Journal of Science and Technology, Imo State University, Owerri (JOST)

©

Volume I issue I

Assessment of The Potentials of a Plant-Based Coagulant (Phoenix Dactylifera) As Substitute For Alum In Conventional Water Treatment Process

*Akuboh, D.O.[1,] Saidu M.[1], Abdulkareem A.S.[2] and Busari, A.O.[1]

[1]*Department of Civil Engineering, Federal University of Technology, Minna, Nigeria.*

[2]*Department of Chemical Engineering, Federal University of Technology, Minna, Nigeria.*

**Corresponding Authors Email Address: dominicakuboh@yahoo.com*

Telephone No: +234 (0) 806 069 1042

Abstract

In a bid to providing potable water, chemical coagulants are employed in water treatment for the purpose of coagulation and flocculation.This process have an effect on human health. This research was carried out to assess the potentials of a plant-based coagulant (Phoenix dactyliferaseed) as substitute for alum, coagulation aids or sources of dilution. The water sampled from river Gorao along Minna-Bida Road in Niger State was done in accordance with the standard laboratory procedures of the American Public Health Association (APHA) for the evaluation of the efficacy of the two coagulants (Plant-Based Coagulant – PBC) and Aluminium Sulphate (Alum). Jar Tests were conducted for some turbidity range.The findings of this research shows that Phoenix dactylifera has potential to act as coagulant with turbidity removal efficiencies of 89.48% and colour removal efficiencies of 66.07%.. However, the WQI shows that phoenix dactylifera produces very poor water quality (grade D) with WQI of 83.59. Optimum Combination of Alum with the plant-based coagulants was ascertained at 40mg/L at 80% Alum and 20% Phoenix dactylifera. The 80% Alum and 20% Phoenix dactylifera mix was observed to possess disinfection properties as the bacteriological water quality parameters namely Total Coliform Count and e-Coli were nil with WQI of 56.26 (Grade C – Poor Quality Water).

Keywords: Alum, Colour, Plant-Based Coagulants, Phoenix dactylifera, Turbidity

1. Introduction

Water is one of the most indispensable resources and is the elixir of life on planet earth (Yisa et al, 2012). The World Health Organisation has stated that safe/potable water is colourless, odourless, tasteless and free of all disease causing organisms or pathogens. Improving access to safe drinking water can result in tangible improvements in health. This is corroborated by the United Nation's Sustainable Development Goal (SDG) 6 which aims to 'Ensure availability and sustainable management of water and sanitation for all' and comprises six technical targets relating to drinking water, sanitation and hygiene, wastewater management, water efficiency, integrated water resource management and protection of aquatic ecosystems.

Water supply is a basic need required for living creatures and human being specifically. Developing countries and third world countries are facing potable water supply problems because of inadequate financial resources. The cost of water treatment is increasing and the quality of river water is not stable due to suspended and colloidal particle load caused by land development and high storm runoff during the rainy seasons. During the rainy seasons, the turbidity level increases and the need for water treatment chemicals increase as well, which leads to high cost of treatment which the water treatment companies cannot sustain. As a result, the drinking water that reaches the consumer is not properly treated (Muhammad et al, 2015). Therefore, it is of great importance to find a natural alternative for water coagulant to treat the turbidity.These alternatives to chemical coagulants are referred to as Nature Based Solutions for Water (WWDR, 2018). Nature Based Solutions for water may be employed to address water availability, improved water quality and reduce risks associated with water related disasters and climate change (WWDR, 2018). Globally, the amount of resources available to living creatures is limited. Safe drinking water is essential to the health and welfare of a community, and water from all sources must have some form of purification before consumption (Muhammad et al, 2015).

Drinking water treatment involves a number of combined processes based on the quality of the water source such as turbidity, amount of microbial load present in water and others include cost and availability of chemicals in achieving desired level of treatment (Muyibiet al, 2009). Conventional methods used for purification of water include coagulation, sedimentation, filtration, aeration and also chemical treatment.

