



Optimisation of using a blend of plant based natural and synthetic coagulants for water treatment: (Moringa Oleifera-Cactus Opuntia-alum blend)

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ABSTRACT

The research presents a comparative study on the effectiveness of blending plant based natural coagulants (*Cactus Opuntia* and *Moringa Oleifera* extracts) and a synthetic coagulant (aluminium sulphate or alum) in treatment of raw water. The low production rates of natural coagulants has derailed their commercialization this has driven the idea of blending synthetic coagulants which is envisaged to be the more appropriate means of application in this study. To measure the effectiveness of the coagulant, the following parameters were measured; turbidity, pH, conductivity and total alkalinity. The simplex lattice experimental design was applied using Minitab Software to obtain the optimal coagulant blend. The models were validated by statistical analysis which showed that the model was sufficient and no further modelling was required. The optimization results showed that a combination of alum, *Moringa Oleifera* and *Cactus Opuntia* in proportions of 13%, 42.6% and 44.4%, respectively with a total coagulant dosage of 45 mg/L gave the best overall results with the resultant water having a turbidity, pH, conductivity and total alkalinity of 2.7 NTU, 6.99, 308 µS/cm and 137.7 mg/L respectively. These physiochemical parameters are within required limits for potable water as per WHO guidelines. From the results, it was concluded that aluminium sulphate (alum) can be successfully blended with natural plant-based coagulants for raw water treatment.

1. Introduction

Water from surface bodies contain billions of microscopic particles and impurities dissolved in it due to its high solubilizing power. These dissolved impurities encompass minerals, organic and inorganic compounds that change the physical, chemical and biological characteristics of water (Devrimci et al., 2012). Water from most surface bodies must therefore undergo treatment and purification to meet the expected limits for potable water. The purification technique applied varies depending on the characteristics of water to be treated (McConnachie et al., 1999).

The purification process typically includes the removal of the dissolved impurities to improve the turbidity and colour of water through sedimentation by allowing suspended particles to settle down by gravity. However, these colloidal particles are too tiny to settle individually hence they must agglomerate to increase their weight so that they settle by gravity. Each of the suspended tiny particles usually has a

negative electrical charge on its surface. These negatively charged particles will repel each other. For this reason, they will stay suspended rather than clumping together and settling at the bottom. This has resulted in the development of a process called coagulation in preparation for sedimentation.

Coagulation refers to the process of chemically destabilizing suspended matter, in raw water so that they come together to form larger agglomerates known as flocs (Gebbie, 2006). Coagulants are substances that are used to remove colour and turbidity from raw water. They achieve this by facilitating the formation of large agglomerates that can settle at the bottom and can be removed in downstream sedimentation processes. Coagulants are classified as inorganic or organic coagulants. Organic coagulants comprise the polyDADMAC (polydiallyldimethyl ammonium chloride) range of cationic polymers (Gebbie, 2006) and Chitosan. Chitosan is also a natural organic coagulant which has been found to be more effective at low concentrations in turbidity reduction in water treatment compared to inorganic coagulants. It has a partial

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positive charge and therefore acts as a polycationic coagulant during water treatment (Fabris et al., 2010). Inorganic coagulants refer to the common chemicals that base on metals usually aluminium or iron. Examples of inorganic coagulants include ferric chloride, alum, calcium hydroxide ferrous sulphate, polyelectrolytes etc.

Conventional water treatment plants in developing countries use synthetic coagulants mainly alum due to its high turbidity removal efficiency. However, alum is costly, and research suggests that aluminium is neurotoxic in large quantities and might be involved in the development of Alzheimer's disease (Rajendran et al., 2015). Alum also increases the total dissolved solids concentration of treated water and it also produces high volumes of sludge which is non-biodegradable and difficult to dispose. Hence these drawbacks call for tremendous research with the respect to the development of alternative, cost effective and environmentally friendly coagulants. These alternatives come in form of natural coagulants which are known to be eco-friendly and cheaper since they are locally available.

The use of plant based natural coagulants for turbidity removal in water is not a new idea, various researchers have done investigations on different plant extracts to check their ability to remove turbidity in water. Powder obtained from *Moringa Oleifera* seeds proved to be an effective alternative coagulant (Madsen et al., 1987). *Moringa Oleifera* seeds contain proteins that produce a positive charge when introduced to water resulting in the electrostatic attraction with the negatively charged particles in water. Studies revealed *Moringa Oleifera* to be non-toxic, less expensive as compared to chemical coagulants, biodegradable hence eco-friendly and it also generates less volumes of sludge (Judith et al., 2014).

