International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
www.allsubjectjournal.com
Volume 4; Issue 1; January 2017; Page No. 36-41

Performance evaluation of *Moringa oleifera* seed powder in surface water treatment and its coagulation kinetics

[1] Iloamuzor FE, [2] Ude CN, [3] Ezekannagha CB, [4] Nwabueze HO

[1, 2] Projects Development Institute (PRODA), P.M.B. 01609, Emene-Enugu, Enugu State, Nigeria
[3] Department of Chemical Engineering, Nnamdi Azikiwe University, Awka, P.M.B.5025, Anambra State, Nigeria
[4] Department of Chemical Engineering, Institute of Management and Technology, (IMT), Enugu, Enugu State, Nigeria

Abstract

The efficiency of *Moringa oleifera* seed powder as a coagulant for the removal/reduction of turbidity from surface water was studied. Batch experiments were carried out to study the effect of various process parameters such as pH, coagulant dose, and settling time on turbidity percentage removal efficiency and the optimum condition for maximum turbidity removal was identified. The kinetics study was carried out to determine parameters such as rate constant and rate order. The results revealed that treating highly turbid and contaminated raw water with *Moringa oleifera* seed powder is viable for household/community use. The optimum dosage, pH and time recorded were 400g/ml, 10 and 25minutes, respectively with percentage removal efficiency of 92.97%. The kinetics study showed that the coagulation was second order.

Keywords: *Moringa oleifera*, coagulation, surface water, turbidity

1. Introduction

Water is essential to human life. The availability of portable water is one of the major challenges facing developing and underdeveloped countries of the world. The common sources of water for people living in these countries are untreated and unprotected water sources such as streams and rivers etc. These sources receive pollutants from surface runoff and cause preventable diseases such as diarrhoea. In developing countries about 2 million people die every year due to diarrhoeal disease; most are children of less than 5 years of age [1]. Other water related diseases reported in Nigeria are trachoma, schistosomiasis, ascariasis, trichuriasis, ancylostomiasis (hookworm), malaria and encephalitis [2, 3].

There is compelling need to make water safe for people in developing countries like Nigeria in order to control outbreak of water related diseases. The common methods of household water treatment require coagulation/flocculation followed by sedimentation, filtration and disinfection. Several chemical coagulants have been employed in conventional water treatment processes for portable water production that includes inorganic, synthetic organic polymer and naturally occurring coagulants [4, 5]. Generally, alum (Aluminum sulphate), an inorganic coagulant and its synthetic polymeric derivatives are widely used in water treatment [5, 6]. However, there is a fear that inorganic coagulant like aluminum may induce Alzheimer's disease and strong carcinogenic properties [3, 5, 7, 8]. On the other hand, there is evidence that the use of extracts from plant species possessing both coagulating and antimicrobial properties are safe for human health [4, 9, 10, 11, 12].

Moringa oleifera (*M. oleifera*) extract is one of the plant extracts that has been tried in various countries and found very successful in the flocculation of suspended matter in waters [3, 5]. In Nigeria even though this plant is grown in many households, its use is limited for food preparation and medicinal applications. For water treatment, the efficiency is dependent on the turbidity of the raw water, as reported by Katayon *et al.*, [13, 14]. *M. oleifera* has also been shown to produce significantly less sludge than aluminium sulphate, which is an advantage especially if the sludge is to be dewatered or treated in some other way before disposal [15]. It can also be used in combination with other coagulants such as aluminium sulphate [16]. The coagulation and flocculation ability of the seeds has been investigated in several studies [15, 17]. These studies have shown that neither pH nor alkalinity nor conductivity was affected during water treatment, but an increase in COD, nitrate and orthophosphate was observed.

