WATER TREATMENT USING *Piliostigma thonningii* SCHUM (PT) LEAF

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Abstract: Coagulation, softening and disinfection processes are of great importance in water treatment. In this study, experiments were conducted in the laboratory to investigate the coagulation, softening and disinfection properties of *Piliostigma thonningii* Schum (PT) leave in the treatment of synthetic and natural waters. Synthetic turbid water of high and medium turbidities was prepared in the laboratory using bentonite clay, kaolin clay and black cotton soils. A series of experiments was performed on high (439.7- 487 NTU) and medium (160.8 NTU) turbid waters with 83, 167, 333, 500, 835 1169 mg/l of the coagulant (PT). Effects of pH and temperature on flocculation efficiency of the coagulant have been investigated. Bacterial reduction and hardness of water softening properties of the leave were also studied. The results showed that PT was effective in turbidity removal and softening but less effective in disinfection than. PT recorded 83.15 high turbidity removal; 90.21 medium turbidity removal. 900 mg/l initial water hardness was reduced by PT to 383.67 mg/l (57.37%). PT showed 99.72% disinfection activity. The best result for turbidity removal was found at pH ranges from 7 to 7.5 and at temperatures between 20 and 30°C. Although the leave showed some levels of effectiveness, the water treated with this leave did not meet standard. The leaves are therefore not adequately effective in water treatment.

Keywords: *Piliostigma thonningii*, turbidity, softening, disinfection, Jar test, pH, temperature

Introduction

The provision of safe drinking water is an enormous task, especially in developing nations and most importantly in rural areas. This can be attributed to the scarcity of chemicals required for treatment, namely: alum, lime and chlorine. Chlorination being a well-proven technique has its own unique challenges. For instance, waterborne pathogens such as *Cryptosporidium* and *Giardia* have high resistance to it. Also, it is well established that people dislike the strong odor and disagreeable taste associated with free chlorine (Micheal *et al*., 2010).

Also excess use of amount of chemical coagulants can affect human health e.g. Aluminum has been indicated to be a causative agent in neurological diseases such as pre-senile dementia. In rural and undeveloped countries, people living in extreme poverty are presently drinking highly turbid and microbiologically contaminated water as they lack knowledge of proper drinking water treatment and also not afford to use high cost of chemical coagulants. Some drinking water treatment plants in developing countries face a myriad of problems which are: large seasonal variation in raw water quality e.g. turbidity, high cost of water treatment chemicals, under dosing of chemicals leading to supply of poor drinking water. To overcome problems associated with the use of coagulants, it is necessary to increase the use of natural coagulants for drinking water treatment (Mangale *et al.*, 2012). The history of the use of natural coagulant for the removal of turbidity is long. Natural organic polymers have been used for more than 2000 years in India, Africa, and China as effective coagulants and coagulant aids at high water turbidities. They may be manufactured from plant seeds, leaves and roots. Natural coagulants have bright future and are concerned by many researchers because of their abundant source, low price, environment friendly, multifunction, and biodegradable nature in water purification (Madhavi *et al.*, 2013; Kawamura, 1991)

Moringa oleifera and *Tamarindus indica* are among the alternatives (Mangale *et al*., 2012; Bichi, 2013). Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from microorganisms, animals or plants.

Piliostigma thonningii Schum is a plant known across Africa and other sub-Sahara countries as camel's foot (English); mukolokote (Venda); mokgoropo (North Sotho). In Nigeria it bears such local names as abefe (Yoruba), kalgo (Hausa), okpoatu (Igbo), ejei –jei (Igala), omepa (Igede) and nyihar (Tiv). (Kayode *et al*., 2012; Jimoh *et al*., 2005; Kwaji *et al*., 2010; Simon *et al*., 2014)

P. Thonningii leave as depicted in Figs. 1 and 2 is environmentally friendly and is widely available and relatively cheaper, uncultivated and under-explored. Previous research findings have shown that both *P. thonningii* contain tannins and tannins were found to have antioxidant as well as antimicrobial properties.