Cactus Opuntia extracts have also been experimented on and they were found to be effective in turbidity removal from water. *Cactus Opuntia* inner and outer pads possess polygalacturonic acid which is an anion biopolymer with coagulating abilities. Adsorption and inter-particle bridging are the dominant mechanisms for floc formation (Nharingo et al., 2015). It is also non-toxic and biodegradable therefore it has reduced environmental impact.

However, the two natural coagulants have lower individual turbidity removal efficiency than the synthetic coagulant in raw water treatment. No work has been done on blending the two natural coagulants and a synthetic coagulant to obtain a high-performance coagulant which is effective on raw water of complex characteristics. This study focuses on blending the two natural coagulants and alum to produce a better coagulant in terms of turbidity reduction performance.

2. Experimental procedure

2.1. Sample collection

Moringa Oleifera seeds and *Cactus Opuntia* pads used for the experimental purposes were obtained from trees available in Mkoba area in Gweru. Alum was obtained from City of Gweru water works. Raw water samples were collected from Gwenoro dam water treatment plant. The sample represented an average of raw water that is received at the treatment plant. Table 1 shows the characteristics of the raw water.

Table 1
Raw water characteristics.

Parameter	Concentration
pH	7.05
Electrical conductivity	298 $\mu\text{S}/\text{cm}$
Turbidity	29 NTU
Total Alkalinity	145 mg/L

2.2. *Cactus Opuntia* solution preparation

Freshly harvested pads obtained from the *Cactus Opuntia* tree were washed with distilled water and cut into small strips about 5 mm by 5 mm and then baked in an oven at 80 °C until pads were dry, which took 7–8 h. The baked strips were subsequently grounded into a fine powder using a mortar and pestle. The powder was then sieved through a 250 μm sieve. Five grams of the powder that passed the 250 μm sieve was measured and added to 500 ml of distilled water forming a suspension. A magnetic stirrer was used to stir the suspension for 1 hour and then it was left to settle for 30 min after which it was then filtered to obtain a 1 wt.% *Cactus Opuntia* stock solution termed cactus

2.3. Preparation of 1 wt.% *Moringa Oleifera* solution

Matured and dry *Moringa Oleifera* seeds (brown pods) were obtained from the *Moringa Oleifera* tree and removed from the pods. They were then de-husked manually by hand and placed in an oven at 35 °C until they were dry. The dry seeds were then ground into a fine powder using a mortar and pestle. The powder was then sieved through a 500 μm sieve. Five grams of the powder that passed the 500 μm sieve was measured and added to 500 ml of distilled water forming a suspension. A magnetic stirrer was used to stir the suspension for 1 hour and then it was left to settle for 30 min after which it was then filtered to obtain a 1 wt.% *moringa*.

2.4. Preparation of alum solution

Five grams of alum was added to 500 ml distilled water and stirred until it completely dissolved resulting in a 1 wt.% solution.

2.5. Simplex lattice experimental design

The experimental procedure was modelled using the Simplex lattice experimental design obtained with the use of Minitab Software. The three coagulants in the blend i.e. moringa, cactus and alum are considered as X_1 , X_2 and X_3 respectively. "The experiment was conducted under two situation, situation one where the coagulants X_1 , X_2 and X_3 are in equally space proportions of 0, 0.5, and 1, situation is designated as {3, 2} Design while situation two where the coagulants X_1 , X_2 and X_3 are in equal proportions of 0, 1/3, 2/3, and 1 for each factor designated as {3, 3} Design. The Simplex Lattice design using all possible blends of these three coagulants gives six different mixtures for the {3, 2} Design and ten different mixtures for the {3, 3} Design. These design points are arranged such that all factor levels and combinations are tested. The statistical design is known as the {q, m} Simplex Lattice Design, where q represents number of factors with $m + 1$ equally spaced proportions for each component from 0 to 1 (Bondari, 2005; Cornell et al., 2002).

Simplex "coordinates on the corners of the simplex triangle represents a pure blend with only one component as in Fig. 1. Simplex coordinates for the centre point represent blends containing all three components in equal proportions and midpoints of the triangle sides represents binary points (Montgomery, 2013).

The simplex design allows us to investigate the interdependency of the components with respect to targeted responses. The responses monitored in this case is turbidity. The test runs to be carried out are represented in Table 2, one set has thirteen runs as shown in the table. These test runs will be done for the dosages estimated from runs with individual coagulants. The different coagulant ratios were tried out as shown in Table 2.