The seeds from *Moringa oleifera* have been shown to be one of the most effective primary coagulants for water treatment especially in rural communities [18, 19, 20]. Scientifically, the coagulant properties of *M. oleifera* seeds were first confirmed by the German scientist Samia Alazharia Jahn [21]. The active component, a protein, acts as a cationic polyelectrolyte, which attaches to the soluble particles and creates bindings between them, leading to large flocs in the water. Stirring and mixing was found to accelerate the electrostatic flocculation, and the flocs condense the contaminants [22]. So far, the seeds of *M. oleifera* have not been much used as natural coagulants in surface water treatment in Nigeria. Therefore, this work investigates the efficacy of *M. oleifera* seed powder (MOSP) in purification of water sample from Amansea River in Nigeria.

2. Materials and Methods

2.1 Materials

2.1.1 Sample Collection

Riped dried fruits (pods) of *M.oleifera* were bought from Ogbete Market, Enugu, Enugu State, Nigeria. A jar test apparatus improvised using electronic stirrers and beakers were used to obtain the optimum M. Oleifera seed powder coagulant dose for each experiment run and a sample of raw water was collected from Amansea River, Awka, Anambra State, Nigeria.

2.2 Methods

2.2.1 Sample Treatment

The seed wings and coat were removed and the seed kernel was dried in an oven at 50ºC for 24 hrs. The seeds were ground using a domestic food blender. The oil was removed by mixing the powder in 98% ethanol for 30mins and the solids was separated by centrifugation in a centrifuge machine and dried at room temperature.

2.2.2 Proximate analysis of *Moringa oleifera*

The proximate analyses were carried out according to the procedure of Association of Official Analytical Chemist [23].

2.2.3 Preparation of *Moringa oleifera* Seed Suspension

5% (w/v) solution were prepared using distilled water, NaCl solution or ammonium acetate buffer from the dried sample of M.Oleifera powder, stirred for 30min and filtered through Whatman filter paper and 0.4µm fiber glass. The filtrate obtained is the bio-coagulant.

2.2.4 Characterization of water sample

The methods used by Adejumo *et al.*, [3] were employed to analyze the raw and filtered water sample. The water samples were analysed for pH (using Jenway pH meter) and turbidity (using HACH DR/2000 spectrophotometer at wavelength of 450 nm and expressed as NTU then converted to mg). The conductivity was measured using Jenway 470 Conductivity meter. Total Dissolved Solids (TDS) was determined using Jenway 470 TDS meter; total alkalinity by titration with standard acid (HCl, using methyl orange indicator). The titrimetric method (using disodium dihydrogen ethylenediamine-tetra-acetate) was used to determine total hardness (using powdered Eriochrome Black T (EBT) indicator) and calcium hardness (using powdered murexide indicator). A colorimeter (Jenway 6510, England) at 410 nm was used to determine NO_3-N while an Atomic Absorption Spectrophotometer (Hanna C-100 spectrophotometer (made in UK)) was used for the determination of Iron (Fe), Magnesium (Mg) and Calcium (Ca) by direct reading [24].

2.2.5 Coagulation using MOFP

The procedure employed by Menkiti & Onukwuli [25] was used. Electronic stirrer was set up at a constant speed of 150rpm to stir the solution at different time interval, 5, 10, 15, 20, 25mins. Before the mixing, the pH of the solution adjusted using 1M HCl and 2M $Ca(OH)_2$ added in drops to obtain the pH of 2, 4, 6, 8, 10. After stirring, the sample was allowed to settle for 12hrs after which it was decanted to separate the floccs (denser layer). The turbidity of the collected upper layer was read using HACH turbidity meter which is normally in NTU. Further the results were converted to mg/l concentration by multiplying it with a factor 2.35.

2.3 Kinetics analysis of optimum dosage using numerical method of differential equation

The kinetics of the optimum dosage 400mg/l *Moringa oleifera* was determined using numerical methods of differential equation using three point differential formulas [26].

