



## Efficiency of Avocado Seed Extract as Natural Coagulant in Sustainable Purification of Drinking Water

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### Abstract

There is an increasing need for affordable water treatment solutions especially in developing countries and natural coagulants as alternatives to conventional chemical coagulants with their attendant environmental and health implications, low effectiveness in low temperatures, high procurement cost, large sludge volumes and pH effects. An experimental study was conducted on efficiency of avocado seeds powder as a natural coagulant for drinking water purification. Avocado seeds contain bioactive compounds like tannins with known coagulating properties. A suspension of 5g/l of avocado seed extract prepared and used on raw untreated water samples from Lake Bunyonyi. Results showed optimum avocado seed extract dosage of 0.35mg/L reduced turbidity from 12.8 to 4.5 NTU, with removal efficiency of 65% and is in line with the Ugandan National Water Quality Standard for potable water. Colour was reduced from 30 to 13 PCU with removal efficiency of 57%. The pH of the treated water ranged from 7.0-7.4 for all samples while sludge volume was comparably very low. The avocado seed can be used as a natural coagulant at concentration and dosage comparable to conventional chemical coagulants. These findings suggest that avocado seed extract is a viable, eco-friendly, and cost-effective coagulant for rural household water purification systems.

**Key words:** *Avocado seed; Natural coagulant; Potable water; Optimum dosage*

### 1. Introduction

Quantitative and qualitative water usage contributes to the well-being and development of the user in pursuance of the sustainable development goal 6. Surface water sources usually have high turbidity (Ramavandi, 2014) and it has been noted that turbidity and colour due to colloidal suspension constitute a critical hindrance to accessing clean water in many developing countries (Kumar & Oommen, 2012). Therefore, there is need for raw surface water to be treated to lower turbidity and colour before use.

The most effective methods to remove colloidal particles in water or wastewater are coagulation and flocculation. In coagulation, the electrostatic surface potential neutralization of the particles is as a result of a double layer compression caused by the addition of coagulants. Coagulation brings non-discrete micro particles together to form agglomerations of long chain polymers (Ebeling et al., 2003). There are two types of coagulants; natural or plant-based coagulant (biocoagulant) and the chemical coagulants such as aluminum sulphate (alum), polyaluminum chloride (PAC) and ferric chloride (Vishali & Karthikeyan, 2015). Previous research has warned of the potential health risk associated with

use of common chemical coagulant alum as its compounds can trigger Alzheimer's disease (Putra et al., 2020). Natural coagulants may serve as an alternative coagulant to the chemical coagulants because of their safety to the environment and humans (Putra et al., 2020)

Alum is also associated with high procurement cost (especially for developing countries like Uganda), large sludge volume yield, effect on water  $p^H$  and being ineffective in water at low temperature as observed by Fitzpatrick et al. (2004). In comparison to natural coagulants from plant materials, natural coagulants are cost-effective and biodegradable, making them sustainable alternatives coagulant for low-cost drinking water treatment for rural areas not connected to central water supply system. Thus, to increase safe and clean drinking water coverage in Uganda, investigating the potential of using natural coagulant is important.

Research has shown that tannin a water-soluble polyphenol from plant has a good ability to remove water pollutants by coagulation. Moringa oleifera seed extract in dosage 0.05-0.3 mg/l proved to have efficiency of 95-99% pollutant removal (Ali et al., 2009; Ndagengesere et al., 1995), while avocado seed powder was found to remove up to 99.6% turbidity and 94-95% dyes from wastewater as observed by Zourif et al. (2024). Avocado fruit is common in Uganda however its seeds are discarded as waste. Avocado seeds contain up to 7g per kg tannin. For effectiveness, the tannin-based coagulant properties are influenced by mixture preparation as well as agitation time and temperature (Colombo and Papetti, 2019; Lwasa et al., 2024) while extraction has been found to be most effective using water as solvent when compared with lesser effective solvents like acetone and ethanol (Setyawan et al., 2021).

In this study, the coagulation efficiency of tannin-containing avocado seeds for purification of lake Bunyonyi surface water for drinking was assessed.