2.6. Jar test procedure

Water samples were added to six 1 L jars and the different proportions of coagulants mixtures according to Table 2 were added to the jars, with a coded value of 1 corresponding to 45 mg/l of total

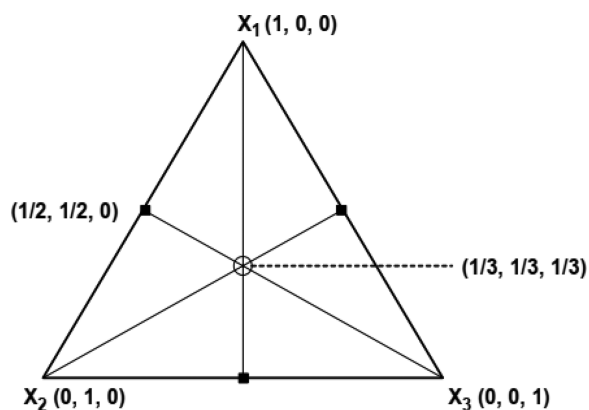


Fig. 1. Simplex triangle for 3 component mixture (Bondari, 2005).

Table 2

A Three Component Simplex lattice design (Bondari, 2005).

Test Run	Design 3:3 Alum	Moringa	Cactus
RUN 1	1	0	0
RUN 2	0	1	0
RUN 3	0	0	1
RUN 4	0.67	0.17	0.17
RUN 5	0.17	0.67	0.17
RUN 6	0.17	0.17	0.67
RUN 7	0.33	0.67	0
RUN 8	0.33	0	0.67
RUN 9	0	0.33	0.67
RUN 10	0.67	0.33	0
RUN 11	0.67	0	0.33
RUN 12	0	0.67	0.33
RUN 13	0.33	0.33	0.33

coagulant. The jars were put into the jar test apparatus in which they underwent flash mixing at 200 rpm for 2 min followed by 10 min of slow mixing at 20 rpm and then 30 min of settling. This was repeated three times at these conditions and the average values for turbidity, pH and total alkalinity were calculated from a sample collected from the supernatant. This procedure was repeated for different dosages and combinations. Turbidity was measured using the portable turbidity metre, while the portable Hannah instrument HI9813–6 metre was used to measure pH and electrical conductivity and the total alkalinity was obtained from titrations.

3. Results and discussion

3.1. Effects of the coagulants

The initial jar tests were done using individual coagulants separately so as to investigate the effect of each coagulant on turbidity, pH, conductivity and total alkalinity. The test results are shown in the sections that follow.

3.1.1. Effect of the alum, Moringa Oleifera and Cactusopuntia on turbidity

It was observed that an increase in the concentration of each of the three coagulants generally reduces the turbidity of water as shown in Fig. 2(a). Alum reached an optimum dosage of 45 mg/l as it reduced the turbidity from 28.4 to 2.4 NTU thereby achieving a turbidity reduction of 91.5%.

When *Moringa Oleifera* was used as a coagulant, an optimum dosage of 50 mg/l was obtained as the turbidity was reduced to 3.2 NTU thereby achieving 88.7% turbidity reduction. *Cactus Opuntia* achieved an optimum dosage of 55 mg/l, the turbidity was reduced to 3 NTU thereby achieving 89.4% turbidity reduction. According to WHO

guidelines (Howard et al., 2012), potable water should have turbidity less than 5 NTU hence the observed minimum turbidities for each coagulant are within the permissible limits for potable water. It was observed that further increase in the coagulant concentration beyond the optimum dosage did not substantially change the turbidity. The optimum coagulant concentration is identified by the lowest value of residual turbidity after which the turbidity begins to increase as more coagulant is added as shown on the graph (Kawamura, 1991). This increase is due to re-stabilization of the destabilized particles and the coagulant itself also causes turbidity at high concentrations (Gunaratna et al., 2007).

3.1.2. Effect of the alum, Moringa Oleifera and Cactusopuntia on pH of water

Raw water had an initial pH of 7.05 and when aluminium sulphate coagulant was added, there was a drastic reduction in pH as coagulant dosage was increased recording a lowest pH of 5 at 60 mg/L alum dosage. The pH reduces during coagulation with alum due to hydrolysis which releases H^+ ions (Miller et al., 1984). *Moringa Oleifera* and *Cactus Opuntia* generally showed a slight reduction in pH as coagulant dosage increased. The reduction was minimal with a pH value of 6.4 when *Moringa Oleifera* was used at 60 mg/L, whereas a pH value of 6.5 was achieved when *Cactus Opuntia* was used at a dosage of 60 mg/L which is within the desired pH range of 5.5–8.5 for potable water. These trends can be seen on the graphs in Fig. 2(b).

3.1.3. Effect of the alum, Moringa Oleifera and Cactusopuntia on total alkalinity of water

Fig. 2(c) shows the general trend of total alkalinity as coagulant dosage increases. *Moringa Oleifera* and *Cactus Opuntia* based coagulants showed a slight decrease in alkalinity from 144 mg/L to 132 mg/L as the dosage increased from 0 to 60 mg/L. Alum showed a significant decrease in alkalinity from 144 mg/L to 100 mg/L (31% decrease) as the coagulant dosage was increased from 0 to 60 mg/L. However, the alkalinity obtained when using all three coagulants was still within the desired range since the maximum permissible alkalinity for potable water is 200 mg/L, according to WHO guidelines. The marked decrease in alkalinity when alum was used may be due to the coagulation mechanism of the alum which involves a reaction with alkalinity in water. Since the aluminium trivalent cation act as a Lewis acid in solution, this inherently lowers the alkalinity of water (Flaten, 2001).

