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Water purification improvement using moringa oleifera seed extract pastes for coagulation follow scoria filtration

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A R T I C L E I N F O

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A B S T R A C T

Currently, millions of people are exposed to dangerous levels of chemical and biological water pollution in drinking water due to source contamination. The rising of populations and industrialization or agricultural wastewaters were causes of water contaminations. The aim of this study was to design, develop and performance evaluation of point of use drinking water purification technology using MoringaOleifera seed coupled followed by scoria coag-filtration media. Experimental laboratory based aquas solution of contaminated water was prepared for evaluations. Moringa Oleifera seed coagulation/flocculation and sedimentation tests were carried out using jar test with the batch experiment. The potential treatment of the sequential ordered unit process stages were evaluated by the determination of physicochemical parameters of the water; such as turbidity, Color, PO_4^{-3}, Fe^{+3} and F^{-}concentration. The factor that affects the purification where coagulant doses, pH, and contact time. Based on this, the physicochemical parameter analysis indicated that turbidity from (150-8NTU), PO_4^{-3} (20–5.95 mg/L), Fe^{+3} (7–2.93 mg/L) and F^{-} (9–2.83 mg/L), Moringa Oleifera seed dose (10–40 mL/L) extract paste. The maximum pollutant removal efficiency was achieved at 35 mL/L of Moringa Oleifera seed extractdose, within 6.5–7.5 pH range. Then VSco filtration was conducted after jar test under small column experiment as a function of contact time (0, 2, 4 h s). The VSco removal capacity showed that the removal of turbidityfrom (8–2.54NTU), PO_4^{-3} (5.95–1.07 mg/L), Fe^{+3} (2.93–0.43 mg/L) and F^{-} (2.83–1.94 mg/L) were achieved after 4hr detention time. The percent removal of turbidity, PO_4^{-3}, Fe^{+3} and F^{-} increases remarkably with increasing of their initial concentration. At an initial concentration of turbidity (150NTU), PO_4^{-3} (20 mg/L), Fe^{+3} (7 mg/L) and F^{-}(9 mg/L), the removal efficiency were 98%, 84%, 85% and 60% respectively. Therefore, we recommend Moringa Oleifera seed –Vscoas an economic, efficient and simple Point of Use drinking water treatment technology.

1. Introduction

Currently, due to source contamination by population growth, industrialization, and agricultural effluent millions of people are exposed to harmful amounts of chemical pollutants and biological contaminants in drinking water [1]. Water quality has considerably declined, and access to clean drinking water has emerged as one of the biggest issues, particularly in developing nations [2]. In

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Ethiopia, Serious attention was not given in controlling the point and non-point sources of contaminants due to lack of potentially strong castigation and failure of empowering the society with lesson [3]. In Ethiopia water body always contaminated by PO_4^{-3} due to phosphate fertilizer highly consumsion in agricultural [4]. Florid ions were naturally presence in Ethiopia specially in Riftvalley which simple soluble with water [5]. Fe^{+3} ions were consider as metallic contaminant from anthropogenic sources and the turbidity were always causes due to the flading and erosion [6,7].