## 2. Materials and Methods

### 2.1 Study Area

Kabale District, located in Southwestern Uganda, has a population of 500,000-600,000 people predominantly Bakiga, one of Uganda's major ethnic groups, known for their resilience and hardworking nature. The town of Kabale is a major urban centre with the district headquarters. Kabale experiences high rainfall, typically ranging from 1,000-1,500 mm annually, with two main rainy seasons of March-May and September-November. The region's cool, highland climate contributes to its fertile soils and the abundant vegetation while high and low terrains gave rise to lakes as water sources lake Bunyonyi for one. Figure 1 shows the aerial view of Kabale and her diverse water sources.

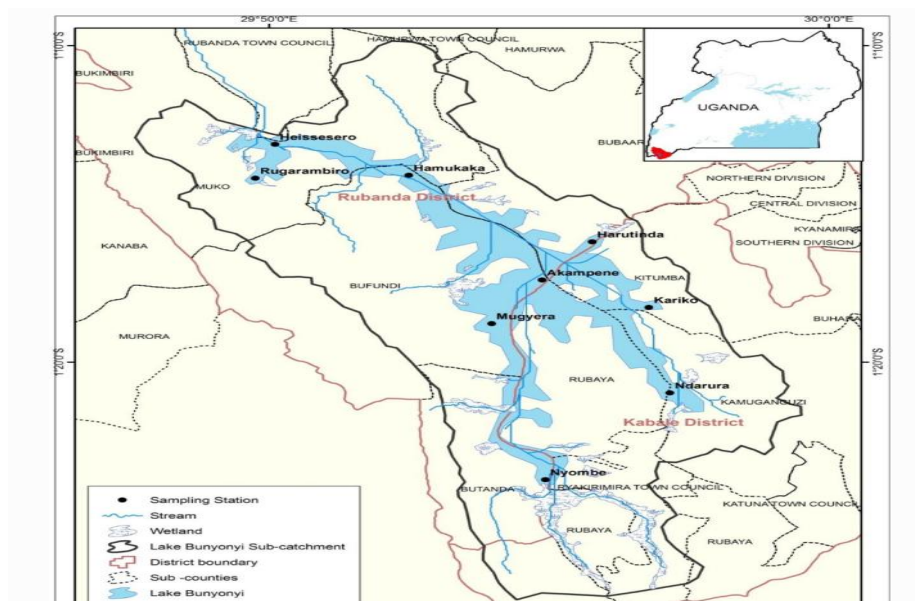


Fig. 11. Map of Kabale District

## 2.2 Raw water sample

The raw water sample for the study was collected from Lake Bunyonyi at the National Water and Sanitation Corporation (NWSC) intake plant. Lake Bunyonyi is located between 1.2833°S (-1° 16' 60.00" S) and 29.9167°E.(29° 54' 59.99" E).

Raw water samples were collected from lake Bunyonyi and analysed for various water quality parameters including pH, turbidity, conductivity, colour, total dissolved solids (TDS) and temperature at the National Water and Sewerage corporation (NWSC) Mbarara Regional Laboratory and later treated with the avocado seed extract as a natural coagulant.

**Table 1.** Raw water properties

| Parameter            | Result | National Standards (Uganda) |
|----------------------|--------|-----------------------------|
| Turbidity (NTU)      | 12.8   | <5                          |
| Colour (PCU)         | 30     | <15                         |
| Conductivity (µs/cm) | 102    | <450                        |
| pH                   | 8.2    | 6.5-8.5                     |
| TDS (mg/l)           | 280    | <1000                       |
| Temperature (°C)     | 23.4   | <30                         |
| TSS (mg/l)           | 48     | 0.0                         |
| E. coli (cfu/100ml)  | 110    | 0.01                        |

The results in table 1 above for the raw water showed that the mean pH, temperature and Electrical Conductivity (EC) were 8.2, 23.4° C and 102 µs/cm respectively and are close to the results obtained by (Saturday, 2018) on lake Bunyonyi. The results for Colour, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Turbidity values were 30 PCU, 280 mg/l, 48 mg/l and 12.8 NTU respectively. The TSS refer to the particles larger than 2 microns found in the water column. Most suspended solids were made up of inorganic materials like silt and sediments, though bacteria and algae also contributed to the total solids concentration. Turbidity levels in a water body may also be affected by the water flow velocity, point source pollutants, land use management and resuspension of discrete particles.