3.1.4. Effect of the alum, Moringa Oleifera and Cactus Opuntia on the electrical conductivity of water

Fig. 2(d) shows that the electrical conductivity (EC) of water increased as the coagulant dose increased for all three coagulants. The electrical conductivity of raw water sample was initially at 298 $\mu S/cm$ and it increased to 449 $\mu S/cm$ (51% increase) as alum dosage increased from 0 to 60 mg/L. Similarly, the conductivity increased from 298 $\mu S/cm$ to 411 $\mu S/cm$ (38% increase) as the *Moringa Oleifera* dosage increased from 0 to 60 mg/L. The conductivity also increased from 298 $\mu S/cm$ to 406 $\mu S/cm$ (36% increase) as the *Cactus Opuntia* coagulant dosage increased from 0 to 60 mg/L. The increase in electrical conductivity along with the coagulant dose is a result of dissociation of the coagulant producing ions that raise electrical conductivity. *Moringa Oleifera* and *Cactus Opuntia* have lower dissociation capacity in water than alum hence the increase in electrical conductivity is lower for these coagulants (Marobhe et al., 2007).

3.2. Effects of the coagulant blends

After investigating the performance of the individual coagulants and obtaining the optimum doses, test runs were done to investigate the performance of the coagulants when they are combined in different proportions at the optimum dosage of 45 mg/L obtained for Alum for maximum turbidity reduction in the first runs. The Simplex Lattice