It is also a known local practice among rural populace in the North-Eastern Nigeria, the placement of *Piliostigma thonningii* leave in water containing vessels, while fetching water from rivers, wells, etc.

Fig. 1: *Piliostigma thonningii* leave

Fig. 2: ***Piliostigma thonningii***

The research work aimed at providing alternative means of water treatment for people and especially in the rural areas so that they have access to treated water for their domestic uses; health risks due to use of untreated water will hence reduce.

Materials and Methods

In this study, the following materials and sampling procedure were applied:

Materials

Water samples

The synthesized water was prepared at the Public Health Laboratory, Bayero University Kano. The water quality parameters were checked before and after treatment. Doses of the PT leave filtrate i.e. 0.5, 1.0, 2.0 ml and 3.0, 5.0 and 7.0 ml (Aweng *et al.*, 2012) were chosen. That gave corresponding final concentrations of 83, 167, 333, 500, 835 and 1169 mg/l in accordance with method of calculation in Kawo *et al*. (2011).

Piliostigma thonningii Schum (PT) leaves sample

Good quality fresh leaves of the plant were selected manually and randomly from

Bayero University, Kano (BUK), authenticated from the Department of Botany, BUK and dried under room temperature for two weeks (Kwaji *et al*., 2010).

Methods

Preparation of leaf powders

The dried leaves were ground to fine powder using domestic pestle and mortar. The ground powders were then sieved through a 210 µm sieve.

Extraction of active ingredients from leaves

The extraction was in accordance with Aweng *et al.* (2012): Crude extracts were prepared by using 1 L of distilled water to 50 g of the prepared powder, mixed by a British made (RPM=1400, HP=1/86, watt=8.6) stirrer for 60 min and left to settle for 20 min. The crude extracts were finally filtered through Whatman filter paper. The filtrates were prepared at the time of conducting the tests, since deterioration sets in with delay (Muyibi *et al.*, 1994). The filterates were used within 48 h.

Preparation of synthetic water

Synthetic water was prepared to guarantee the homogeneity of used raw water with specific concentrations. Chemicals and equipments used in this work were:

a) For turbidity: The stock suspension was prepared as described by Patil *et al*. (2013).10 grams of bentonite, kaolin and black cotton soil were added in 500 ml of water and allowed to soak for 24 h. That was used as stock solution of 10000 mg/L concentration. The stock solution was then diluted to prepare water samples of high and medium turbidities.

b) For hardness: Synthetic hard water was prepared in accordance with Usaid *et al*. (2014): This was prepared with the help of calcium chloride dihydrate ($CaCl_2.2H_2O$). Concentrations of 300, 500, 700 and 900 mg/l were used for this experiment. Stock solution of 1000 ml was prepared for each different concentration. Calcium chloride dihydrate has a molecular weight of 147.02; hence 441 mg (that is 120 mg Ca^{2+}), 735 mg (200 mg Ca^{2+}), 1029 mg (280 mg Ca^{2+}) and 1323 mg (360 mg Ca^{2+}) (calculated using Equation 1) of it was added in a litre of deionised water to give 300, 500, 700 and 900 ppm respectively (Kevin, 1999 and Vernier Software & Technology**)**. 300 ml of the stock solution was then distributed in three different beakers of 500 ml capacity. Leaf filtrates of 333, 500 and 835 mg per liter of water were added separately in different set of three beakers.

$$\text{Hardness (mg/L as CaCO3)} = (\text{mg/L of } Ca^{2+}) \times \frac{eq.\ wt\ of\ CaCO_3}{eq.\ wt\ of\ Ca^{2+}} \quad (1)$$

Where: eq. wt of $CaCO_3$ = 100; eq. wt of Ca^{2+} = 40

c) For disinfection: The *E. coli* culture was prepared as described in Obire *et al.* (2005) and Bichi *et al.* (2012). Nutrient broth (130.0 gm) was dissolved in 1000 ml distilled water by heating slightly. The mixture was sterilized at 130^0C for 15 min in Prestige Medical Series 2100 Clinical autoclave. The sterilized broth was then cooled to room temperature and used to prepare the *Coliform* culture.