Agriculture is the backbone of Kabale's economy, but largely subsistence-based. Important crops include: Irish potatoes, Beans, Sorghum, Maize, Cabbage and Avocado. Apart from being a fresh food staple, avocados are also processed into oil, body lotions, and cosmetics in Uganda but the seeds are discarded as wastes.

26kg of Hass type avocado fruits from Kabale and Ntungamo districts were collected and seeds were extracted. The seeds were rinsed in water thoroughly to remove fruit residue, chopped to pieces of maximum size 20mm and dried under a shade (away from direct sun to prevent degradation of bioactive compounds) for 72 hours as shown in Fig. 2 . The dried seeds were ground into fine powder sieved through a 150micron sieve. Figure 3 shows the ground and sieved seed powder.



*Fig 22. Drying chopped pieces of avocado seed*



*Fig 3. Seed powder*

### **2.3 Extraction Process of Coagulant**

A solution of the coagulant was prepared by adding 5g of the avocado seed powder to distilled water to make 1000 ml of the suspension which was stirred for 45 minutes in a stirrer at room temperature and filtered as shown in Fig. 4.

The filtrate was the coagulant used to in doses for experiments of raw water purification in line with the Uganda National Standards.



*Fig. 4. Making the filtrate*

In the jar test experiment, raw water was mixed in beakers as shown in Fig. 5 with varying dosages of coagulant. The mixing speed and time were maintained at 260 rpm for 1 minute for rapid mixing, reduced to 30 rpm for 20 minutes. Figure 6 shows the suspensions allowed to cool for sedimentation.



**Fig. 5.** Mixing raw water with coagulant



**Fig. 6.** Sedimentation

The turbidity reduction was measured before and after treatment using a turbidimeter in Fig.7.



**Fig. 73.** Turbidimeter used

The pH levels and temperature were recorded before and after coagulation. The colour was determined based on Platinum-Cobalt Colour Standards using spectrophotometer.

The Total Dissolved Solids (TDS) and Conductivity were measured using TDS and a Conductivity meter.

The dosage at which the lowest residual turbidity and colour was attained was noted and test data in the range analyzed.

Water treatment tests were done using the chemical coagulant alum as well in equal dosages to make a comparison.

### 3. Results and Discussion

The effect of varying the dosages of the avocado seeds extract from Kabale and Ntungamo Districts are shown in Tables 2 and 3 respectively. As the dosages increased from 0 to 0.35 mg/l, the pH, TSS, TDS, conductivity, temperature of the water sample did not change significantly. However, there was a significant change in turbidity and colour of the water sample as the dosages increased.

**Table 2.** Results of treated water using seed extract of Kabale.

| Dosage (mg/l) | pH   | Temp (°C) | EC (µS/cm) | Turbidity (NTU) | Color (PCU) | TDS (mg/l) | TSS (mg/l) |
|---------------|------|-----------|------------|-----------------|-------------|------------|------------|
| 0.05          | 7.10 | 24.3      | 102.1      | 12.8            | 29          | 285        | 41         |
| 0.1           | 7.14 | 25.8      | 102.2      | 12.7            | 27          | 291        | 41         |
| 0.15          | 7.14 | 25.7      | 102.4      | 11.2            | 26          | 297        | 39         |
| 0.2           | 7.25 | 24.9      | 103.1      | 9.7             | 23          | 300        | 40         |
| 0.25          | 7.25 | 25.9      | 104.6      | 6.8             | 19          | 305        | 30         |
| 0.3           | 7.30 | 24.1      | 105.4      | 4.9             | 15          | 314        | 32         |
| 0.35          | 7.40 | 25.0      | 105.8      | 4.5             | 13          | 321        | 34         |