In Ethiopia all the rular area of the community tapped the drinking water directly from their sources and used without any purification or pre-treatment [8]. The main source's area's drinking water quality has been negatively impacted by ion pollutants. For instance, the presence of harmful ions like phosphorous, fluoride, iron, and turbidity in water poses a significant threat to the quality of drinking water [9]. Aluminum sulphate ($Al_2(SO_4)3{\cdot}18H_2O$) most used synthetic coagulant for water treatment of public supplies since it has a rapid aggregation speed, forms heavy flocs [10]exhibiting better efficiency than other coagulants for color and turbidity removal and has smaller pH dependence [11]. Despite the well-known performance one of its major problems is the high concentration of residual aluminum remaining in water after treatment, which has been associated with the acceleration of worsening processes of Alzheimer's disease [12]. Therefore it is interesting to propose alternatives to reduce the quantity of the synthetic coagulant, such as utilization of natural coagulants in water treatment. Natural coagulants are biodegradable and present low toxicity and low levels of residual sludge production as well as considered health-friendly [13]. Among the natural coagulants, Moringa Oleifera seed (MOs) which is a multipurpose drought-resistant and salt tolerant farm tree referred as a "miracle tree" stands out as one of the most used natural coagulant. On the other hand the introduction of Virgin Scoria and Pumice, the most abundant finely porous volcanic rock [14] were highly calling the attention of researchers because of their nature. The Ethiopian Rift Valley, which covers around 30% of the area of the country, has several of these cinder cones and lava fields [15]. These volcanic rocks have received considerable interest for heavy metals removal capacity mainly due to their valuable properties: high surface area, low cost and local availability in large quantities. The chemical composition of the Scoria vindicated that SiO_2 and Al_2O_3 contents make up about 63% and FeO and CaO compose about 21% [16]. Pumice and Scoria from volcanic rocks have been used as a natural adsorbents having better features to be used as low-cost adsorbents of pollutants for the removal of phosphate, heavy metals and organic pollutants for water pollution control [17]. Therefore, according to the aim of this study the addition of porous VSco as a filter media was designed to remove the remains of any suspicious of organic matter and COD developed in MOs treated water. Therefore this study was designed to investigate the sustainable drinking water purification potential of Moringa Oleifera seed (MOs) from natural plant origin as coagulant/flocculent agent followed by Virgin Scoria (VSco) from volcanic rock of Ethiopia as filter media.

2. Methodology

Collect dried moringa olifera seed from Arbaminch Southern part of Ethiopia and remove Shell seeds or seed coat, Crush the moringa oleifera seed using mortar & pestle to obtain a finepowder and sift the powder through a screen or small mesh. Mix seed powder with a small amount of deionized water to form a paste then shake for 1min to activate the coagulant. Filter this solution with cloth/mesh screen to remove insoluble part/residue from paste. Then after add different dosage of coagulant pastes to the contaminate water prepared laboratory with in jar test experiment design parameters (turbidity, PO_4^{-3}, F^-, and Fe^{+3}) and stirred with 120 rpm for 1min Fig. 2A. Then sediment for 24 h to separate flocs. When the particles have settled to the bottom, the clean water can be carefully poured off. The clean water can then transferred to VSco filtration tank for final filtration to make it completely safe for drinking.

Virgin Scoria (VSco) was a naturally occurring material consists different mineralogical and chemical composition (Fig. 1A). Initially VSco was washed several times with distilled water to remove any impurities, then after it was dried in oven at 105°c for 12 h to remove the moisture. The dried VSco sample was crushed and separated [18] in to different sieve size (0.212–20 mm) shown in Fig. 1.

The white milky paste suspension of MOs was clean, the dry to sunlight then milled to extract the paste as shown in Fig. 1 B and C. De ionized water was used throughout this study for the preparation of synthetic aqueous solution of PO_4^{-3}, F^- and Fe^{+3} including turbidity. The three salt used for the three analyst were Anhydrous Potassium dihydrogen phosphate KH_2PO_4 (0.7165 g) for phosphorus (1 mL KH_2PO_4 represents 0.5 mg PO_4^{-3}), anhydrous Sodium Fluoride NaF (**0.**2210 g) for fluoride (1 mg NaF represents 0.1 mg F^-) and iron chloride $FeCl_3$ (0.5 g) for iron (1 mg $FeCl_3$ represents 0.2 mg Fe^{+3}) including various turbidity levels from clay. The stock

A B C

Fig. 1. Raw material used for the treatment (A, Virgin Scoria after sieve analysis; B, Moringa oleifera seed and C, Moringa Oleifera seed prepared for past extracts).

Fig. 2. Moringa Oleifera seed coagulation and settling (A, moringa staring and coagulating; B, Settling).

solution of synthetic turbidity, PO_4^{-3}, F^- and Fe^{+3} was prepared from those salt and different initial concentrations of each were taken from the stock solutions (100, 200, 300 NTU turbidity) (6, 12, 20 mg/L PO_4^{-3}), (3, 6, 9 mg/L F^-) and (2, 5, 7 mg/L Fe^{+3}) [4]. "The F^- concentration ranged from 0.5 to 1.29 mg/L in water from shallow wells and from 0.48 to 5.61 mg/L in water from deep wells" [19], The PO_4^{-3} surface water contaminations were between 6 and 30 mg/L [20], while the surface water turbidities considers as highly pollutant where the value were greater than 50NTU. This wide range was necessary, because in extreme conditions (speciallythe phosphate and fluoride) content in Ethiopia reach about 30 mg/L and 17 mg/L, respectively. The optimum dosage of the coagulant was investigated for different levels of turbidity, phosphate, fluoride, iron and monitoring of the properties of the water was performed.