Procedure for laboratory analysis

Phytochemical analysis was first conducted on the leave of the plant to confirm the presence of tannins and flavonoids. Level of contamination of the synthetic water was determined. The synthesized water was then separately treated using *PT* leave filtrates. The test was carried out batch wise. Three water samples were each mixed homogeneously with the chosen doses of *P. thonningii* leaf extract (giving corresponding final concentrations of 83, 167, 333 mg/L and 500, 835, and 1169 mg/l filtrate per synthetic water) and allowed to rest. The treated water samples were then analyzed to determine the levels of coagulation, hardness, disinfection (*Coliform*), temperature and pH.

a) Turbidity test: Coagulation/flocculation test was carried out in 'Jar Test' (with PEF Flocculation Test Unit), using three beakers for a dose. 0.5 ml of the *P. thonningii* leaf filtrate was added to 300 ml of synthetic waste water. The mixture was stirred at 95 rpm for 3 min. Thereafter, the samples were left to rest for 120 min. The procedure was repeated using 1.0, 2.0, 3.0, 5.0 and 7.0 ml of the filtrate. 100 ml of the sample was then taken from the top of each beaker for the tests using a turbidity meter (SGE-200BS). Coagulation activity was calculated thus:

$$\text{Coagulation activity (\%)} = \frac{Ts - Tb}{Tb} \times 100 \quad (2)$$

Where: T_s – Turbidity concentration after treatment (NTU); T_b – Turbidity concentration of blank (NTU)

b) Hardness test: 50 ml of water sample was measured into a clean beaker followed be addition of 0.5 ml of 0.1N HCl to the sample. The mixture was heated to expel CO_2. It was then cooled to 50ºC and mixed with 2ml of buffer solution of pH 10. Two drops of Erichrome T indicator were added and the solution titrated with EDTA standard titrant until the colour changes to from wine red to blue. The volume of EDTA used was recorded and the procedure repeated for the remaining samples. Hardness of water was calculated using the formula below:

$$\text{Hardness (as mg/l } CaCO_3) = \frac{(vol\ of\ EDTA\ titrant) * f * 1000 * 0.1 * 17.8}{ml\ of\ sample} \ldots\ldots\ldots\text{Equ.3}$$

Where f = 1

c) Disinfection test: This was done in accordance with Food and Agriculture Organization of the United Nations, Rome 1979 (FAO EC/Microbiol/75/Report 1/Annex v):

In the enumeration of Mesophilic Aerobic Bacteria (Aerobic Plate Count), 1ml of coliform containing water was serially diluted in distilled water into 10^{-1}, 10^{-2}, 10^{-3} and 10^{-4} mg/l and then 1.0ml of each of these diluents was plated aseptically onto nutrient agar for total coliformcounts. 0.25, 0.5, 1 and 2 ml of the leaf extract was added to 10 ml of the cell cultures and incubation was carried out at 37°C (in Gallenkamp Cooled Incubator) for 24 h for Total coliforms test. The bacterial counts were enumerated visually. The cell survival ratio was estimated by comparison to a control experiment where no leaf extract was added as suggested by Bichi (2012). This method was also used to validate the findings using raw water from Chalawa Dam, Kano.

pH variation with turbidity

Jar tests were performed using six paddle PEF Flocculation Test Unit (Serial No. PEF 0031/11). Coagulant doses of 333 and 167 mg/l were used respectively for high and medium turbidities. The pH was targeted from 6.5 to 8.5. The pH was adjusted by adding drops of 0.1NHCl or 0.02NaOH prior to the addition of coagulant. The pH of the samples was taken using PHS-25 pH meter (Ahamed *et al*., 2010).

Temperature variation with turbidity

Jar tests were completed for optimum doses of 333 mg/l for high turbidity and 167 mg/l for medium turbidity of PT at 40, 30, 20, 10, 5 and 0.5°C (Larry *et al.,* 2001). The procedure for the jar test was as stated in Section 2.4.1 above. Gallenkamp water bath and a controlled fridge were used to control temperature.