**Table 3.** Results of treated water using seed extract of *Ntungamo*

| Dosage (mg/l) | pH   | Temp (°C) | EC (µS/cm) | Turbidity (NTU) | Colour (PCU) | TDS (mg/l) | TSS (mg/l) |
|---------------|------|-----------|------------|-----------------|--------------|------------|------------|
| 0.05          | 7.04 | 24.2      | 102.1      | 12.8            | 30           | 275        | 45         |
| 0.1           | 7.10 | 25.8      | 102.2      | 12.7            | 27           | 282        | 41         |
| 0.15          | 7.19 | 25.7      | 102.5      | 11.2            | 26           | 290        | 39         |
| 0.2           | 7.25 | 24.9      | 103.1      | 9.5             | 26           | 294        | 39         |
| 0.25          | 7.29 | 25.9      | 104.7      | 6.7             | 21           | 300        | 30         |
| 0.3           | 7.32 | 24.1      | 105.3      | 4.4             | 15           | 311        | 32         |
| 0.35          | 7.33 | 25.0      | 105.9      | 4.8             | 13           | 318        | 35         |

Higher decrease in turbidity was observed at a dosage of 0.3 mg/l as it decreased from 12.8 NTU to 4.4 NTU. High decrease in colour was observed at 0.35 mg/l as it decreased from 29 PCU to 13 PCU, corresponding to turbidity removal 12.8 NTU to 4.5 NTU. These values are within the recommended standards for drinking water.

The conventional chemical coagulant alum performed better than the tannin extract during coagulation as shown in Table 4.

**Table 4.** Results of treated water using *Alum*

| Dosage (mg/l) | pH  | Temp (°C) | EC (µS/cm) | Turbidity (NTU) | Colour (PCU) | TDS (mg/l) | TSS (mg/l) |
|---------------|-----|-----------|------------|-----------------|--------------|------------|------------|
| 0.05          | 7.7 | 24.4      | 120.1      | 7.5             | 21           | 290        | 35         |
| 0.10          | 7.5 | 25.1      | 129.1      | 7.2             | 16           | 301        | 33         |
| 0.15          | 7.2 | 25.2      | 139.6      | 6.2             | 12           | 315        | 28         |
| 0.20          | 7.0 | 24.8      | 148.2      | 5.9             | 7            | 324        | 16         |
| 0.25          | 7.1 | 25.3      | 159.8      | 4.3             | 3            | 333        | 12         |
| 0.30          | 6.9 | 25.6      | 167.3      | 2.9             | 2            | 344        | 05         |
| 0.35          | 5.3 | 25.4      | 179.9      | 2.2             | 1            | 359        | 02         |

At dosage of 0.35 mg/l, the pH value decreased to 5.3 which was out the range recommended WHO drinking water standards as it was slightly below. The turbidity and colour of the water sample also decreased significantly to 2.2 NTU and 1 PCU respectively at 0.35 mg/l dosage. The conductivity values also increased as the dosage increased. Dosage of 0.35 mg/l of the avocado seeds extract led to a decrease in the turbidity of the water up to a point where the turbidity tremendously reduced by about 66 % and beyond this dosage, turbidity started to increase again. Dosages from 0.05 mg/l to 0.30 mg/l was the best dosage for turbidity removal. The coagulation capabilities of the avocado seeds are to be expected because the active agent of the natural coagulant (tannin extract from Avocado seeds) is believed to be positively charged cation, thus, mechanism of action may be by charge neutralization and adsorption as suggested by (Putra et al., 2020). The stability of colloidal suspensions that caused turbidity and colour in waters depended on the repulsive forces between the negative electrostatic charges of the particles. Destabilization of colloids thus involved the adsorption of positively charged compounds to the surface of the particle, that reduced the repulsive forces and led to aggregation and eventual settlement. However, it was observed that residual turbidity increased with increasing avocado seed extract dosage beyond 0.3 mg/L. This was due to the saturation of adsorption sites and thus resulted in the restabilization of the destabilized particles. Turbidity removal was found to be 66% for the water sample whose initial turbidity was 15.2 NTU.