Initial point

$$\left(\frac{dCA}{dt}\right)_{ti} = \frac{-3CA_0 + 4CA_1 - CA_2}{2\Delta t} \qquad (1)$$

Interior points

$$\left(\frac{dCA}{dt}\right)_{ti} = \frac{1}{2\Delta t}\left[CA_{(i+1)} - CA_{(i-1)}\right] \qquad (2)$$

e.g.

$$\left(\frac{dCA}{dt}\right)_{t3} = \frac{1}{2\Delta t}\left[CA_4 - CA_2\right] \qquad (3)$$

Last point

$$\left(\frac{dCA}{dt}\right)_{t5} = \frac{1}{2\Delta t}\left[CA_3 - 4CA_4 + 3CA_5\right] \qquad (4)$$

Note: the units of reaction rate $\frac{dcA}{dt}$ is $mg\,l^{-1}s^{-1}$ and is applicable to every calculated rate.

2.4 Computation of Coagulation-Flocculation constants

Computation of Menkonu Coagulation-flocculation rate constant, (km)

The rate of depletion of particle count (TSS or turbidity removal) can generally be represented as:

$$-r = K_m N_t^{\alpha} \qquad (5)$$

Where $r = -\frac{dN_t}{dt}$ (6)

$$-\frac{dN_t}{dt} = K_m N_t^{\alpha} \qquad (7)$$

Integrating the above equation gives,

$$\ln(-r) = \alpha \ln N_t + \ln K_m \qquad (8)$$

The above equation is similar to the equation of a straight (y = mx + c). Therefore, a graphical plot of $\ln(-\frac{dC}{dt})$ verses $\ln C$ gives a slope of α and an intercept of $\ln K_m$

Computation of coagulation period, ($\tau_{1/2}$)

This was done using the formula;

$$\tau_{1/2} = {}^{1}/_{(0.5\, N_o K_m)} \qquad (9)$$

Calculation of Friction Factor (β_{BR})

This was done using the formula;

$$K_m = \frac{1}{2}\beta_{BR} \qquad (10)$$

Calculation of Diffusion Coefficient, D'

This was done using the formula;

$$D' = K_B\, {}^{T}/_{\beta_{BR}} \qquad (11)$$

Where;

K_B is Boltzmann constant which is 1.3806488 x 10^{-23} $m^2kgs^{-1}k^{-1}$ and T is temperature which is 301^{O}K.

Calculation of Von Smoluchowski Constant, K_r

This was done using the formula;

$$K_R = 8\pi a D' \qquad (12)$$

Where; a is particle radius (from sieve measurement) = 0.3 x 10^{-3}m.

Calculation of Collision Frequency, E_p

This was done using the formula;

$$K_m = \varepsilon_p K_R \qquad (13)$$

Therefore

$$\varepsilon p = \frac{K_M}{K_R} \quad (14)$$

3. Results and Discussion

3.1 Proximate Analysis of *Moringa oleifera*

Table 1 shows the percentage composition of Moringa seeds powder. In nutritive terms, the percentage composition of carbohydrates, proteins and fats are reasonably obtained from the seeds of this tree in addition to its highly nutritive leaves [27]. Yang *et al.*, [28] reported the nutritional and functional qualities of Moringa, indicating a value of 5.7% for protein and 3% for carbohydrate in the leaves. Comparing these values with values of 2.88% for protein and 5.54% for carbohydrate obtained from the seeds in the present work suggests a reasonable comparative nutrient content of the seeds to the leaves as source of energy [29]. Furthermore, Jiru *et al.*, [30] reported that *Moringa oleifera* is a good source of micronutrient. Earlier reports [31, 32] showed values of 30-40% crude fat content from Moringa seeds which is in agreement with our result of 40% crude fat. The same authors suggested that the fat content of the seeds could have additional uses as lubricating, cooking and soap making oil.

Table 1: Result of Proximate Analysis of *Moringa oleifera*

Parameter	%
Carbohydrate	5.54
Protein	2.88
Crude fiber	30.02
Ash	9.25
Fat	40.00
pH	6.23
Moisture	6.10

3.2 Raw water characteristics

Table 2 presents the results of physico-chemical quality of the raw water used in the study. The source was prone to pollution from dumping domestic and industrial waste into the water body as well as pollution from surface runoff. Most of the parameters were within the permissible limits specified by W.H.O except for turbidity.