Validity of results

Raw water samples were collected from Chalawa water and the above tests conducted on the sample for validity in accordance with the procedure outlined in 3.4 above. For hardness test, sample of hard water was also obtained from Gwarmai Open Well, Bebeji Local Government Area.

Results and Discussion

Phytochemical analysis was conducted on the prepared leaf powder at the Medical Laboratory, Ahmadu Bello University Zaria. The result confirmed the presence of tannins, flavonoids and saponins in the leave (Table 1).

Table 1: Phytochemical analysis of PT leaves

S/N	Test	PT leaf powder
	Test for Carbohydrate	
1	Molish Test	+ve
	Fehling Test	+ve
	Test for Cardiac Glycosides	
2	Kello- killiani's test	++ve
	Kedde test	+ve
	Salkoski's test	+ve
	Test for Anthraquinones Derivatives	
3	Free anthraquinone (Borntragers)	-ve
	Combined Anthracene (modified Borntragers)	-ve
	Test for Saponins	
4	Frolling Test	+ve
	Hemolysis Test	+ve
	Flavonoid Test	
5	Shinoda Test	+ve
	Sodium hydroxide Test	+ve
	Tannins Test	
6	Lesd sub-Acetate	-ve
	Ferric Chloride	+ve
	Steroid and Triterpenes Test	
7	Ueberman-Bio	+ve
	Alkaloids test	
8	Meyers test	-ve
	Dragendoff's test	-ve
	Keaqner's test	-ve

Effect of PT on turbidity removal

Table 2 gives the initial turbidities of different waters used; Table 3 shows the effects of the plant filtrate doses on turbidity while Table 4 gives the variation of residual turbidities with the doses.

Table 2: Initial turbidities of raw waters

	Synthetic high turbid water	Synthetic medium turbid water	Chalawa water
Initial turbidity values (NTU)	439.7- 487.0	160.8	295.9

Table 3: Variation of turbidity with doses of PT

Dose (ml)	Concentration (mg/l)	Turbidity removal (%) with PT	Turbidity removal (%) with Alum
High turbid synthetic water			
-	60	-	98.95
0.5	83	82.15	-
1	167	82.95	91.18
2	333	83.15	-
3	500	82.67	-
5	835	82.47	-
7	1169	82.11	-
Medium turbid synthetic water			
0.5	83	89.99	-
1	167	90.21	-
2	333	89.49	-
3	500	89.21	-
5	835	87.87	-
7	1169	87.13	-
Chalawa water			
2	333	50.06	-

Table 4: Comparison of residual turbidity with coagulant dose

Source	Dose of Coagulant	Conc. of Coagulant (mg/l)	Residual turbidity (NTU): High turbid water+PT	Medium turbid water+PT	High turbid water+Alum
Column	1	2	3	4	5
Synthetic water	-	60	-	-	4.6
	0.5	83	81.83	16.1	-
	1	167	78.47	15.75	38.77
	2	333	77.53	16.9	-
	3	500	79.73	17.35	-
	5	835	80.63	19.5	-
	7	1169	82.33	20.7	-
Chalawa water	2	333	219.6	-	-
NIS requirement (NTU) max				**5**	

From Table 3, it can be seen that the percentage turbidity removal varied between 82.15 and 83.15 with PT doses.

Figure 3 shows that for high turbid synthetic water, a maximum of 83.15% turbidity removal was achieved with 333mg/l of PT. Higher percentage turbidity removal was recorded for medium turbid synthetic water whereby 90.21 and 89.77% turbidity removal were achieved with 167 mg/l of PT. There was, therefore, a notable decrease in turbidity of the synthetic high and medium turbid waters. This can be compared with *Cassia alata with coagulation activity of* 93.33% (Aweng *et al*, 2012), water melon seed of 88% (Muhammad *et al.*, 2015) and *Moringa oleifera* seed extract of 92.99% (Mustapha, 2013).