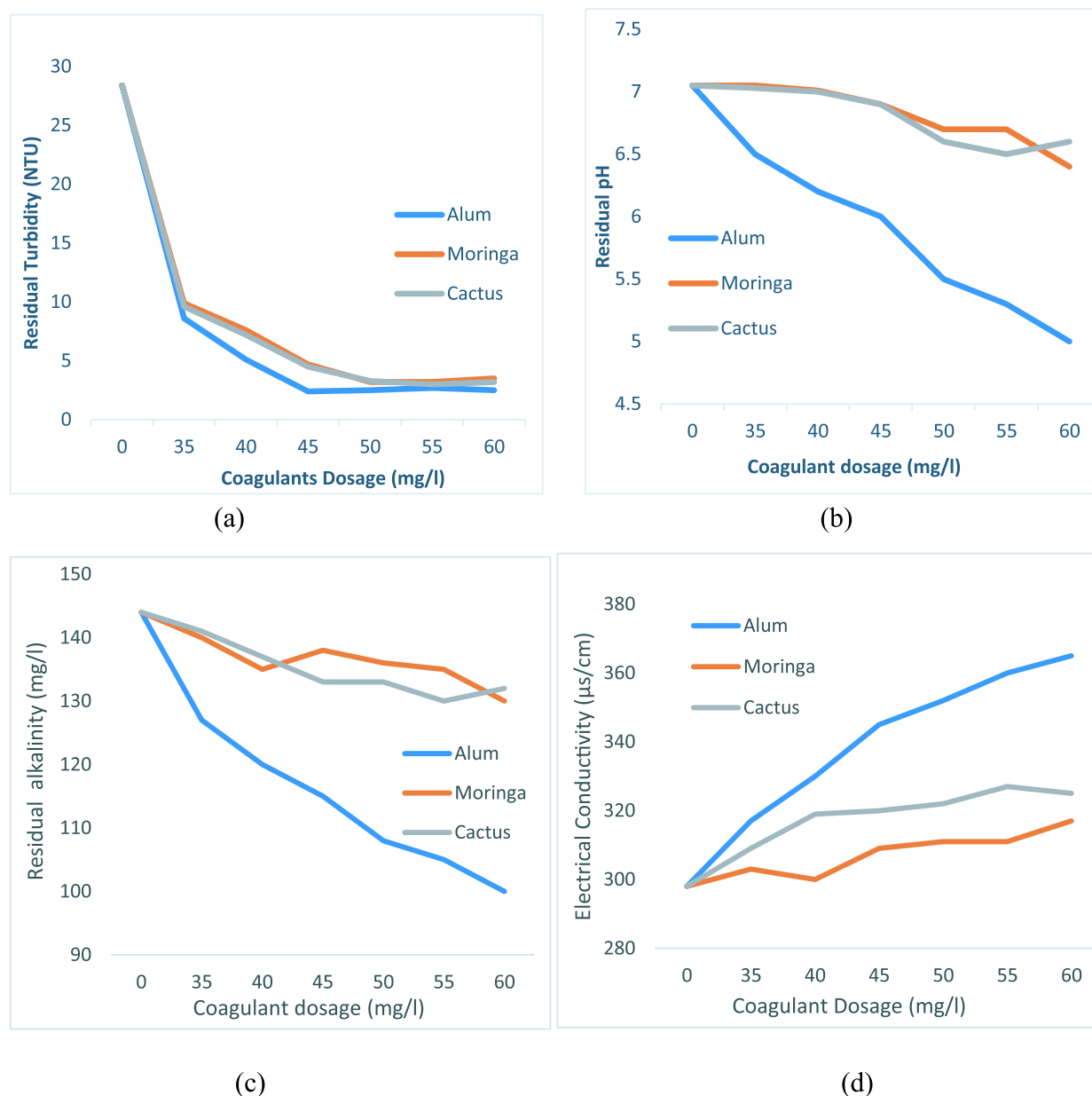


Fig. 2. Variation of (a) residual turbidity (b) pH (c) Total Alkalinity (d) electrical conductivity with coagulant dose.

Experimental design was used to model the experiments at different coagulant ratios.

3.2.1. Effect of coagulant blends on turbidity at 45 mg/L total dosage

It can be observed that a combination of the three coagulants in equal proportions produced the highest turbidity removal efficiency of 92.3% as shown by run 13 on the graph in Fig. 3, while individual coagulants alum, *Moringa Oleifera* and *Cactus Opuntia* had 91.5%, 83.5% and 84.2% as shown by run 1, 2 and 3 respectively similarly with a total coagulant dosage of 45 mg/L. This may be due to the fact that the three coagulants have different desirable attributes that complemented each other as well as a variation in coagulation mechanisms such that a myriad of particles with varying properties were effectively targeted in the water sample. Their combination enhances the strength of the coagulant and is useful over a wider particle charge variation. The blend is envisaged to merge the desirable characteristics of the three coagulants.

4. Optimization of coagulant combinations

The numerical optimization of coagulation using a blend of organic and inorganic blends was done from a polynomial equation obtained from Minitab using the design experiment aforementioned. The optimization process involved investigating the effect of each combination of coagulants on the turbidity reduction as this is a critical parameter. The pH, total alkalinity, and electrical conductivity were deduced at the optimal coagulant blend dosage to ascertain if they are within the desired limits.

4.1. Turbidity optimization with respect to alum, *Moringa Oleifera* and *Cactus Opuntia*

Minitab analysis software was used to fit the data shown in Fig. 3 into a model that can be used to analyse data easily and obtain an optimum response. A second order model was found to be the best fit model as the values of R-squared and R-squared adjusted are 97.96% and 91.83% (Table 3) respectively, which are high, therefore the

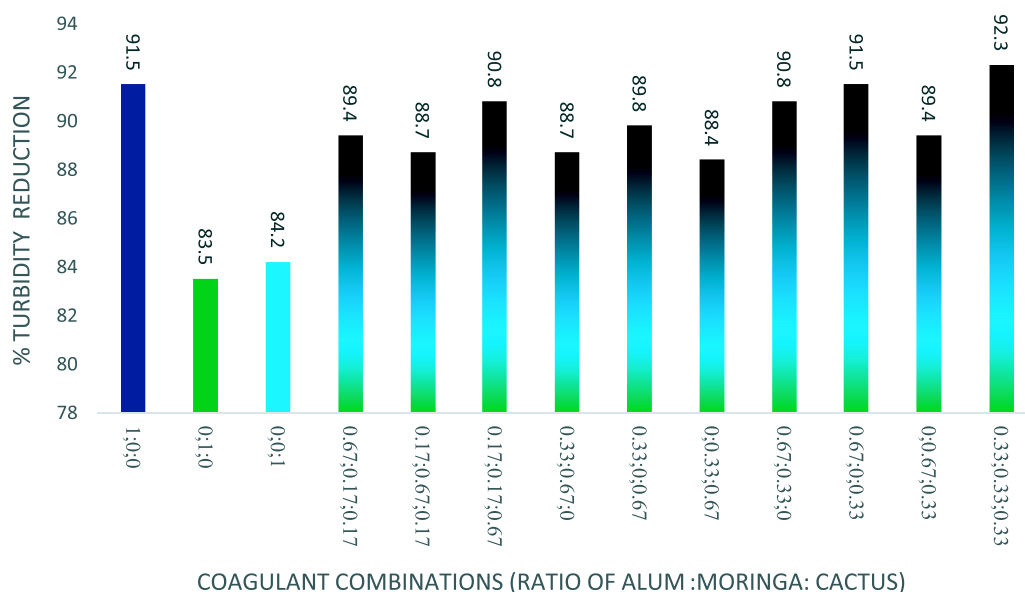


Fig. 3. Turbidity reduction at different coagulant ratios.