Table 2: The result of the Amansea River Water Analysis

Parameter	Value	Unit	W.H.O Guideline Limits
pH	7.69		6.5-8.5
Fe^{2+}	1.2	ppm	3
Alkalinity	32	mg/l	100
Acidity	96	mg/l	
Ca^{2+}	0.07	mg/l	
Mg^{2+}	0.09	ppm	
Turbidity	9969	NTU	5
TDS	82277.29	mg/l	500
TSS	13712.8	mg/l	
COD	13.92	mg/l	
DO	3.54	mg/l	
BOD	17.46	mg/l	
Conductivity	24.12	ms/mc	

3.3 Influence of *Moringa oleifera* coagulant (MOC) on water quality

3.3.1 Influence of MOC dosage and pH on percentage removal of turbidity

Figures 1, 2, 3, 4 and 5 show the influence of *Moringa oleifera* coagulant (MOC) dosage and pH on percentage removal of turbidity at different time. It was observed from these figures that increasing time leads to an increase in the percentage removal of turbidity. It can also be seen from these graphical representations that the as MOC dosage increases with pH, the percentage removal of turbidity increases. Therefore turbidity obtained from the raw water samples were higher as compared to when treated with MOC. This is as a result of the coagulation properties of the *Moringa* seed which is able to remove most of the particles in the raw water within a short time. From the figures, it could be observed that optimum MOC dosage is 400mg/l, optimum pH is 10 and optimum time is 25minutes with percentage removal efficiency of 92.97%.

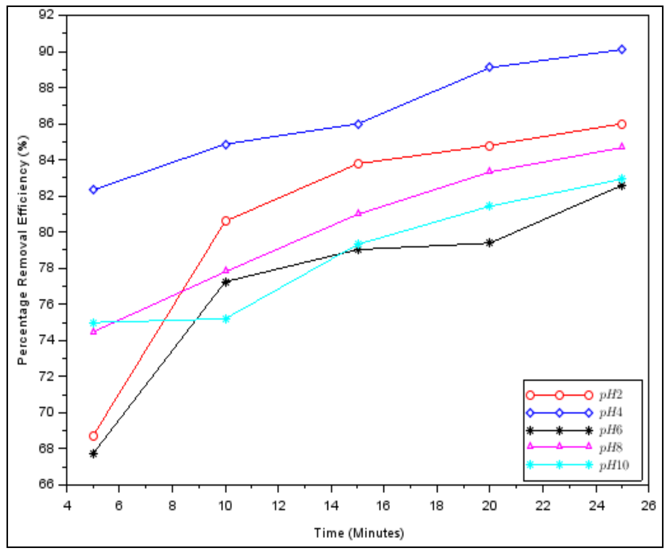

Fig 1: A graph of Removal efficiency against time for MOE at various pH values in 100mg/l dosage.

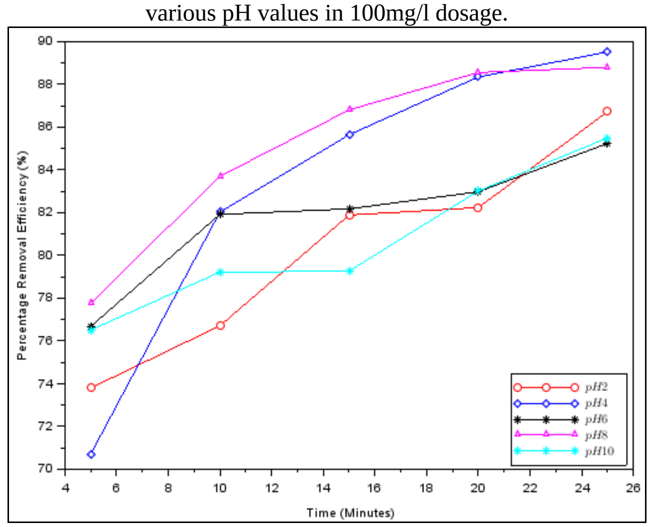

Fig 2: A graph of Removal efficiency against time for MOE at various pH values in 200mg/l dosage.

