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Original Article

Comparative studies between aluminium sulphate, moringa seed and green plantain peel as coagulants

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ABSTRACT

Aluminium sulphate (alum) is the most commonly and widely used coagulant in water treatment plants however, literatures have revealed that it has certain setbacks that needs to be addressed including imparting acidity and hardness to water. Hence, the coagulation capacities of the seeds of moringa (*Moringa oleifera*) and peels of unripe or green plantain (*Musa paradisiaca*) which are abundantly available and currently considered as waste in most developing countries, were investigated in comparison with alum. This was achieved by using standard methods to treat raw water at different dosages of coagulants (100-600mg/l) prepared from moringa seed and plantain peel, and comparing the performances of these coagulants with that of aluminium sulphate (alum) used in treating same raw water at same dosages. Parameters checked are turbidity, pH and hardness. Results showed that alum performed best in terms of turbidity removal followed by moringa seed solution and then plantain peel solution. This is because alum reduced the water turbidity by 99.94% at an optimum dosage of 100mg/l while moringa seed and plantain peel solutions reduced the turbidity by 80.27% at 300mg/l and 63.99% at 500mg/l respectively. Nevertheless, it was noted that at optimum dosage of alum, the water pH was reduced from 6.7 to 6.2 as against the WHO permissible limits (6.5 – 8.5), and the harness level was increased by 22.43%. On the contrary, at the optimum dosages of moringa seed and plantain peel solutions, the pH were raised to 7.3 and 7.5 respectively, which is within the permissible limits and also, the hardness levels were reduced by 13.41% and 8.52% respectively. It was concluded that moringa seed solution could replace alum successfully but plantain peel solution needs modifications in order to improve the turbidity removal capacity before replacing alum although, it could be used in the absence of other conventional coagulants.

1. Introduction

Turbidity in water is a major parameter that aesthetically limits the use of water. Apart from aesthetic limitation, it has negative effect on water disinfection process because the colloidal materials associated with turbidity usually shield microbes from disinfectants. Also, the fine suspended mud particles and colloidal matters provide adsorption sites for chemicals that may be harmful or cause undesirable taste and odour. Hence, turbidity removal or reduction is very important in water treatment process. The suspended or colloidal materials causing turbidity hardly settle down by gravity in plain sedimentation tanks hence, certain chemicals called coagulants are added to the water which on through mixing, form sticky precipitates called flocs. The fine colloidal particles get attracted and absorbed in these flocs, forming bigger sized flocculated particles that settles down by gravity.

There are numerous chemicals used as coagulants however, aluminium sulphate, commonly known as alum ($Al_2(SO_4)_3.18H_2O$) is most commonlly and widely used in water treatment plants and at homes. However, several researchers [1, 2, 3, 4] have revealed that alum reduces the pH of water thereby imparting acidity to it. Water having

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low pH (acidic) corrode plumbing pipes and leach metals into the water consequently, causing leakages of water in pipes as well as making the water toxic. Due to these reasons, lime is usually added to water during treatment process to raise the pH, thus incurring more treatment cost. Also when alum is added to raw water, it reacts with the bicarbonate alkalinities, which are usually present in raw supplies to form flocs of aluminium hydroxide that attracts the suspended and colloidal particles. The chemical equation is given in equation (1) as follows.

$$Al_2(SO_4)_3.18H_2O + 3Ca(HCO_3)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3 \downarrow + 6CO_2 \uparrow \quad (1)$$

From Equation (1), it is obvious that the addition of alum to water imparts permanent hardness to it, in the form of calcium sulphate ($CaSO_4$). Hard water is undesirable because it leads to greater soap consumption, scaling of boilers, incrustation of pipes, and making of food tasteless. Due to these reasons and financial constraints especially in developing countries, there is need to investigate the possibility of using coagulants made from biological materials (bio-coagulants) to substitute alum.

