefit from the use of each coagulant was determined by the relationship between the daily cost per dosage and the average efficiency of turbidity removal. Results showed that the cost-benefit of the coagulants was 0.002 LE/%, 0.01LE/%, 0.0003 LE/% and 0.032 LE/%, respectively. In other words, date seeds coagulant showed the lowest cost and the highest treatment efficiency during its use in water purification.

Table 6. Cost of water treatment using four coagulants under study

Coagulant Material	Concentration (mg/l)	LE/g*	LE/L	LE/day**
Alum	30	70.1	510.00	0.23
Moringa seeds	150	20.	30.0	1.35
Date seeds	60	0.011	0.00066	0.03
Watermelon seeds	200	280.	560.0	2.52

* The prices are based on local commercial costs in Egypt
** The prices are based on the amount of coagulant per day

4. Conclusion

Moringa seeds and date seeds as plant-based coagulant were investigated for their ability to remove turbidity from Nile water. Date seeds as bio-sorbent in groundwater approved high efficiency removal for turbidity and iron without the need to use a filter after sedimentation. The use of rapid sand filters of medium silica sand grains is essential for improving water purification especially at high turbidity levels, suspended solids concentration and iron concentration in water. The natural coagulation-sedimentation process followed by rapid filtration is suitable for the separation of the flocs formed using Moringa Oleifera seeds. It is an eco-friendly technology that is economically more advantageous than other treatment alternatives. Compared with chemical coagulation, life cycle assessment revealed that natural coagulation is more safety for human health and acts as an environmental renewable resource for water purification. After the treatment process, the sludge settled at the bottom of tank can be used as bio-fertilizers is an added advantage of natural coagulation in rural areas. The cost-benefit analysis implies that using date seeds as a natural coagulant is an environmental economic process for water purification.

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Statements and Declarations

Funds: No funding was received to assist with the preparation of this article.

Data Availability: The data concerning more experimental sampling for bacteriological analyses are available on request.

Ethical Approval: There was no ethical approval required in this work.

Competing Interests: The authors have no competing interests to declare that are relevant to the content of this article.

References

[1] Muyibi, S.A., Ali, E.N., Salleh, H.M. (2009) Moringa oleifera seeds as natural coagulant for water treatment, Thirteenth International Water Technology Conference, 13(2), 1-10.

[2] Diver, D., Nhapi, I., Ruziwa, W.R. (2023) The potential and constraints of replacing conventional chemical coagulants with natural plant extracts in water and wastewater treatment. Environmental Advances 13, 100421.

[3] Ravikumar, K., Sheeja, A.K. (2013) Fluoride removal from water using Moringa oleifera seed coagulation and double filtration. International Journal of Scientific & Engineering Research, Volume 4, Issue 8.

[4] Badr, E., Agrama, A., Badr, S. (2011) Heavy metals in drinking water and human health, Egypt. Nutrition & Food Science.

[5] Amran, A.H., Zaidi, N.S., Muda, K., Loan, L.W. (2018) Effectiveness of natural coagulant in coagulation process: A review. International Journal of Engineering and Technology 7 (3.9) 34–37.

[6] El-taweel, R.M. et al. (2023) A review of coagulation explaining its definition, mechanism, coagulant types, and optimization models; RSM, and ANN. Current Research in Green and Sustainable Chemistry 6, 100358.

[7] Al-Sameraiy, M. (2012) A Novel Water Pretreatment Approach for Turbidity Removal Using Date Seeds and Pollen Sheath. Journal of Water Resource and Protection.

[8] Gauthier, E., Fortier, I., Courchesne, F., Pepin, P., Mortimer, J., Gauvreau, D. (2000) Aluminum forms in drinking water and risk of Alzheimer's disease. Environmental Research, Volume 84, Issue 3, Pages 234-246.

[9] Safwat, S.M., Mohamed, N.Y., El-Seddik, M.M. (2023) Performance evaluation and life cycle assessment of electrocoagulation process for manganese removal from wastewater using titanium electrodes. Journal of Environmental Management 328, 116967.

[10] Kartikasari, I.B., Santoso, R.I.B. (2023) Impact of drinking water treatment process using life cycle assessment (LCA) to minimize environmental impact risk. Journal of Social Research.

[11] Marobhe, N.J., Renman, G., Jacks, G. (2007) The Study of Water Supply and Traditional Water Purification Knowledge in Selected Rural Villages in Tanzania. Environmental Science.