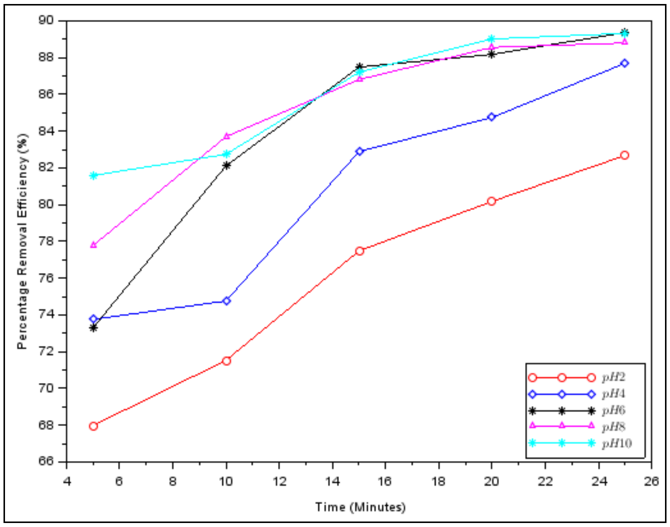

Fig 3: A graph of Removal efficiency against time for MOE at various pH values in 300mg/l dosage.

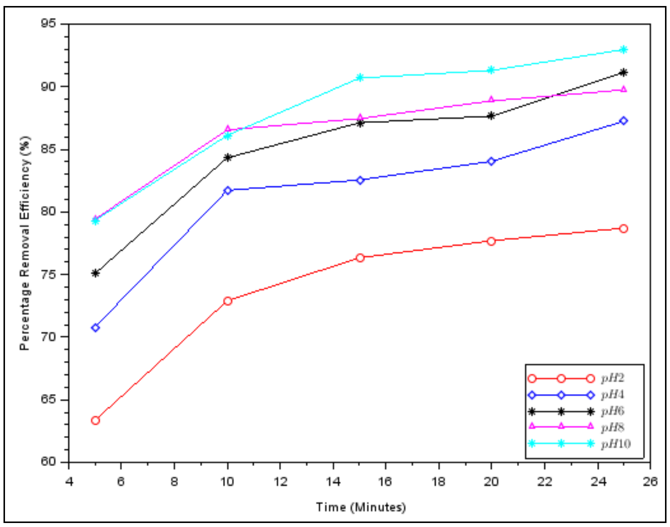

Fig 4: A graph of Removal efficiency against time for MOE at various pH values in 400mg/l dosage.

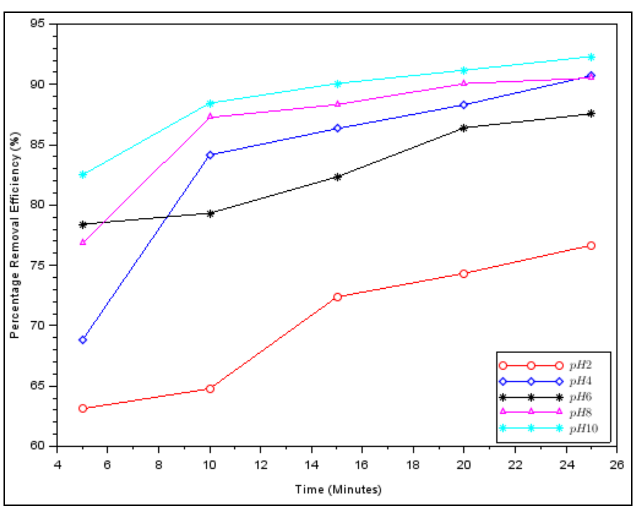

Fig 5: A graph of Removal efficiency against time for MOE at various pH values in 500mg/l dosage.