Alum dosages from 0 to 3.5 mg/l led to a decrease in turbidity of the treated water with 0.35 mg/L giving the best turbidity of 1 NTU. Avocado seed tannin extract gave 0%, 0.8%, 12.5%, 26%, 47%, 66% and 63% turbidity removal for dosages of 0.05mg/l, 0.1mg/l, 0.15mg/l, 0.2mg/l, 0.25mg/l, 0.3mg/l

and 0.35mg/l respectively. The turbidity removal efficiency increased gradually as dosages increased. This increment in turbidity removal is due to the increment in active tannin of the avocado seed extract.

### 3.1 Turbidity removal

The turbidity removal efficiency  $\epsilon_T$  at the optimum dosage of 0.35 mg/L for each of Alum and two Avocado seed extracts  $E_N$  and  $E_K$  for seeds obtained from Ntungamo and Kabale respectively, for was computed using Equation (1)

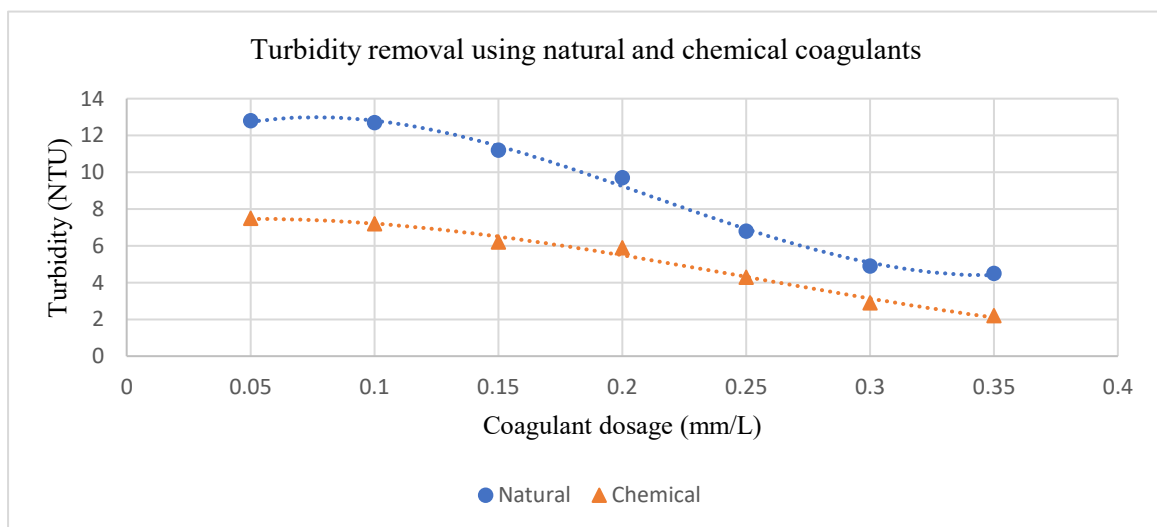
$$\epsilon_T = \frac{T_I - T_F}{T_I} \times 100\% \dots \dots \dots (1)$$

Where  $T_I$  is initial turbidity and  $T_F$  is final turbidity after treatment.

**Table 5.** Comparison of Turbidity removal efficiencies

| Coagulant | Initial Turbidity (NTU) | Final Turbidity (NTU) | Removal Efficiency (%) |
|-----------|-------------------------|-----------------------|------------------------|
| $E_N$     | 12.8                    | 4.8                   | 62.5                   |
| $E_K$     | 12.8                    | 4.5                   | 64.8                   |
| Alum      | 12.8                    | 2.2                   | 82.8                   |

Further trend analysis has been done and the graph in Fig. 8 below shows that natural coagulant begins to compete favorably with chemical coagulant in dosages above 0.2mg/L. It shows also that dosages higher than 0.35mg/L may not produce significant improvement in turbidity removal, implying this is the optimum dosage.