Moringa (*Moringa oleifera*); a tree native to Asia but naturalized in Africa is very common in Nigeria. In fact, it could be found in every household or compound in Northern Nigeria. Presently, the leaves are used for preparing tea as well as different soup delicacies while the seeds are considered as waste. On the other hand, plantain (*Musa paradisiaca*) is a crop that is very common in Southern Nigeria. It has been reported that Nigeria produced about 2.8million metric tonnes of plantain annually [5]. This amount to annual production of about 1million metric tonnes of plantain peels, disposed in dumpsites as solid waste. Both Moringa seeds and unripe or green plantain peels have been reported to contain polysaccharide [6, 7]; a molecule known to have flocculation properties. Hence, it is important to investigate the possibilities of utilizing these biodegradables in coagulating water, instead of considering them as wastes.

2. Materials and Methods

Moringa seeds removed from pods (Fig 1) as well as unripe or green plantain peels (Fig 2) were thoroughly washed with distilled water thereafter, both were sun dried for 2 days and further dried in an oven (model E028-230VT) at 45^{o}C for 24 hours. The dried moringa seeds and plantain peels were pulverized separately using a laboratory grinding machine (EcoMet 30). Each set of the pulverized particles were sieved through a 150µm mesh and stored in different airtight containers until further usage. In order to avoid suspended and floating particles from the bio-coagulants during water treatment, 2.5g of the pulverized and sieved particles for each bio-coagulant was mixed in 250ml distilled water thus, producing a concentration of 0.01g/ml or 10mg/ml for each.

Fig 1. Moringa seed inside dried pod

Fig 2. Unripe (green) plantain and its peel

Also, aluminium sulphate (alum) was pulverised into fine particles by means of laboratory mortar and pestle, and was used in preparing stock solution of 10mg/ml as well. The prepared stock solutions were used as bio-coagulants at dosages 10ml, 20ml, 30ml, 40ml, 50ml and 60ml, corresponding to 100mg, 200mg, 300mg, 400mg, 500mg and 600mg respectively, since the concentration is 10mg/ml. The turbidity, pH and hardness of raw water obtained at New-Calabar River (4°53'58.50"N, 6°53'52.02"E) in Port Harcourt, Nigeria during dry season were recorded via turbidimeter (HACH 2100N), pocket-sized pH meter (pHep®,$\pm$0.1) and titrimetric method respectively. Thereafter, each of the jars contained in jar-test apparatus (Fig 3) were filled with one litre of raw water. Different dosages of the bio-coagulants varying from 100, 200, 300, 400, 500 and 600mg were added in each of the jars. The water samples were fluctuated rapidly at room temperature (20-25^{0}C) for 5minutes at 80rpm, followed by gentle stirring at 30rpm for 15minutes using the magnetic stirring device in the apparatus. The jars were removed from the stirring devices and allowed to stand for 30minutes for the settling of flocs. The supernatants were decanted and analyzed for turbidity, pH and hardness. The jar-test was also conducted on the raw water using alum at same dosages, in order to compare the performances of both bio-coagulants with alum, which is most commonly used.

3. Results and Discussion

The turbidity, pH and hardness of the water sample prior to treatment (i.e. at zero dosage of coagulants) are 11.183NTU, 6.7 and 48.24mg/l as $CaCO_3$ respectively, which is in line with past report [8]. The quality obtained after treating with the various coagulants are given in Table 1.