3.4 Coagulation Kinetics Parameters

The values of some coagulation kinetic parameters and coagulation-flocculation constants were obtained and calculated from Figure 6 and presented in Table 3. The coefficient of regression value R^2 is within $0.600 \leq R^2 \leq 0.899$. The value of α is an indication that the reaction is approximately a second order with the rate constant. $\tau_{1/2}$ relates inversely to K, $\tau_{1/2}$value corresponds to low K as seen in Table 3. This accounts for high rate of settling in high turbidity water which is in agreement with previous work [33]. It is known that coag-flocculation process is favored in alkaline medium following easy delamination of the coag-flocculation phase [33, 34]. However, the results obtained in this work indicate that the best performing medium is highly influenced by the nature of the coagulant. ε_p and K_R are the functional kinetic parameters instrumental to coag-flocculation process. K_R is related to temperature and viscosity of the effluent medium. Because the experiment was conducted under room temperature there were minimal variations in temperature and the effluent viscosity is constant. This may be attributed to the low value of K_R obtained in the experiment as posted in Table 3. In a situation of such low value in K_R, ε_p has a direct relationship with 2k = β_{BR}, which is in line with [33]. Consequently, high ε_p requires enough kinetic energy necessary to overcome the repulsive forces of particles by complete colloid destabilization.

$\tau_{1/2}$, which is understood to be one of the coagulation effectiveness factors, accounting for coagulation efficiency are evaluated based on Equation (9), from thence it is intuitively obvious that $\tau_{1/2}$ is an inverse function of k. As recorded in Table 3, $\tau_{1/2}$value is inversely proportionally to k. That is why the coag-flocculation was recorded at pH of 10 supporting values of $\tau_{1/2}$and k. This is attributed to the fact that the aggregation process in surface water is controlled by stabilizing repulsive interaction mechanism. Finally, the rate equation is found to be a dependent function of k.

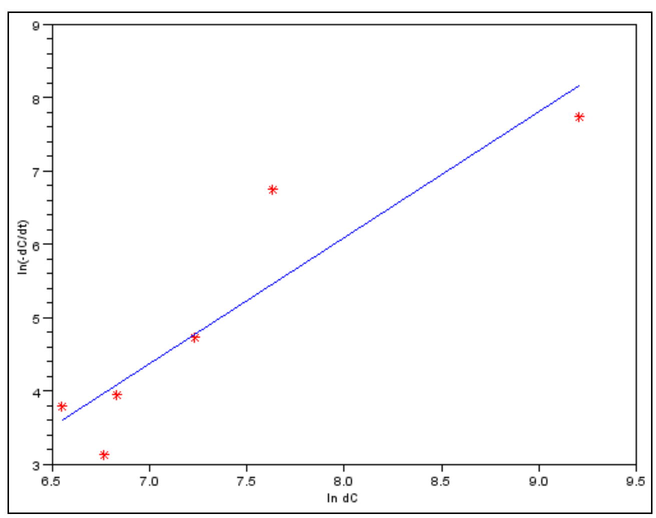

Fig 6: A plot of $\ln(-\frac{dC}{dt})$ *verses* $\ln C$ in 400mg/l MOE dosage of pH 10

Table 3: Coagulation kinetics parameters of *Moringa oleifera* in 400mg/l optimum MOE dosage of various pH at 28°C temperature.

Parameters	pH10
A	1.762
R^2	0.827
K_M (m^3 $kg^{-1}S^{-1}$)	3.288E-04
β_{BR} (m^3 $kg^{-1}S^{-1}$)	6.576E-04
$\tau_{1/2}$ (S)	0.610
K_R (kg^2s^{-1})	4.764E-20
ε_P (m^3 kg^{-3})	6.902E15
D' ($kg^2m^{-1}S^{-1}$)	6.319E-18

4. Conclusion

The effectiveness and efficiency of *Moringa oleifera* seed powder (MOSP) as an alternative organic natural resource in surface water treatment was successfully demonstrated. The study revealed that treating highly turbid and contaminated raw water with *M. oleifera* seed powder is viable for household/community use. The optimum dosage, pH and time recorded are 400g/ml, 10 and 25minutes, respectively. The kinetics study showed that the coagulation was second order.