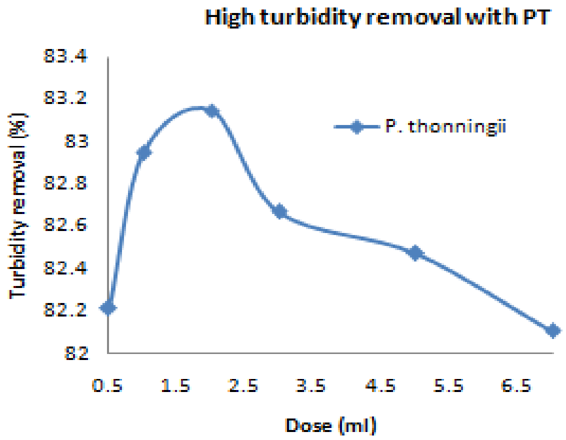

Fig. 3: High turbidity removal with PT

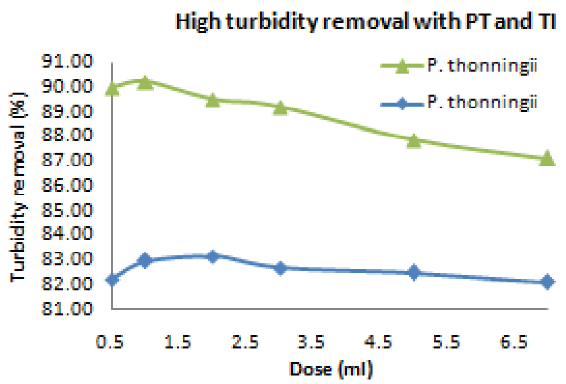

Fig. 4: Medium turbidity removal with PT

It can be observed from Table 4 above that, although, the turbidity of the raw water was drastically reduced, the residual turbidity was still higher than 5NTU specified by the Nigerian Standard for Drinking Water Quality (NIS 554, 2007).

The fall in the coagulation activity in doses above 333 mg/l for high turbid and 167mg/l for medium turbid waters could be attributed to the coagulant that remained excess of the optimum coagulant dose.

Based on this assumption, sample of synthetic water was treated with alum in the concentrations of 60 mg/l (which is the practice at Chalawa Water Treatment Plant, Kano) and 167 mg/l. For the former concentration, 98.95% turbidity removal was achieved. This reduced the initial turbidity of 439.7 to 4.6NTU, conforming to the requirement of Clause 5.1.1 of the Nigerian Industrial Standard for Drinking Water Quality (NIS 554, 2007). The latter dose, however, was less effective, with 91.18% turbidity removal and the final turbidity of the treated water was 39.4NTU, a value that did not meet the requirement of the standard.

Sample of Chalawa water (with initial turbidity equal to 295.9NTU) was treated separately with PT in 333 mg/l concentration. The coagulants appeared much less effective, having only 50% removal. It is worth mentioning that turbidity is caused by chemical, biological or physical factors and its removal depends on the type and size of the impurities present. In fact, Ahamed *et al.* (2010) emphasized that there were many parameters that affect coagulation performance (and hence turbidity removal) and that include the amount and type of particulate material, the amount and composition of natural organic matter (NOM), and chemical and physical properties of the water. The common parameters are: coagulant type, dose and pH (Yan *et al.*, 2008; Uyak and Toroz, 2006). Many researches, they said, have shown that natural organic matter reacts or binds with metal ion coagulants and that coagulant dosage is determined by NOM-metal ion interaction and not particle-metal ion interaction (Matilainen *et al.*, 2012).

The much difference in effectiveness of the two coagulants in the treatment of synthetic and natural turbid waters could be attributed to these factors. The natural turbid water used (Chalawa Water) could have contained NOM and other substances that the coagulants used did not have effect on.

Effect of the leaf filtrates on the pH of water

The initial pHs of the prepared synthetic water were 8.98 and 8.56, respectively for high and medium turbidities, and the initial pH of the leaf filtrates was 3.92 for PT.

However, when the prepared high and medium turbid waters were treated with various doses of the leaf filtrates, the pH values changed as shown in Fig. 5.