The purpose of this experiment was to estimate the contribution of MOs and VSco filtration in combination for the removal of turbidity, TDS, PO_4^{-3}, F^- and Fe^{+3} from drinking water for point of use daily demand spatially for the community sector directly rely on untreated water source. VSco filtration was conducted directly after the completion of coagulation flocculation processes with MOs. The optimum removing steps from coagulation set-up would be allowed to pass through filtration set up Fig. 2B. The evaluation of any remains of turbidity, TDS, color taste, pH, odor, alkalinity, PO_4^{-3}, F^- and Fe^{+3} after coagulation flocculation using MOs under jar test including organic matter of MOs possibly pass was evaluated at different time interval onto VSco filtration media. Evaluation was based on various contact time design parameters. However, the challenge in conducting the experiment was feeding the water in and out of the VSco filtration tube continuously at a constant rate using a fitting outlet. The flow rate was kept constant by keeping the head from up and below at a constant level.

3. Results and discussion

Jar test Apparatus, IS sieve analysis, Nephelo – Turbidity meter with sample cell, Digital pH meter, and Digital conductivity meter and using for graph and data analysis we used Micro Excel software program.

3.1. Sieve analysis

The easiest way to determine effective particle size was to pass a dried VSco sample through a stack of decreasing sieve sizes as described below. This provides an effective surface filtration of such a very small particles size ranges (0.212–20 mm). The particle size distributions of virgin scoria were distributed according to Indian standard sieve [21] sown as Table 1.

The sieve analyses of VSco indicated that the effective size was 0.45 mm and the uniformity coefficient was 12.40 well graded. Vertical down-flow filtration was adjusted at 0.022 m^3/h filtration rates after the filtration tube was full.

It is for the filtration column arrangement according to size distribution in the column; fine particle size (0.2 mm–2 mm) in column height 300 mm, medium particle size (5.6 mm–16 mm) in 200 mm height, course particle size (16 mm–30mm) in bottom150mm column height.

As indicated in Fig. 3**,** turbidity reduction from 100 to 8.3NTU were achieved at 35 mL/L coagulant paste effective MOs dose and

Table 1
Sieve analysis of VSco.

IS Sieve (mm)	Mass Retainedgm	Percentage Retained	Cumulative Percentage Retained	Percent finer
20	684	4.56	4.56	95.44
16	976.4	6.51	11.07	88.93
11.2	1600.6	10.67	21.74	78.26
5.6	2763	18.42	40.16	59.84
2	3765.5	25.10	65.26	34.74
0.85	2568.8	17.12	82.38	17.62
0.425	1295	8.63	91.02	8.98
0.212	1273.4	8.49	99.51	0.49
pan	74	0.49	100.00	0.00
Σ	**15,000.7**	**100**		

this point is the optimum doses for maximum turbidity removal. With the same turbidity an increase or decrease in dosage from 35 mL/L showed less reduction in turbidities. This was due to the attainment of residual turbidities above 10NTU due to excessive MOs from below and insufficient from above per liter of untreated water. That is why dosage beyond the optimum point would, apart from obvious disadvantages such as increased poor bitter taste, COD content in the water, also lead to an increase in turbidity.

3.2. Effect of turbidity on efficiency of MOs - VSco set up

According to this study, achievement of rapid reduction of turbidity was observed at 35 mL/L (70 mg/L) MOs dose. Though most studies have focused on treatment of drinking water which has low turbidity, the seeds have also shown high coagulation for high-turbid water Fig. 4, shows that low-turbid water of 30–50NTU to 13-12NTU, water of medium turbidity of 50–150NTU to 10-8.7NTU and that of high turbidity of 150–300NTU to 8.7-8NTU was achieved for MOs coagulation. Whereas from 13 to 12 to 3.6–3.7 NTU for low turbid, from 10 to 8.7 to 3.2–2.9NTU for medium and from 8.7 to 8 to 3.0–3.5NTU for high turbid water was achieved from VSco filtration. Some variation was occurred with the previous studies low-turbid of 21.5–49.3 NTU to 2.7 NTU, water of medium turbid 51.8–114 NTU to 2.9 NTU and that of high turbid of 163–494 NTU to 1.4 NTU [22]. This was due to that the seed paste used was neither extracted nor filtered but, as it is.