5. References

1. WHO. Guidelines for Drinking-water Quality, 1st Addendum to the Recommendations, World Health Organization, Geneva, Switzerland, 2006; 3:1.
2. Sridhar MKC, Oloruntoba EO. Water, Development, Health and the Nigerian Millennium Development Goals, Chapter 5, In: T. Agbola CO, Olatubara B, Wahab L. Sanni, Ipingbemi O (Eds). Environmental Planning and Health in Nigeria: Essays in honour of Professor Timothy Olayiwola Egunjobi Department of Urban and Regional Planning, University of Ibadan, Ibadan. 83-112.
3. Adejumo, Mumuni, Oloruntoba, Elizabeth O, Sridhar Mynepalli KC. Use of *Moringa oleifera* (lam.) seed powder as a coagulant for purification of water from unprotected sources in Nigeria. European Scientific Journal. 2013; 9(24):214-229.
4. Okuda T, Baes AU, Nishitimas W, Okada M. Isolation and characterization of coagulant extracted from *Moringa oleifera*seed by salt solution. Water. Resources. 2001; 35(2):405-410. Also available www.elservier.com/located/waters.downloaded.
5. Dalen MB, Pam JS, Izang A, Ekele R. Synergy between *Moringa oleifera* seed powder and alum in the purification of domestic water. Science World Journal. 2009; 4 (4):6-11.
6. Najm I, Tate C, Selby D. Optimizing enhanced coagulation with PAC a case study, Journal of American Water Works Association. 1998; 90(10):88-95.
7. Crapper DR, Krishnan SS, Dalton AJ. Brain Aluminum Distribution in Alzheimer's Disease and Experimental neuro-fibrillary degeneration. Science. 1973; 180:511-513.
8. Mallevialle J, Bruchet A, Fiessinger F. How safe are organic polymers in water treatment. Jounal of American Water Works Association. 1984; 76(6):431-436.
9. Muyibi SA, Okuofu CA. Coagulation of low turbid surface water with *Moringa oleifera* seeds. International Journal of environmental studies. 1995; 46:263-273. http://cat.inistfr/amodele=afficheN$cpsidt=3141587.
10. Ali GH, El-Taweel GE, Ali MA. The cytotoxicity and antimicrobial efficiency of *Moringa oleifera* seeds extracts. International Journal of Environmental Studies. 2004; 61(6):699-708.
11. Akinnibosun HA, Akinnibosun FE, German BE. Antibacterial activity of aqueous and Ethanolic leaf extracts of *Pegeromic Pellucida* (L) H.B & K (Piperaceae) on three Gramnegative bacteria isolates. Science World Journal. 2008; 3(4):33-361.
12. Akinnibosun FI, Akinnibosun HA, Ogedegbe D. Investigation on the antibacterial activity of Aqueous and ethanolic extracts of leaves of Boerhavia diffusa. Science World Journal. 2009; 4(2):15-18.
13. Katayon S, Megat Mohd Noor MJ, Asma M, Thamer AM, Liew Abdullah AG, Idris A, *et al.* Effects of storage duration and temperature of *Moringa oleifera* stock solution on its performance in coagulation. International Journal of Engineering and technology. 2004; 1(2):146-151.
14. Katayon S, Megat Mohd Noor MJ, Asma M, Abdul Ghani LA, Thamer AM, Azni I. Effects of storage conditions of *Moringa oleifera* seeds on its performance in coagulation. *Bioresource technology.* 2006; 97(13):1455-1460.
15. Ndabigengesere A, Narasiah KS, Talbot BG. Active agents and mechanisms of coagulation of turbid water using *Moringa oleifera*. *Water Resources.* 1995; 29(2):703-710.
16. Sutherland JP, Folkard G, Grant WD. Natural coagulants for appropriate water treatment: a novel approach. Waterlines. 1990; 8(4):30-32.
17. Muyibi SA, Alfugara AMS. Treatment of surface water with *Moringa oleifera* seeds and alum– a comparative study using a pilot scale water treatment plant. International Journal of Environmental Studies. 2003; 60(6):617-626.
18. Folkard GK, Sutherland J, Shaw R. Water clarification using *Moringa oleifera* seed coagulant. 2000. Available online at: http://www.lboro.ac.uk/well/resources/technical-briefs/60-water-clarification-using-moringa-oleifera-seeds.pdf (accessed in November 2014).
19. Doer B. Field Guides for Emergency water Treatment with *Moringa oleifera*, 2005. www.cawst.org/technology/watertreatment/filtrationbiosandanphp. Accessed 20th Nov.2014.
20. Onwuliri FC, Dawang ND. Antimicrobial activity of aqueous and ethanolic leaf extract of drumstick plant *Moringa oleifera* Lam on some bacteria species associated with gastro intestinal diseases, Nigerian Journal of Botany. 2006; 9(2):272-279.
21. Schwarz D. Water clarification using Moringa olefiera. Gate Information Service, Germany, Technical Information W1e, 2000. Available online at: http://www.gate international.org/documents/techbriefs/webdocs/pdfs/w1e_2000. pdf (accessed 18th November, 2014).
22. Göttsch E. Purification of turbid surface water by plants in Ethiopia Walia. 1992; 14:23-28. http//www.deutsch aethiopischererein.de/tl_files/downloads/arbeitsgruppen/ moringa/Walia-1992 Purification.pdf (Accessed 19th November, 2014).