In drinking water treatment, the coagulation process is used to destabilize suspended particles and to react with organic materials in the raw water. Proper coagulation is essential for good filtration performance and for disinfection by product (DBP). Common Coagulants are aluminium sulphate, ferric chloride, poly-aluminium chlorides and synthetic polymers. The use of coagulants such as alum is one of the commonest methods employed and it reduces the repulsive force between particulate matter, encouraging particle collision and floc formation (Moramudaii and Fernando, 2001).

Similarly, in wastewater treatment, coagulation has been practiced since earliest times and the main objective is to remove colloidal impurities hence also removing turbidity from the water (Saharudin and Nithyanandam, 2014). Aluminium and iron coagulants are commonly used in most industries for the treatment of wastewater. However, when aluminium is used as a coagulant in wastewater treatment, it can cause several bad effect on human health such as intestinal constipation, loss of memory, convulsions, abdominal colic's, loss of energy and learning difficulties. Therefore, nowadays there have been great attention in the improvement and implementation of natural coagulants in wastewater treatment too. These natural coagulants can be formed or extracted from animals, microorganisms and also plants (Saharudin and Nithyanandam, 2014)..

2. Aim and Objectives

The aim of the research is to determine the potential of using Plant-Based coagulants specifically Date Palm Seed (*Phoenix dactylifera)* Powder in the coagulation/treatment of turbid river water with specific emphasis on turbidity and colour removal. The specific objectives are to:

I. Determine the coagulation potential of plant-based coagulant (*Phoenix dactylifera)* in the coagulation/treatment of raw river water.
II. Compute and compare Water Quality Index of *Alum* Coagulated and *Phoenix dactylifera* Coagulated Water.
III. Establish on a comparative basis, the possibility of using the plant-based coagulant as stand alone or in combination with alum and ascertain the optimum proportion of the coagulant mix.

3. Scope of Research

The scope in this research is limited to the investigation of the potential of plant products and wastes (Re-use) namely Date Palm (*Phoenix dactylifera)* as coagulant and/or disinfectant in the treatment of raw surface water. The American Standard for the Examination of Water and Wastewater published by the American Public Health Association (APHA) was employed in the physico-chemical and bacteriological laboratory investigation and validated by the computation of water quality index (WQI).

4. Literature Review

The health implications of overdose or long term side effects, cost, availability, disposal of sludge and environmental concerns of modern water treatment chemicals has led to a global awareness on the need for natural alternatives in water and wastewater treatment.
Muhammad *et al* (2015) carried out a study titled "Water Melon Seed as a Potential Coagulant for Water Treatment" and recommended that more natural sources should be investigated for potential coagulation abilities amongst other conclusions. Similarly, Sulaiman*et al* (2017), carried out a study titled "*MoringaOleifera* Seed as alternative natural coagulant for potential application in Water Treatment: A Review" and concluded that *MoringaOleifera* seed extract is a potential source for water treatment due to it's efficiency. When used for the treatment of wastewater, excellent results were obtained. The seeds are environmentally-friendly because they do not further deteriorate the environment. Also due to its availability and maximum effluent removal from both domestic and synthetic wastewater, the application of the seeds in wastewater treatment in undeniable. He further recommended the extraction of oil from the seeds before using as a coagulant for water treatment in order to achieve optimum effluent reduction.