According to this study, the setup brings better treatment result in order to decrease the amount of organic matter added. For example by using the optimum dose of MOs (35 mL/L), reduction of turbidity from 150 to 2.92 NTU which was the best result of this finding was achieved Fig. 4B. Therefore, treatment with MOs and VSco filter led to a more successful outcome. Therefore, 35mL/Loptimum dose was used thorough out the whole study as effectivecoagulants for chemical parameters also with different initial concentrations (6, 12, 24 mg/LPO_4^{-3}), (6, 9, 12 mg/L F^-) and (3, 5, 7mg/LFe^{+3}) Fig. 4A.

3.3. Effect of pH on turbidity removal

Based on 35 mg/L of MOs paste the best site of removing evaluation site was registered at pH ranges 6.5–7.5, but almost small variation. One advantages obtained from this range was that the pH of deionized water lies between this rang and hence, pH adjustment did not required. Within this range MOs removing capacity remains at maximum level shown in Fig. 5.

The observed result shows that pH increase with increasing concentrations of the MoringaOleifera seed coagulant. It was reported that the action of Moringa Oleifera seedas a coagulant lies in the presence of water soluble cationic proteins in the seeds [23]. This suggests that in water, the basic amino acids present in the protein of Moringa Oleifera seed would accept a proton from water resulting in the release of a hydroxyl group making the solution basic.

3.4. Phosphate, fluoride and iron removal efficiency on VSco-Moringa

Jar tests were performed in aqueous synthetic PO_4^{-3}, F^- and Fe^{+3}solution of water with different initial concentrations (6, 12, 20 mg/L PO_4^{-3}), (3, 6, 9 mg/l F^-) and (3, 5, 7 mg/L Fe^{+3}). The treatment was performed at optimum MOs seed coagulant dosage of 35 mL/l for all analysis. VSco treatment was performed at different time interval (0, 2, 4 h s). Table 2, shows the effect of contact time versus initial concentration of phosphate, fluoride and iron on Moringa Oleifera seed coagulant supported with VSco filtration media. Accordingly, the removal capacity of MOs coagulant was increased as the initial concentration increase while VSco treatment indicated that when the time of treatment increase, its removing capacity also increase till its efficiency reduced due to clogging [24].

The coagulation followed by VSo filtration treatments in the different ion pollutant species at similar operation time results different efficiency due to surface charges.

As indicated in Fig. 6, PO_4^{-3} and F^- shows clear reduction in the coagulation portion of the setup while Fe^{+3}were less removed. Formation of agglomeration of hydrated ferric oxides and formation of flocs removed by sedimentation would be less relatively in the first setup while adsorption onto the VSco filter media was fast. This was due to its positively charged surface similarity between the

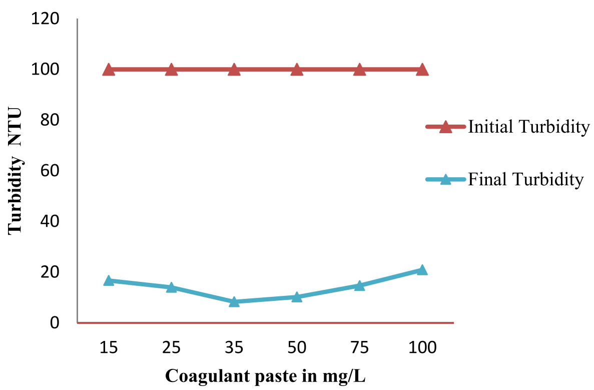

Fig. 3. Effect of Moringa Oleifera seed (MOs) coagulant on turbidity removal.