23. Association of official analytical chemists, AOAC. Official methods of analysis of the association of official analytical chemists, 15th edition, Washington DC, 1990.
24. American Public Health Association standard method for the Examination of water and wastewater (APHA), 20th edition, Washington DC, 1998.
25. Menkiti MC, Onukwuli OD. Coag-flocculation studies of *Moringa oleifera* Coagulant (MOC) in brewery effluent. Nephelometric approach. Journal of American Science. 2010; 6(12)788-806.
26. Fogler HS. Elements of Chemical Reaction Engineering, 3rd edition, prentice – Hall publishers, India, 1999.
27. Jefrey F. Presenting Moringa's potential to decision, 2006. makers.www.treesforlifejournal.org. Accessed 15th Dec.2014.
28. Yang R, Chang L, Hsu J, Weng B, Palada MC, Chadha ML, *et al*. Nutritional and functional properties of Moringa leaves from germplasm to plant, to food, to health. Symposium on Moringa and other highly nutritious plant resources; strategies, standards, and markets for better impact on nutrition in Africa, Accra, Ghana, 2006. www.treesforlifejournal.org. Accessed 15th November, 2014.
29. Lockett CT, Calvert CC, Lipipun VM, Ahmad M. Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought; study of rural Fulani, Northern Nigeria; International Journal of Food Sciences and Nutrition. 2000; 15(3):195-208.
30. Jiru D, Sonder K, Lolisa A, Mekonen Y, Anjulo A. Leaf yield and nutritive value of *M. stenopetala* and *M. oleifera accessions*. Symposium on Moringa and other highly nutritious plant resources; strategies, standards, and markets for better impact on nutrition in Africa, Accra, Ghana, 2006. www.treesforlifejournal.org Accessed 15th December, 2014.
31. Fuglie LJ. The Miracle Tree; *Moringa oleifera*; Natural Nutrition for the Tropics, Church World Service, Dakar, 1999.
32. Anwar FW, Bhanger MI. Analytical Characterization of *Moringa oleifera* seed oil grown in temperate regions of Pakistan. Journal of Agricultural and Food Chemistry. 2003; 51:6558-6563.
33. Menkiti MC, Onukwuli OD. Coag-flocculation studies of Afzeliabella coagulant in coal effluent using single and simulated multi-angle nephelometry. Journal of Mineral Material Characterization and Engineering. 2011; 10(3):279-298.
34. Ugonabo VI, Menkiti MC, Onukwuli OD. Coagulation kinetics and performance evaluation of *corchorus olitorus* seed in pharmaceutical effluent. International journal of multidisciplinary sciences and engineering. 2012; 3(7):20-32.