For medium turbid water, the pH varied with the doses as shown in the figure. At optimum doses (333 mg/l for high and 167 mg/l for medium turbid water), the pH values were as shown in Table 5.

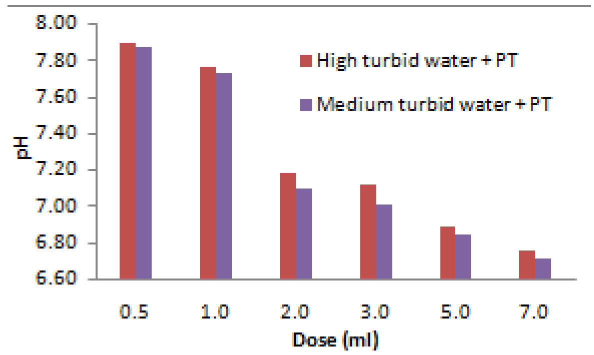

Fig. 5: Variation of pH with coagulant doses

Table 5: Comparison of pH values of different waters

Source	pH	
	Initial	After treatment with pt
Pt filtrate	3.92	-
Synthetic high turbid water	8.98	7.18
Synthetic medium turbid water	8.56	7.1
Chalawa water	7.9	7.03
NIS requirement		6.5 – 8.5

Although the pH of the water varied as a result of the introduction of the plant filtrates, it was within the range set by Clause 5.1.2 of the Nigerian Industrial Standard for Drinking Water Quality (NIS 554:2007) (6.5 - 8.5).

Effect of temperature on turbidity removal

Figures 6 and 7 below show the variation of turbidity with temperature.

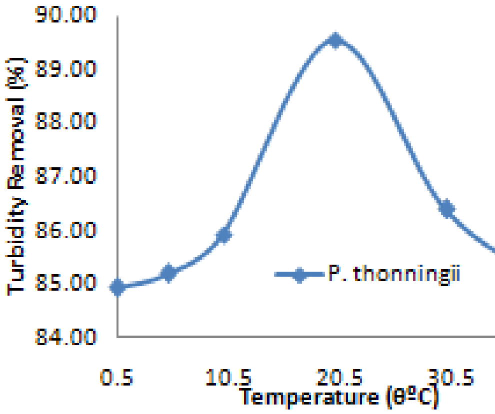

Fig. 6: Graph of high turbidity removal against temperature

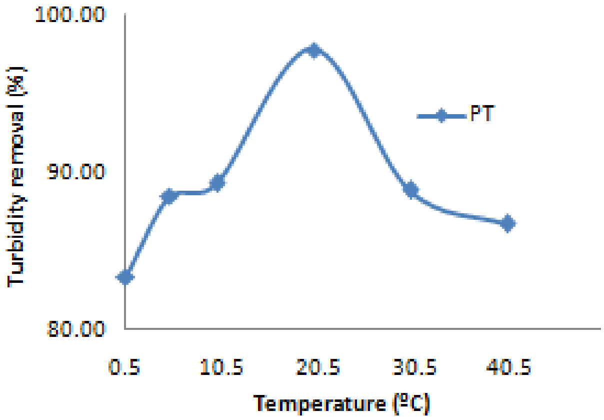

Fig. 7: Graph of medium turbidity removal against temperature

From the graph, it can be deduced that turbidity removal initially increased with increase in temperature from 0.5 to 20°C, with some little deviations at 5°C, until it reached peak at 20°C for both high and medium turbid waters. It then began to fall. Maximum turbidity removal from high turbid water of 89.55% was recorded at 20°C for the optimum dose of 333 mg/l for PT. While higher value of 97.85% was recorded at the same temperature with 167 mg/l of PT.

The deviation of the graph at 5°C could be due to anomalous change in density of water as the temperature varied from 0.5 to 40°C. At temperatures higher than 20°C, the suspended particles in the water might have gained enough kinetic energy to resist the effect of the coagulants, resulting in lesser turbidity removal.