Table 3
Model summary.

Standard Deviation (S)	R-Squared (R ²)	Adjusted R-squared (R ² -adj)	Predicted R-squared (R ² -pred)
0,207,274	97,96%	91,83%	*

overall performance of this model in explaining the data is satisfactory. The model obtained is as shown in Eq. (1).

$$T = 30.4 - 2.52X - 0.43Y - 0.583Z + 0.0377X*Y + 0.0407X*Z - 0.0058Y*Z - 0.000094X*Y*Z + 0.0421X*X - 0.0031Y*Y \quad (1)$$

Where: T = The response (Final turbidity in NTU)

X = Aluminium sulphate concentration in mg/L

Y = Moringa extract concentration in mg/L

Z = Cactus extract concentration in mg/L

The optimum values for the coagulants in the mixture as obtained by using Eq. (1) in Minitab are shown in Table 4. The response parameters evaluated at the optimum conditions are given in Table 5. From Table 5, it can be clearly seen that the values of residual turbidity, pH, final alkalinity and electrical conductivity at the optimum conditions are well within their limits according to the WHO guidelines (Howard et al., 2012).

Fig. 4(a) and (b) displays the effect of alum and Moringa Oleifera coagulants interactions on the final turbidity of water at constant Cactus Opuntia coagulant concentration. As Alum dosage increased, the turbidity decreased at a faster rate initially, with the rate decreasing at higher alum dosages to a point (25 mg/L alum on the plot) where further increase in alum dosages resulted in statistically insignificant changes in residual turbidity showing that the optimal dosage had been

Table 4
Optimum coagulant mixing ratios.

Variable	Optimum Value (wt%)
Moringa Oleifera extract concentration	42.58
Cactus Opuntia extract concentration	44.48
Alum concentration	12.94

surpassed. The reduction in turbidity is due to the electropositive alum molecules which neutralizes the electronegative charge on the particulates in water thereby reducing their zeta potential promoting particle agglomeration and enhancing settling (Flaten 2001; Miller et al., 1984). Similarly, an increase in Moringa Oleifera dosage resulted in a decrease in residual turbidity which concurs with findings (Amagloh and Benang, 2009) which showed that Moringa Oleifera possess cationic polyelectrolyte particles from the protein content which neutralizes the charge of the colloidal particles. Thereafter the agitation process promotes collision of the neutralized particles which agglomerate and coalesce to form large flocs with higher settling rates. However, further increase to higher dosages beyond 30 mg/L caused the turbidity to start increasing, as eventually the particles will have a net charge causing repulsion resulting in a suspension of particles (Marobhe et al., 2007).

From the contour plot in Fig. 4(b), the optimum region is encompassed by the purple line where the turbidity is less than 3 NTU. The plots show that the ideal coagulant blend will have more of alum (> 10 mg/L) and less of Moringa Oleifera (< 20 mg/L) to have a high turbidity reduction. When both coagulant dosages are high, the residual turbidity is also high attaining values of around 6 NTU as shown by the contour lines.

The effect of alum and Cactus Opuntia coagulants interactions on the final turbidity of water at constant Moringa Oleifera coagulant concentration is shown in Fig. 5(a). An increase in alum dosage resulted in a decrease in turbidity until around 28 mg/L alum dosage. Further increment in alum dosages resulted in insignificant changes in residual turbidity showing that we have surpassed the optimum point. However, the turbidity at optimum dosage was 2.4 NTU which was slightly higher than in Fig. 4(a) for the alum-Moringa Oleifera combination which was 2.1 NTU.

Similarly, an increase in Cactus Opuntia dosage resulted in a decrease in residual turbidity. The coagulation capacity of Cactus Opuntia is attributed to the presence of viscous mucilage within the inner and outer pods of the plant, the pods also contains galacturonic acid, identified as the component responsible for enhancing coagulation capability of Cactus Opuntia. The galacturonic acid in aqueous solution exists as an anionic polymer which provides charged active sites for adsorption of colloidal particles in the raw water (Sethu et al., 2019). Further increase of the coagulant dosage beyond 25 mg/L caused the turbidity to start increasing due to destabilizing of the neutralized particles from the excess coagulant particles thus increasing suspended

Table 5

Comparison of response values at optimum conditions with the WHO guidelines (Howard et al., 2012).