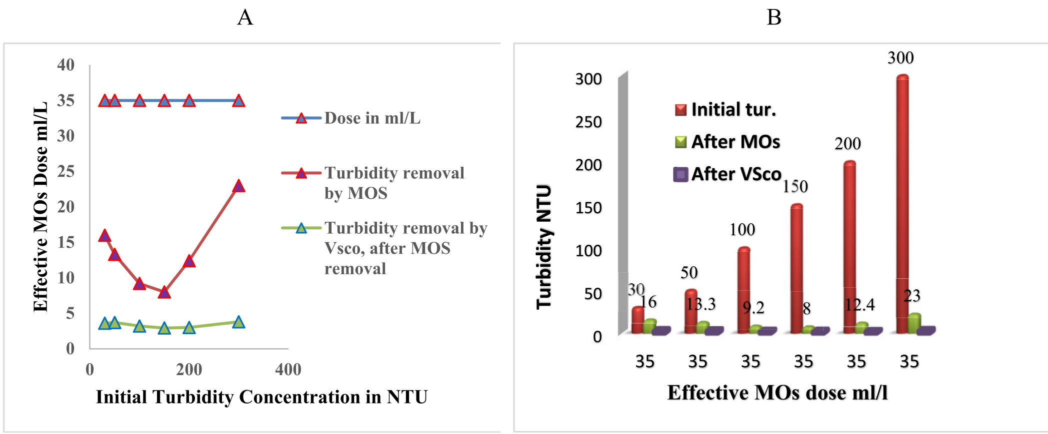

Fig. 4. Effect of turbidity on effective Moringa (MOs) dose (A, Initial Turbidity Concentration; B, removal amounts).

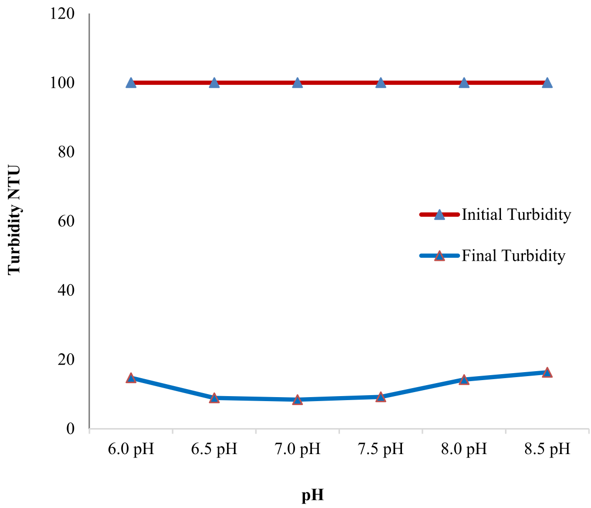

Fig. 5. Effect of pH on effective Moringa Oleifera seed (MOs) dose.

Table 2
Phosphate, Fluoride and Iron of removal efficiency of VSco-Moringa.

Initial concentration (mg/L)		MOS Dose (35 mL/L), in 46min	ViscoFilt. Treatment			Total removal efficiency %
			60min	120min	240min	
A. Phosphate (PO_4^{-3})	6	2.34	1.52	1.23	0.96	61–88.5
	12	2.94	1.64	1.35	1.13	75–91
	20	5.95	1.79	1.43	1.07	70–95
B.Fluoride (F^-)	3	2.33	1.83	1.65	1.57	22–48
	6	2.6	2.24	1.98	1.85	57–69
	9	2.83	2.45	2.07	1.94	69–78
C. Iron ion	3	1.96	0.98	0.63	0.45	35–85
	5	2.7	0.86	0.72	0.53	46–89
	7	2.93	0.75	0.64	0.43	58–94

proteins of MOs and the iron ions. It was hypothesized by other researchers that due to negative charge sand can attract floccules of iron, cations of iron, manganese, and other metals including microorganisms and their metabolic products [25]. The capacity of both setup (coagulation and filtration) was less satisfactory in removing fluoride than phosphate and Iron. At optimum dosage of 35 mL/L of MOs the mean phosphate and iron levels in all the analyzed water samples were below the recommended maximum permissible level (MPL), i.e. 0.1–1 mg/L for phosphate and 0.3–1 mg/L for iron in drinking waterexcept for fluoride which was above 1.5 mg/L.