This finding is supported by Madhavi *et al.* (2013) that turbidity reduction is mostly affected by cold temperatures. Rasha (2014) even argued that low temperatures would impair floc formation because of increased shear stress due to higher water viscosity. According to them, the effect of temperature on the best flocculation time required for efficient sedimentation becomes less when temperature increases and reaches 25°C, and little difference in flocculation times at temperature range from 10 to 25°C, while much higher differences at temperatures less than 10°C.

Variation of turbidity with pH

In this approach, samples of synthetic high and medium turbid waters, at different pH levels, were treated with 333 and 167 mg/l using PT. The raw water pH levels used were 6.5, 7.0, 7.5, 8.0 and 8.5. To adjust pH, 0.1NHCl and 0.02NaOH were used. The pH result is presented in Table 6.

Table 6: Residual turbidities for different pH values

pH		Coagulant	Initial turbidity	Residual turbidity
6.5	High turbidity	PT	475.5	73.3
	Medium turbidity	PT	137.3	21.85
7	High turbidity	PT	475.5	70.45
	Medium turbidity	PT	137.3	18.85
7.5	High turbidity	PT	475.5	72.15
	Medium turbidity	PT	137.3	20.95
8	High turbidity	PT	475.5	77.75
	Medium turbidity	PT	137.3	23.05
8.5	High turbidity	PT	475.5	80.3
	Medium turbidity	PT	137.3	24.8

It can be seen from the table that turbidity removal changed with increase in pH from 6.5 to 8.5, reaching optimum at a pH of 7.0 for all turbidities. This is better observed in Figs. 8 and 9.

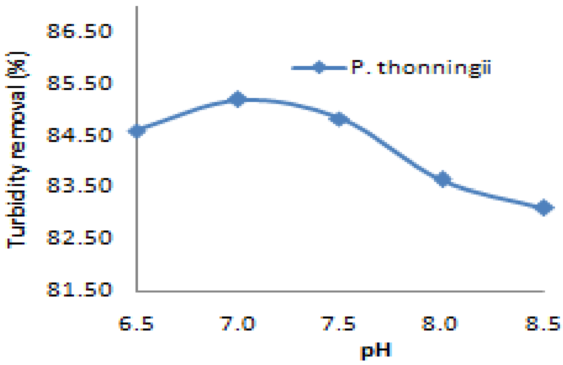

Fig. 8: Variation of percentage high turbidity removal with pH

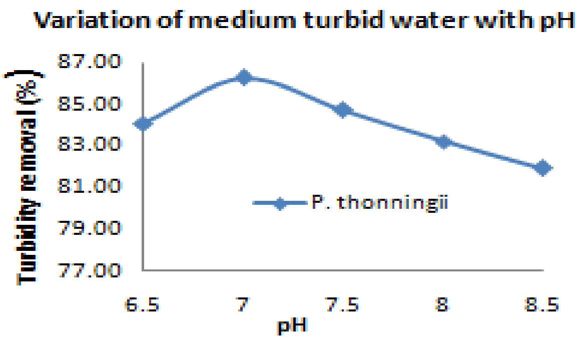

Fig. 9: Variation of percentage medium turbidity removal with pH

At pH of 7.0, high turbidity was reduced by 85.18% and 84.85% with PT, medium turbid water treated with PT by 86.27, while at pH of 7.5. Ahamed *et al.* (2010) reported Yan *et al.* (2008) as saying that the pH at which coagulation occurs is the most important parameter for proper coagulation performance as it affects the surface charge of colloids, the charge of NOM functional group and the charge of the dissolved phase solubility. They pointed out the need for controlling the pH of high turbid water for effective turbidity

removal and found that the best turbidity removal is achieved between pH 5 and pH 6. They, however, showed that for NOM, higher coagulant doses would be required at higher pH values.
Harashit Kumar Mandal (2014), on his part, argued that there was no direct influence of pH on turbidity, although his research was specific on wastewater.