Also, Ogunlela and Famakinwa (2016), carried out a study titled "The Use of *MoringaOleifera*Seed Powder for Treating Recirculatory Aquaculture System (RAS) Discharge" and quoted that Amagloh and Benang (2009) in the study of comparison of effectiveness of *MoringaOleifera*and alum, at 95.0% confidence level, showed that there was significant difference among all the treatments at the varying loading dose concentrations on the *p*H. Increase in alum dosage leads to increase in acidity of water but the reverse was observed with the Moringa treatment. The use of natural materials of plant origin to clarify turbid water is not a new idea (Sani ,1990, Ndabigengesereet *al*., 1995, Folkard and Sutherland, 2001). Among all the plant materials that have been tested over the years, powder processed from the seeds from *Moringaoleifera*has been shown to be one of the most effective as a primary coagulant for water treatment and can be compared to that of Alum (conventional chemical coagulant). It was inferred from their reports that the powder has antimicrobial properties. Also, Oria- Usifo (2014) in a comparative coagulation studies between alum and *Moringaoleifera*concluded that compared to the commonly used coagulant chemicals, *MoringaOleifera*has a number of advantages: it is of low cost, it produces biodegradable sludge, it produces lower sludge volume and it does not affect the pH of the water. The above listed advantages make *MoringaOleifera*consumer and environmentally friendly low cost alternative with significant potential both in developing and developed countries. One major advantage that *MoringaOleifera*seed has over all other coagulants is that it's readily available at cheaper amount. It can be propagated from seed or from cutting of the stem. Within 3 years of planting one tree will produce 300 to 400 pods every year and a mature tree can produce up to 1000 pods. Frequent pruning of the growth tips will maintain and increase leaf growth and the height can be controlled to make harvesting easier (HDRA, 2002).

Aside *MoringaOleifera* and Water Melon, Saleem*et al.,* (2019) carried out an extensive Contemporary review on Plant-Based Coagulants for applications in water treatment from various related literatures and came up with a list of about 46 plant-based coagulants with the use of various parts such as seeds, grains and roots as coagulants. A brief list of some popular plant-based coagulants within the African sub-region that have been investigated are contained in table below:

Table 1.0: Some Investigated Plant-Based Coagulants

S/No	Plant Name	Plant Part	Reference(s)
1.	*MoringaOleifera*	Seeds	Ogunlela and Famakinwa (2016), Amagloh and Benang (2009), Oria- Usifo (2014), Sulaiman*et al* (2017).
2.	*Citrulluslanatus*(Water Melon)	Seeds	Muhammad *et al* (2015)
3	*Abelmoschusesculentus/Hibiscus esculentus (okra)*	Mucilage	Saleem*et al.*,(2019)
4	*Jatropha Curcas*	Seeds	Saleem*et al.*, (2019)
5	*Phoenix dactylifera*	Seeds, Pollen grains	Saleem*et al.*, (2019) Al-Sameraiy (2012)
6	*CeratoniaSiliqua (Locust Bean)*	Seeds	Saleem*et al.*, (2019)
7	*Hylocereus Undatus (Dragon fruit)*	Fruit foliage	Saleem*et al.*, (2019)
8	*MangiferaIndica (Mango)*	Seeds	Saleem*et al.*, (2019)
9	*PisumSativum (Pea)*	Seeds	Saleem*et al.*, (2019)
10	*TamerindousIndica (Tamarind)*	Seeds	Saleem*et al.*, (2019)
11	*VignaUnguiculata (Cowpea)*	Seeds	Saleem*et al.*, (2019)
12	*Zea May (Corn)*	Grain	Saleem*et al.*, (2019)

The use of surface and groundwater for drinking and domestic purposes in most rural communities within many developing countries has become common practice. This source of water usually requires treatment prior to consumption because this water contains dissolved and suspended solids. The essential removal of these contaminants from this source of water can be carried out through coagulation, a process in water treatment involving the destabilization of colloidal particles to form *flocs* that can then be easily removed. This destabilisation is achieved by the addition of positively charged *ions* known as coagulants to water containing colloidal particles, which are almost always negatively charged. Over previous decades, chemical coagulants have been used in water treatment for the removal of suspended solids and the reduction of the turbidity of water, bacteria and viruses. The common types of these chemical coagulants are aluminium sulphate, ferrous sulphate and ferric sulphate. The application of chemical coagulants in water and wastewater treatment has been determined to cause impurities present in colloidal forms to adhere upon contact, forming *flocs* which can then be easily removed (Bhuptawat*et al*, 2007 and Pritchard *et al*. 2010, Bakare, 2016).