**Fig. 84.** Graph showing comparison of trends in turbidity removal

### 3.2 Colour Removal

Applying dosages of avocado seed extract to the raw water resulted in decreased colour in the treated water with a tremendous reduction by up to about 56.7%. An average dosage of 0.35 mg/l gave the best results for colour reduction within potable water standards. However, it was also observed that the colouration tends to increase with increasing avocado extract dosage beyond 0.3mg/L. This was due to the saturation of adsorption sites and thus resulted in the restabilization of the destabilized particles. The results obtained were in agreement with the performance of Moringa Oleifera when used in water treatment, however, during the treatment tests the colour removal was as high as 90%. This was attributed to the purification by the crude extract by batch ion exchange chromatography which might

have increased the tannin concentration in the extract. For chemical coagulant alum, dosages from 0 to 0.35 led to a decrease in colour of the treated water resulting in colour reduction up to 97%. The graph in Fig. 9 shows the trend.

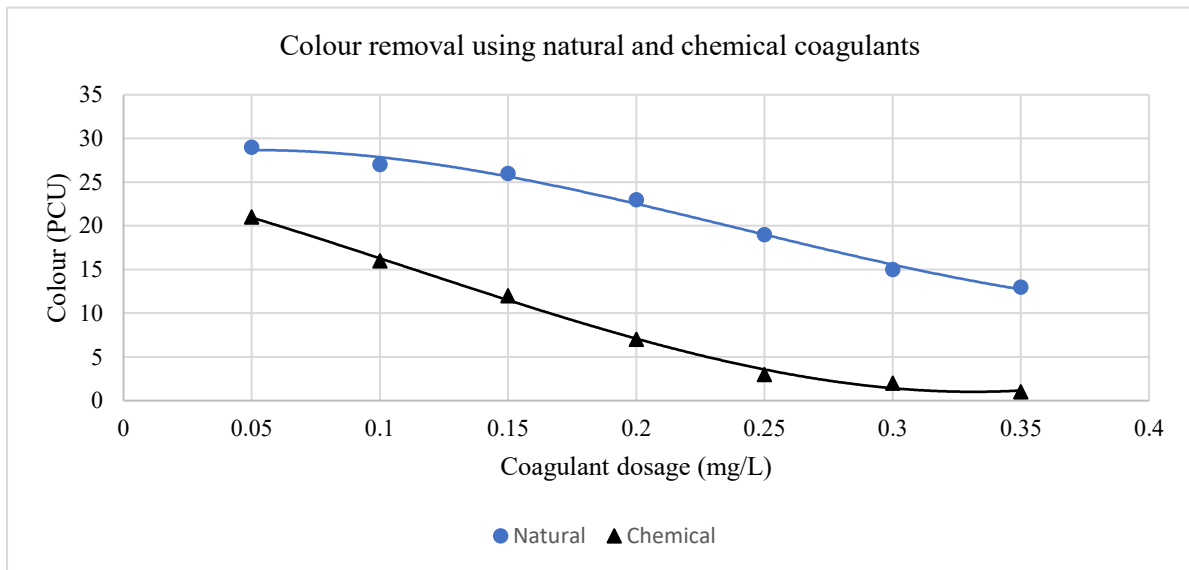


Fig. 9. Graph showing comparison of trends in colour removal

### 3.3 Electrolytic conductivity

The initial conductivity of the raw water sample was 102 $\mu$ s/cm. It was observed that as dosage of the tannin extract increased from 0.05mg/l to 0.35 mg/l, the conductivity of the treated water increased linearly, although only slightly as compared to when alum was used. Figure 10 shows the graphical linear trends with different coagulants.