The effect of contact time on the coagulation flocculation for the removal of PO_4^{-3}, $F^-$and Fe^{+3} were investigated by the standard

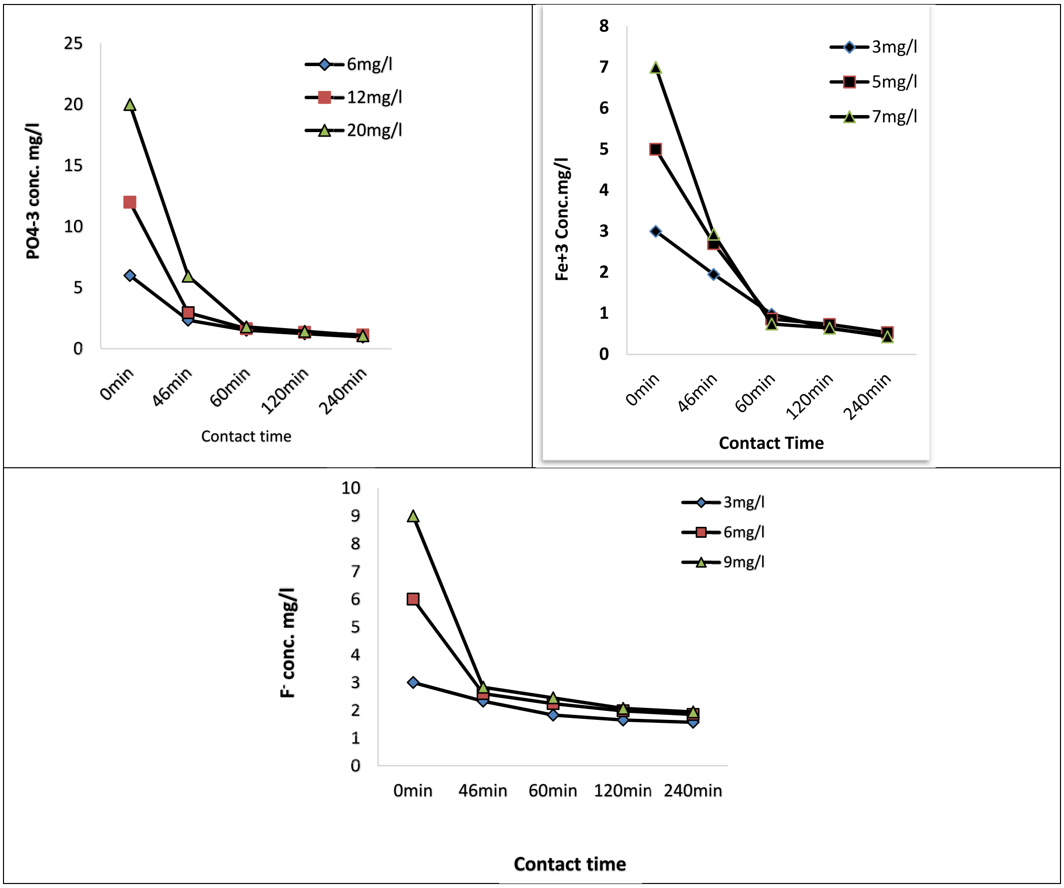

Fig. 6. TheVSco filtration removal efficiency of PO_4^{-3}, F^-, and Fe^{+3}ions as a function of time.

procedure for jar test application using MOs coagulant at 46min (1min for rapid mix, 15min for gentile mix and 30min for sedimentation). As it was indicated, the final result of the treatment was exceedingly time dependent, because when the time of sedimentation followed by filtration increase the removal capacity of Moringa Oleifera seed-VSco also increase for all the tree chemical parameters. It was also observed that within this time the use of MOs showed high affectivity in removing PO_4^{-3} than F^- and Fe^{+3}.

The removal capacity of MOs were 75% for phosphate, 70%for fluoride and 58% for iron and the combination of Moringa oleifera seed-VSco indicates 95%, 78% and 94%at 46 and 240min respectively as shown in Fig. 7.