Fig 3. Jar-test apparatus

Table 1. Quality of water for different coagulants and dosages

Dosage	Turbidity (NTU)			pH			Hardness (mg/l as $CaCO_3$)		
(mg/l)	Alum	Moringa	Plantain	Alum	Moringa	Plantain	Alum	Moringa	Plantain
0	11.183	11.183	11.183	6.7	6.7	6.7	48.24	48.24	48.24
100	0.007	5.153	10.032	6.2	6.9	6.8	59.06	45.21	47.45
200	0.314	2.788	8.552	6.1	7.1	7.0	64.29	43.96	46.64
300	0.899	2.206	5.927	5.9	7.3	7.1	67.33	41.77	45.49
400	1.375	2.382	4.592	5.9	7.4	7.4	68.82	40.05	44.75
500	2.096	2.540	4.027	5.8	7.7	7.5	73.59	39.81	44.13
600	2.351	2.609	4.492	5.6	8.0	7.9	77.41	39.02	43.86

3.1 Turbidity

The optimum dosages for alum, moringa seed and plantain peel solutions were achieved at 100, 300 and 500mg/l respectively. The corresponding turbidity values to these optimum dosages are 0.007, 2.206 and 4.027NTU. This implies that alum reduced the turbidity by 99.94% at optimum dosage of 100mg/l. Similarly, moringa seed reduced the turbidity by 80.27% at optimum dosage of 300mg/l while that of plantain peel is 63.99% at 500mg/l. In other words, alum that has the smallest optimum dosage gives the best turbidity removal followed by moringa seed and then plantain peel. This might be the reason why alum is still majorly used in water treatment processes since the main essence of coagulation is to reduce the water turbidity to as much as possible. Notwithstanding, the turbidity values obtained at optimum dosages of all the coagulants were within the WHO permissible limit (5NTU). The plots of turbidity versus dosage for the various coagulants is shown in Fig 4. It is obvious in Fig 4 that beyond optimum dosage for alum, the curve became very steep compared to the curves obtained after optimum dosages of moringa seed and plantain peel. This suggest that the flocs produced by alum beyond optimum dosage easily deteriorate the water turbidity compared to moringa seed and plantain peel solution.

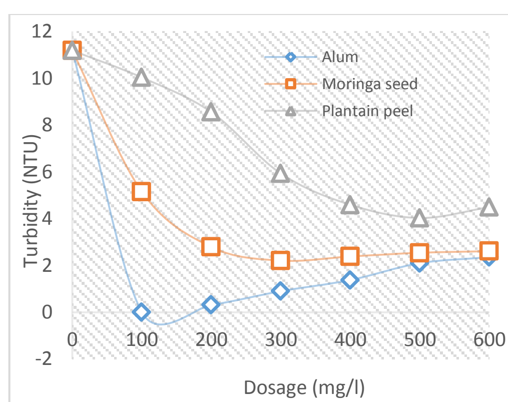

Fig 4. Turbidity versus conagulants dosages

3.2 pH

The pH value of the water decreased with an increase in alum dosage from 6.7 to 6.2 at optimum dosage of 100mg/l, causing the water to deviate from the WHO permissible limits of 6.5 – 8.5. However, the pH increased with an increase in dosage of both bio-coagulants (moringa seed and plantain peel), ranging from 6.8 to 8.0 which is within the permissible limit as could be seen in Fig 5. Treating the water with moringa seed solution increased the pH from 6.7 to 7.3 at optimum dosage of 300mg/l while plantain peel solution raised the pH from 6.7 to 7.5 at optimum dosage of 500mg/l.

The reduction in pH after treating with alum implies that alum impart acidity to water. Similarly, the increase in pH after treating with the bio-coagulants indicate that both moringa seed and plantain peel solutions have the potentials of rendering water alkaline. Hence, the treatment cost associated with the use of lime to raise water pH at water treatment plants could be averted by utilizing the bio-coagulants (moringa seed and plantain peel solutions) which have demonstrated the potentials of raising water pH unlike alum.