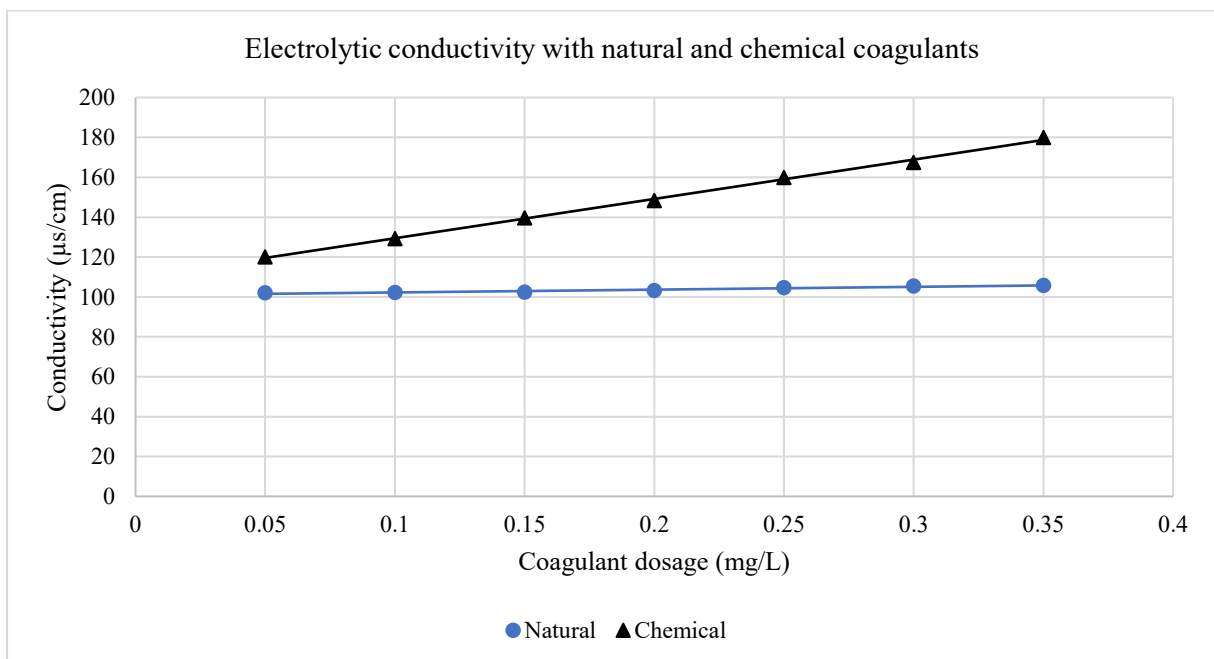


Fig. 105. Graph showing comparison of trends in electrolytic conductivity

This increment of conductivity of the water along with the coagulant dose may be due to the formation of sludge by the coagulants during the coagulation process.

### 3.4 pH variation

The initial pH value of the raw water sample was 8.2. The tannin extract from avocado seeds did not significantly affect the pH and alkalinity of the water sample. This may be because the avocado extract is a natural coagulant that might not have release any significant chemicals in the treated water. The reaction could have been just the physical in which the polyelectrolyte in the extract attracted the suspended colloids which were responsible for turbidity and colour. On the other hand, when the dosages of alum increased from 0 mg/l to 0.35mg/l, the final pH value of the water was significantly decreased from 8.2 to 5.3 which is acidic.

### 3.5 Total dissolved solids

Total dissolved solids (TDS) is mostly used to express the concentration of dissolved minerals in a given water sample. The TDS values increased from 280 mg/l to 321 mg/l as the dosages of the avocado seed extract increased from 0 to 3.5 mg/l. Although alum produced higher TDS values as shown in Fig. 11 below, all were within the specifications for potable water.