Response	Value at optimum coagulant ration	Maximum permissible value
Residual turbidity	2.74 NTU	<5
Final pH	6.99	6.5 – 8.5
Final Alkalinity	137.72 mg/l	600 mg/l (Max. desirable 200 mg/l)
Final Electrical conductivity	308.2 μ s/cm	800 μ s/cm (Max. desirable 500 μ s/cm)

particles (Marobhe et al., 2007).

Fig. 6(a) shows the effect of *Moringa Oleifera* and *Cactus Opuntia* coagulants interactions on the final turbidity of water at constant alum coagulant concentration. An increase in *Moringa Oleifera* dosage resulted in a decrease in turbidity until around 32 mg/L aCactus Opuntia dosage, when further increment in the dosage resulted in insignificant change in residual turbidity showing that we have surpassed the optimum point. However, the turbidity at optimum dosage (2.0 NTU) was slightly lower than in Fig. 4(a) for the alum-*Moringa Oleifera* combination which was 2.4 NTU.

Similarly, an increase in *Cactus Opuntia* dosage resulted in a decrease in residual turbidity, however further increase to higher dosages beyond 25 mg/L caused the turbidity to start increasing due to re-stabilization of the previously destabilized particles and the turbidity due to the coagulant itself. There was no significant difference in the turbidity at optimum in the alum-*Cactus Opuntia* interactions and the *Cactus Opuntia*-*Moringa Oleifera* interactions which was around 2.4 NTU.

2. Conclusion and recommendations

All three coagulants under investigation substantially reduced the turbidity of the raw water. Although both natural coagulants had a turbidity removal efficiency less than that of aluminium, they both exhibited high potentials in turbidity reduction. Alum showed a marked reduction of pH increasing the acidity of water compared to the natural coagulants. Optimal dosages of the coagulant blend require the following proportions of 13 wt.%, 44.6 wt% and 42.4 wt% for alum, *Moringa Oleifera* and *Cactus Opuntia* respectively with a total coagulant dosage of 45 mg/L. An experiment was carried out at these conditions to verify the accuracy of the model, the reduction in turbidity was 2.81 NTU with a 2.5% error compared to that obtained from the model. The blending of synthesized coagulants with natural coagulants paves way

for the commercialization of the coagulants as this is technically and economically feasible. The blending also results in a sludge that can be degradable as about 87 wt.% of the blend is organic and this improves the waste management from water treatment plants. Blending of organic coagulant with inorganics can have a positive impact on the shelf life as these have been shown to disintegrate with time (Garcia-Fayos et al., 2015). More work should be done in investigating the preparation, extraction, preservation and shelf-life of *Cactus Opuntia* and *Moringa Oleifera* extracts to determine conditions required to maintain the coagulants in good condition for water treatment applications.

Credit author statement

Bruce I. Gandiwa; Investigation, Original draft preparation, Langa Bright Moyo; Supervision, Methodology, Sokesimbone Ncube; Data curation, Software, Validation, Liberty Lungisani Mguni; Original draft Preparation, Supervision; Tirivaviri Augustine Mamvura; Review and Editing, Nkosikhona Hlabangana; Conceptualization, Review and Editing

Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with

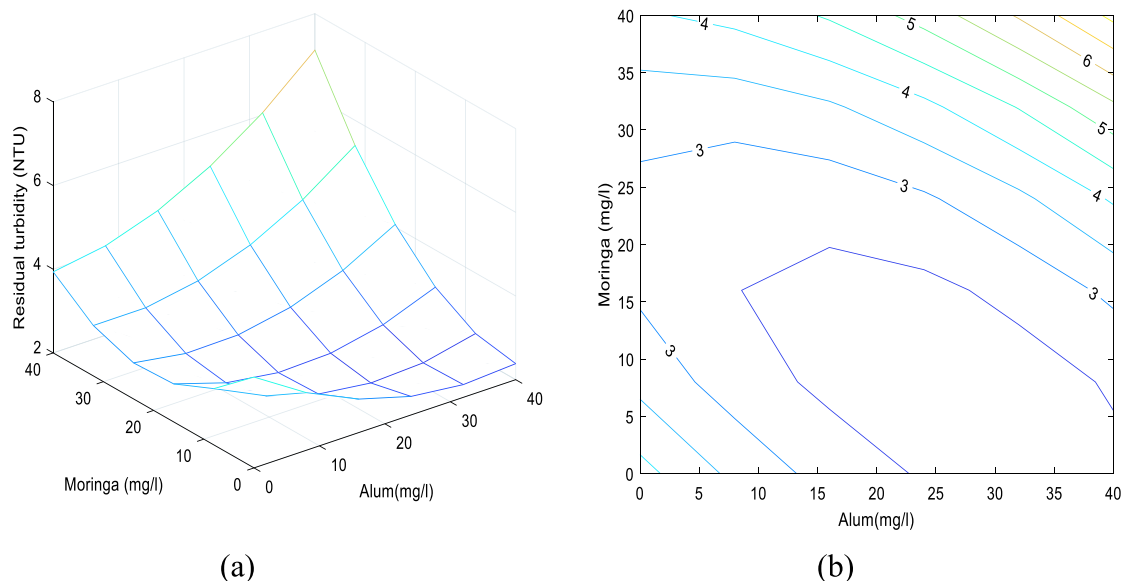


Fig. 4. (a) Surface response plot of Moringa oleifera and Alum concentration on Turbidity; (b) Contour plot for Moringa and Alum interaction.