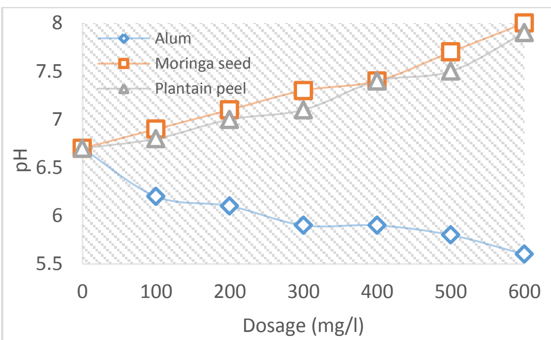

Fig 5. pH versus conagulants dosages

3.3 Hardness

The hardness level of the water increased (deteriorated) with increase in dosage of alum but decreased (improved) with increase in dosage of both moringa seed and plantain peel solutions as could be seen in Fig 6. Treating the raw water with alum solution increased the hardness level from 48.24 to 59.06mg/l as $CaCO_3$, at optimum dosage thus, increasing the hardness level by 22.43% at optimum dosage of 100mg/l. On the other hand, moringa seed solution reduced the hardness level of the water from 48.24 to 41.77mg/l as $CaCO_3$, corresponding to 13.41% reduction at optimum dosage of 300mg/l. Likewise, plantain peel solution reduced the turbidity from 48.24 to 44.13mg/l as $CaCO_3$, which is 8.52% reduction at optimum dosage of 500mg/l.

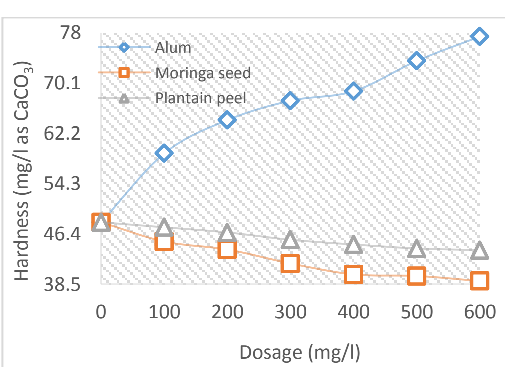

Fig 6. Hardness versus conagulants dosages

The decrease in hardness level of the water with increase in dosages of moringa seed and green plantain peel solutions suggest that both bio-coagulants contain binding sites that might have adsorbed the divalent metallic ions (Ca^{2+} and Mg^{2+}) associated with carbonates and bicarbonates, responsible for temporary hardness. This implies that moringa seed and green plantain peel solutions could as well be used as bio-adsorbents in adsorption of metallic ions thus, affirming previous reports [9, 10, 11]. The reduction in hardness of the water when treated with both bio-coagulants could as well be attributed to the high pH (alkaline) recorded in these bio-coagulants, which might have affected the metallic ions causing hardness to precipitate. In other words, increase in water pH inversely affects the hardness level of the water. This explains why the curves in Fig 6 are roughly the reverse of their corresponding curves in Fig 5.

4. Conclusion

Aluminium sulphate (alum) performed best in terms of turbidity removal since it reduced the turbidity by 99.94% at a small optimum dosage of 100mg/l compared to moringa seed and plantain peel solutions that reduced the turbidity by 80.27% at 300mg/l and 63.99% at 500mg/l respectively. However, alum at optimum dosage lowered the pH of the water from 6.7 to 6.2; a level not recommended by WHO, unlike moringa seed and plantain peel solutions that raised the pH to 7.3 and 7.5 at their optimum dosages respectively without deviating from WHO permissible limits. Also, alum increased the hardness level of the water by 22.43% at optimum dosage while moringa seed and plantain peel solutions reduced the hardness level by 13.41% and 8.52% respectively at their optimum dosages. Hence, due to the drawbacks of alum with respect to pH reduction and hardness formation, which both bio-coagulants have shown to perform well in these aspects, it is recommended that moringa seed solution could be used to replace alum successfully since it also requires small optimum dosage to produce acceptable water quality. However, plantain peel solution needs to be modified in order to increase the turbidity removal efficiency, before using it to replace alum although, it could be used as coagulant in the absence of moringa seed and alum.

Conflict of Interest

The authors declare that they have no conflict of interest.

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