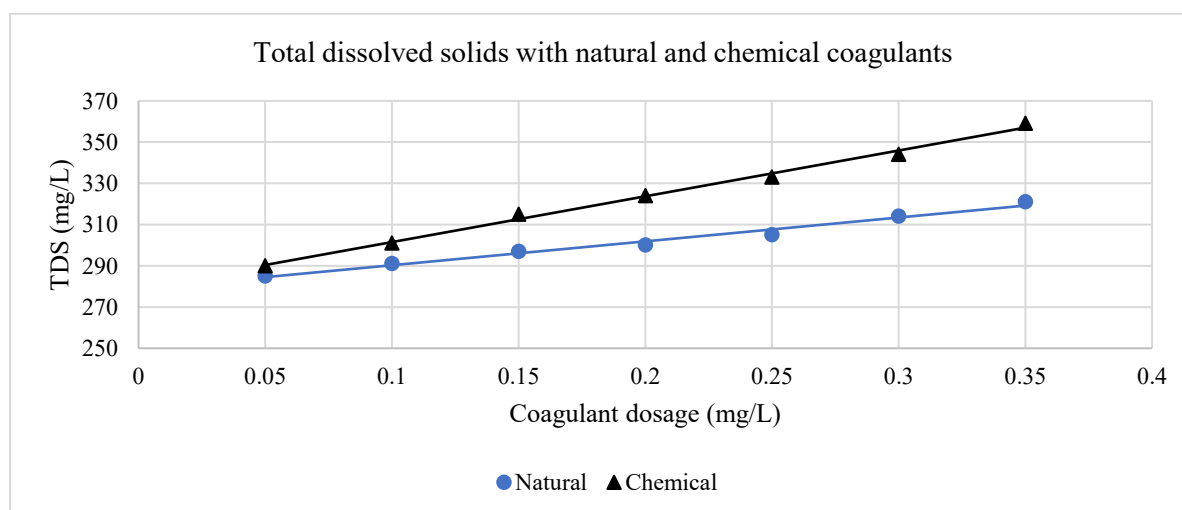


Fig. 11. Graph showing comparison of trends in total dissolved solids

### 3.6 Flocs volume

The addition of the tannin extract from the avocado seeds to the raw water resulted in the formation of flocs which were clearly visible to the naked eye after about 5 minutes of slow mixing. The flocs formed were fine in nature and increased in number with increase in dosage. The settling time was also observed to be longer mainly due to the light weight of the finely formed flocs. The settling time for the coagulant decrease with increased dosages. Variation of flocs volume produced was a function of coagulant dosage. At the optimal dosage of 0.30mg/l, the avocado seed extract produced 1.53ml of sludge. Only initially present suspended particles have agglomerated into larger particles which settled.

Alum produced a higher quantity of sludge as compared to avocado seeds with a volume of 6.5ml at its optimum dosage of 0.10 mg/l. This is in agreement with the findings of previous research ((Ndabigengesere, 1995) that the sludge production of alum to be 4 to 5 times higher than that of natural coagulant.

### 3.7 Optimization of coagulant dosage

Coagulant dose is the main factor that determines the removal of turbidity from water. Studies conducted for testing the efficiency of coagulants brought about optimized the dosage. The minimum dosage corresponding with the lowest turbidity was taken as the optimum dosage but varied on the different samples. From the results obtained during these experiments on turbidity removal, 0.30 mg/L dosage of tannin extract from avocado seeds gave the lowest turbidity of 4.4NTU and was taken as the optimal dosage. The efficiency and optimization of the coagulant was also considered based on the sludge formed in comparison with alum.

## 4. Conclusions

Avocado seeds are a source of tannin extract for water treatment due to its coagulation properties. Coagulation process involves neutralization of the negative surface charges on the colloidal particles, which allow the particles to clump, hence adhere through the addition of the opposite charges. The natural coagulants are environmentally friendly as they will not further deteriorate the environment.

With raw water samples from Lake Bunyonyi having elevated levels of turbidity (12.8 NTU), colour (30 PCU), and Total Suspended Solids (TSS) of 48 mg/l, exceeding WHO and Ugandan standards for potable water, the optimal dosage of avocado seed extract was found to be 0.35mg/l, turbidity and colour removal efficiencies were achieved up to 64.8% and 56.7%, respectively. Conductivity and Total Dissolved Solids (TDS) levels increased only slightly due to sludge formation but remained within acceptable limits. The natural coagulant from avocado seed extract produced substantially less sludge, making it more environmentally sustainable.

This study established that avocado seeds possess important phytochemical properties particularly tannins which are essential for coagulation. However, further research should be conducted to purify and standardize the avocado seed extract to enhance its coagulation efficiency and consistency thereby increasing the concentration of active compounds such as tannins and flavonoids. Additional studies should explore the performance of the avocado seed extract under different pH conditions to help assess its efficacy across a broader range of raw water types and environmental scenarios.

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