Effect of PT on hardness

The synthetic hard water was treated separately with 333, 500 and 835 mg of PT per litre of hard water, and with 167 mg Na_2CO_3 and calcium zeolite per litre of hard water. Natural hard water from Chalawa Dam and Gwarmai Open Well were treated with 333 mg of PT, and with 167 mg of Na_2CO_3 and calcium zeolite ($CaAlSiO_3$) per litre for validity.
Table 7 shows the results obtained. From the table, it can be observed that hardness removal, by the filtrate, increased with increase in initial hardness.

Table 7: Effect of PT on hardness of water

	Initial hardness mg/l	Residual hardness					
		835 mg/l	500 mg/l	333 mg/l	167 mg/l	167 mg/l	167 mg/l
		PT	PT	PT	PT	a_2CO_3	$CaAlSiO_3$
Synthetic hard water	300	278.02	280.91	290.14	291.56	36.8	35.44
	500	350.33	340.06	357.78	463.87	95.8	74.76
	700	412.86	411.32	427.2	540.76	143.86	108.58
	900	383.67	401.36	439.66	591.32	200.82	186.58
Chalawa water	297.26	-	-	284.8	-	41.8	38.32
Gwarmai open well	461.02	-	-	302.6	-	53.92	43.66
NIS requirement	-	**150 mg/l max.**					

Although the leaf filtrate reduced the hardness of the water by some percentages, the residual hardness of the treated water was above the maximum value of 150mg/l specified by Clause 5.1.2 of NIS 554:2007.
Calcium zeolite at 167 mg/l, however, reduced as high hardness as 700 to 108.58 mg/l, a value meeting the requirement of the standard. Sodium carbonate also reduced 700 to 143.86 mg/ at 167 mg/l.
This indicates that PT can only reduce hardness in water, but the effect is insignificant when compared with sodium carbonate and calcium zeolite. *Moringa oleifera*, also, as reported by Usaid *et al.* (2014), proved more effective in water softening and is therefore accepted as natural softener.

Conclusion

In an effort to provide an alternative method of water treatment that is environmentally friendly, widely available and relatively cheaper, and to overcome the chemical coagulant problems, especially for rural duelers, *Piliostigma thonningii* Schum leaves was tested for coagulation, disinfection and softening properties. Effects of pH and temperature on turbidity removal were also studied.
Phytochemical analysis confirmed the presence of tannins, flavonoids, saponins and alkanoids. Turbidity removal varied with doses of the filtrate: PT recorded 83.15 and 90.21% for high and medium turbidities.
The pH of the treated water decreased with increase in the coagulant dose, but was within the range specified by the Nigerian Industrial Standard for Drinking Water Quality (NIS 554:2007).
Turbidity removal activity of the the leave varied with temperature and pH. Maximum removal was recorded at pH range of 7.0 to 7.5 and temperature range of 20 to 30°C.
Hardness removal increased with increase in initial hardness. PT only reduced hardness in water, but the effect was insignificant when compared with sodium carbonate and calcium zeolite. 900 mg/l initial water hardness was reduced by PT to 383.67mg/l (57.37%).
Although the disinfection activities of the leave was significant, the residual coliform levels (2650 and 3500 cfu/ml) were above the maximum *Coliform* level (10 cfu/ml) specified by NIS 554: 2007.
Although the leave showed some level of effectiveness in water treatment, the treated water did not meet standard. The leave is therefore not adequately effective in water treatment.

Recommendations

Based on the findings of this research work, it is recommended that:

i. The mixing and settling time of water treated with PT should be studied to observe their impacts on turbidity removal.
ii. The leave should be tested for efficacy in other water treatment parameters such as colour, conductivity, acidity and alkalinity.
iii. Phytochemical analysis conducted confirmed the presence of tannins, flavonoids, saponins, etc. which have been reported, in other research work, to be effective antioxidants and antimicrobial. In this research work, the leave appeared to be ineffective. Further research is therefore needed to study the type and extent of these antioxidant and antibacterial substances in the leaves.
iv. Other coagulants of plant origin such as *Moringa oleifera* have been used as coagulant aids. Study should therefore be done on PT as coagulant aids.

Conflict of Interest

Authors declare that there is no conflict of interest related to this paper.

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