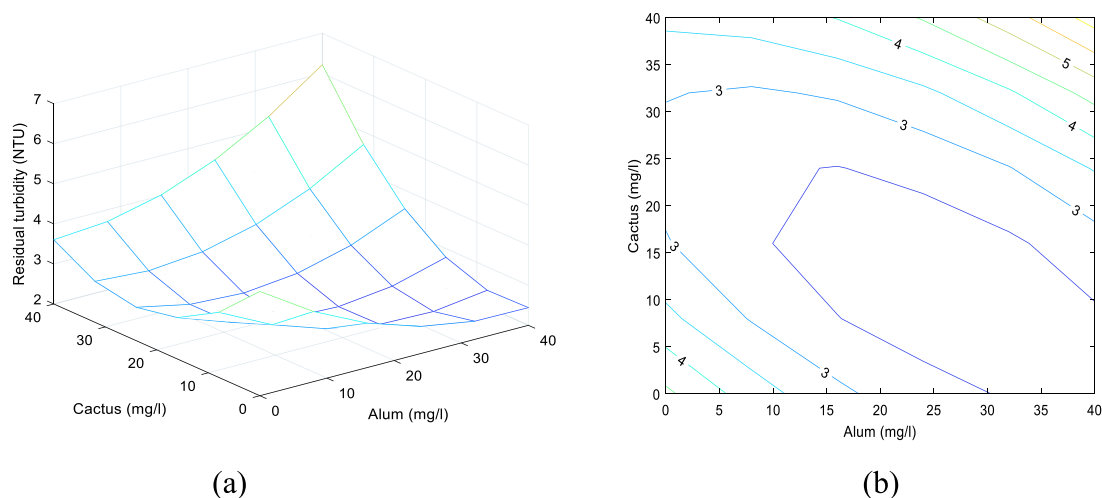


Fig. 5. (a) Surface response plot of alum and *cactus Opuntia* interaction on Turbidity; (b) Contour plot for alum and *Cactus Opuntia* interaction.

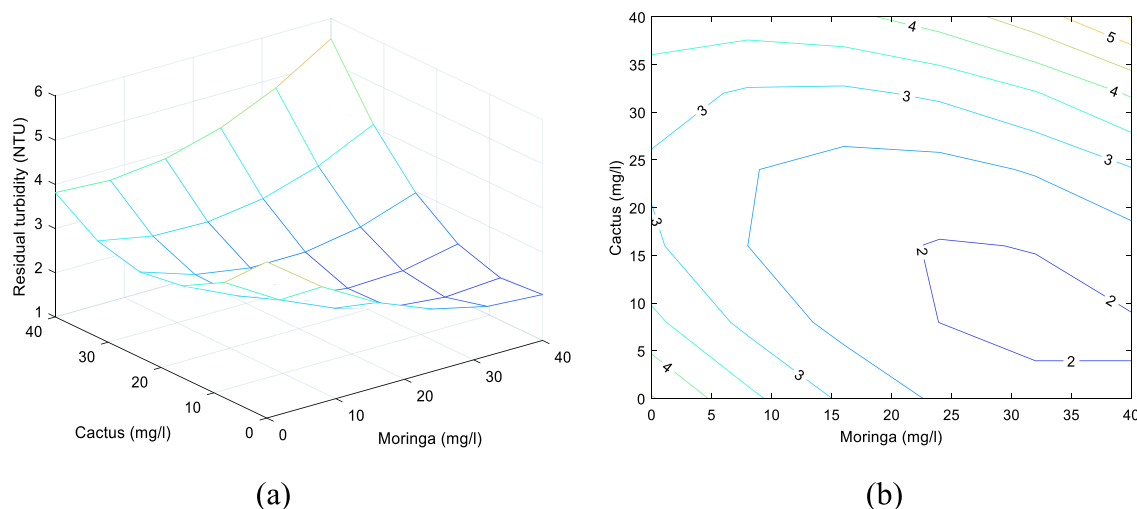


Fig. 6. (a) Surface response plot of *Moringa Oleifera* and *Cactus Opuntia* interaction on Turbidity; (b) Contour plot for *Moringa Oleifera* and *Cactus Opuntia* interaction.

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