The overall pollutant removal capacity of the sequence coagulation/flocculation followed by virgin viscoria filtration method for drinking water treatment shown in Table 3, summarized with numerical standard values.

4. Conclusion

This study provides valuable information about the coagulation/flocculation, and sedimentation and filtration behavior of MOs –Vscoand their efficiency to reduce phosphate, fluoride, iron and suspended matter. Based on this finding, water containing undesirable fluoride, phosphate and Iron concentrations was treated successfully by this simple and safe method. Based on the experimental test results: Moringa Oleifera seed possess effective coagulation properties, the optimum dose of MOs coagulant was achieved at 35 mL/L for treating water polluted with several undesirable physicochemical conditions. The final Moringa Oleifera seed-VSco efficiency of removing quality of PO_4^{-3} (20 mg/L), F^- (12 mg/L) and Fe^{+3} (7 mg/L) including turbidity (150NTU) were gained to 89%, 70%, 92% and 96%respectively.Virgin Scoria filtration that have been promised after MOs coagulationwas suitable for the retaining of the fine flocs remained in MOs treated water in resolving Customer complain.

Data availability statement

Data included in article/supp. Material/referenced in article.

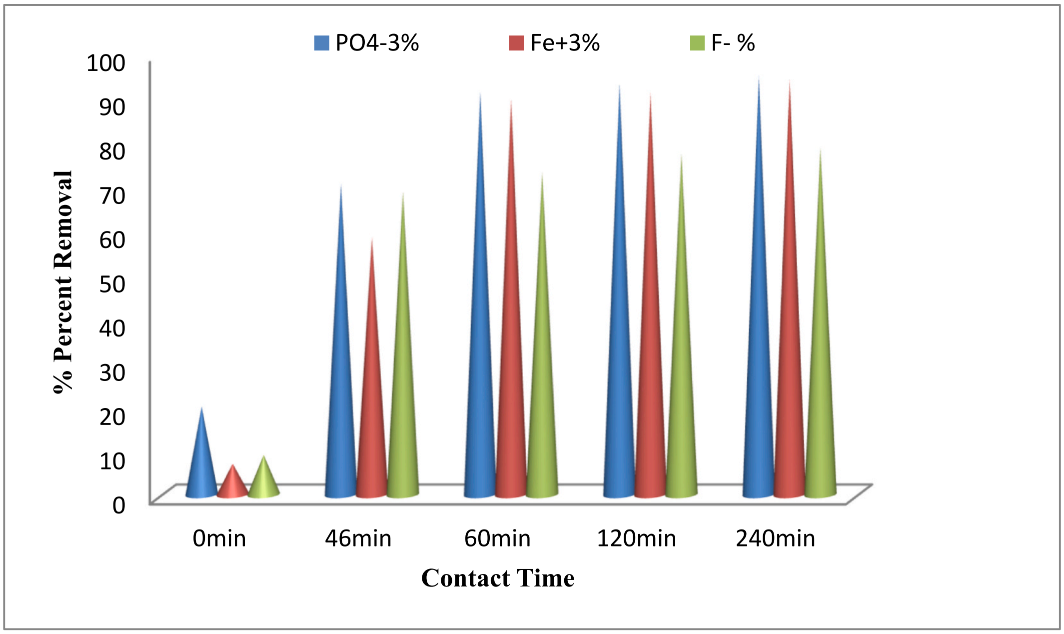

Fig. 7. removal (100%) of $PO4^{-3}$, F^{-} and Fe^{+3} by using Moringa-VSco.

Table 3
Physicochemical characteristics of synthetic water sample before and after.

Synthetic water samples	Physicochemical Parameters	Initial conditions	Retained results			Maximum permissible limits (WHO norms)
			Control	MOs Coag.	VSco Filt.	
Phosphate water	Turbidity (NTU)	150	2.63	9.4	2.54	5–10
	Concentration of PO_4^{-3} mg/L	20		5.95	1.07	
Fluoride water	Turbidity (NTU)	150	2.63	9.9	2.97	5–10
	Concentration of F^{-}mg/L	7		2.83	1.94	
Iron water	Turbidity (NTU)	150	2.63	9.8	2.93	5–10
	Concentration of Fe^{+3} mg/L	9		2.93	0.43	

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e17420.

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