[12] Nouhi, S., Kwaambwa, H.M., Gutfreund P., Rennie, A.R. (2019) Comparative study of flocculation and adsorption behaviour of water treatment proteins from Moringa peregrina and Moringa oleifera seeds. Scientific Reports 9:17945, https://doi.org/10.1038/s41598-019-54069-2.

[13] Muyibi, S.A. et al. (2002) Effects of oil extraction from Moringa oleifera seed on Coagulation of Turbid water. Article in International Journal of Environmental Studies. DOI: 10.1080/00207230210924.

[14] Owodunni, A.A., Ismail, S., Olaiya, N.G. (2023) Parametric study of novel plant-based seed coagulant in modeled wastewater turbidity removal. Environmental Science and Pollution Research 30:124677–124685.

[15] El Marouani, M., Azoulay, K., Bencheikh, I., El Fakir, L., Rghioui, L., El Hajji, A., Sebbahi, S., El Hajjaji, S., Kifani-Sahban, F. (2018) Application of raw and roasted date seeds for dyes removal from aqueous solution. Journal of Materials and Environmental Sciences, Volume 9, Issue 8.

[16] Muhammad, I.M., AbdulSalam, S., AbdulKarim, A., Bello, A.A. (2015). Watermelon seed as a potential coagulant for water treatment. Global Journal of Researchers in Engineering: Chemical Engineering. Global Journals Inc. (USA), Vol. 15, 1, pp 17-25.

[17] Jinna, A., Anu, M.R., Krishnan, N., Sanal, V., Das, L. (2019) Comparative study of efficiency of local plants in water treatment. International Research Journal of Engineering and Technology, Volume: 06, Issue: 04.

[18] Azam, M., Wabaidur, S.M., Khan, M.R., Al-Resayes, S.I., Islam, M.S. (2021) Removal of Chromium (III) and Cadmium (II) Heavy Metal Ions from Aqueous Solutions Using Treated Date Seeds. Molecules. DOI: 10.3390/molecules26123718.

[19] Shashank, J.S. et al. (2022) Treatment of Water Using Watermelon Seeds as a Natural Coagulant. International Journal of Engineering Research and Applications, Vol. 12, Issue 7, (Series-I), pp. 126-130.

[20] Awadh, H.H., Salah, R. (2022) Turbidity removal from aqueuse solution by three materials coagulates. Journal of University of Babylon for Engineering Sciences, volume 30 (2).

[21] Ali, G.H., Hegazy, B.E., Fouad, H.A., El-hefny, R.M. (2008) Comparative study on natural products used for pollutants removal from water. Journal of Applied Sciences Research, 5(8): 1020–1029.

[22] Abuelkhair, N.Y., El-Nadi, M.H., Fouad, H.A., Hefny, R.M. (2022) Dynamic sand filter performance against high solids loads in raw water. Benha Journal of Applied Sciences, volume 7, issue 4, 97-101.

[23] Madsen, M., Schlundt, J., Omer, E.E. (1987) Effect of water coagulation by seeds of Moringa oleifera on bacterial concentrations. The Journal of tropical medicine and hygiene 90(3):101-9, DOI:10.1016/0378-8741(88)90285-1, Source PubMed.

[24] Mangale, S.M., Chonde, S.G., Jadhav, A.S., Raut, P.D. (2012) Study of Moringa oleifera (Drumstick) seed as natural Absorbent and Antimicrobial agent for River water treatment. Journal of Natural Product and Plant Resources, 2 (1):89-100.

[25] Arasaretnam, S., Keerthanan, S. (2018) Plant Seeds as Biosorbents for the Purification of Water. Journal of Modern Chemistry & Chemical Technology. Volume 9, Issue 2.

[26] Abu Amr, S.S., Abujazar, M.S.S., Karaağaç, S.U., Mahfud, R., Alazaiza, M.Y.D., Hamad, R.J.A. (2023) Application of plant-based natural coagulant for sustainable treatment of steel and iron industrial wastewater, Karabuk, Turkey. Desalination and Water Treatment, 287, 39–45, doi: 10.5004/dwt.2023.29393.

[27] Sotheeswaran, S., Nand, V., Maata, M., Kanayathu, K. (2011) Moringa Oleifera and other local seeds in water purification in developing countries. Research journal of chemistry and environment, 15 (2), 135–138.

[28] Ang, T.-H. et al. (2020) Insight on extraction and characterisation of biopolymers as the green coagulants for microalgae harvesting. Water, 12, 1388, doi: 10.3390/w12051388.