However, chemical coagulants are not readily available in developing countries, can be quite expensive for people living in remote rural areas in developing countries, and can pose adverse effects on public health if not applied at the correct dose. Therefore, the use of natural coagulants of plant origin is a viable alternative to chemical coagulants. It has been widely documented that extracts from plants such as *MoringaOleifera* have proven effective in the removal of suspended solids, in turbidity removal, in softening of hard water, and also in the reduction of slurry produced as compared with that produced by chemical coagulants (Folkard*et al*, 1989, Muyibi and Evision, 1995 and Ndabigengesere*et al*, 1998, Bakare, 2016).

The use of *MoringaOleifera* leaves the seeds as waste or by-product. Similarly, the consumption of Date Palm produces the seeds as by-products. These organic by-products may be said to be wastes most especially after oil extraction when practicable, but could however, be recycled as natural coagulant for the treatment of water and wastewater

Muhammad *et al* (2015) concluded their research on the use of water melon as a potential coagulant for water treatment by recommending that more natural sources should be investigated for potential coagulation abilities. Naturally occurring coagulants are usually presumed safe for human health (Ogunlela and Famakinwa, 2016). The above narratives justifies the reason why we are investigating the potential of Date Palm seed (*Phoenix Dactylifera*) in comparison with alum in this study.

A number of studies have pointed out that the introduction of natural coagulants and adsorbents as a substitute for metal salts may ease the problems associated with chemical coagulants. Using natural coagulants instead of aluminium salts might give advantages, such as lower cost of water production, less sludge production and ready availability of reagents. There are also disadvantages such as increased concentration of nutrients and chemical oxygen demand (COD) in the treated water due to the organic nature of this type of coagulants (Muhammad *et al*, 2015).

The findings ofAl-Sameraiy (2012) in a paper titled " A Novel Water Pre-treatment Approach for Turbidity Removal Using Date Palm Seeds and Pollen Sheath" reveals that date palm seeds are environmentally-friendly,It achieved a significant reduction in turbidity to less of 5 NTU that meeting WHO drinking water guidelinesfor all tested synthetic turbid water, It produced excellent water quality having residual turbidityless of 0.1 NTU, decreased the settling time to 30 minutes and minimize risks of alum dose requiredto 60% and was therefore recommended as pre-treatment approach in advanced water treatment.

From the foregoing, the development of natural, environmentally-friendly/biodegradable, renewable, cost-effective, easy to use and alternative sources of water treatment by recycling and re-use of organic wastes especially for use in rural areas and developing countries can therefore not be over-emphasized.

Table 2.0: Characterisation of *Phoenix dactylifera*

S/No.	Description	*Phoenix dactylifera*(Date Palm)
1	Nature of Plant	Tree
2	Botanical Name	*Phoenix dactylifera*Linn
3	Chemical/Nutrient Composition	Cellulose, hemicellulose, and lignin, oil and protein, 0 to 65 % sugar (glucose and fructose), about 2.5 % fibre, 2 % protein and less than 2 % each of fat, minerals, and pectinsubstances.
4	Plant Type	Perennial Tree
5	Parts used for Water Treatment (Absorbent) in existing researches.	Seeds
6	Availability in Nigeria	Predominant in North-West and North East e.g. Jigawa, Katsina, Sokoto, Bauchi, Gombe.
7	Specie	Variable
8	Native Names	*Debino (in Hausa Language)*
9	Common Uses	Human Consumption, Food, shelter, timber products and all the parts can be used.
10	Suitable Vegetation Belt	Guinea and Sudan savannah.
11	Environmental Benefits	Controls Desert Encroachment, Soil erosion and conserves soil water.
12	Family	*Arecaceae*

Source: Mehdi *et al*., 2019.

5.0 Materials and Methods

5.1 Materials & Instrumentation

The material and equipment used for this research are as follows:

i. Aluminium Sulphate (Alum)
ii. Date Palm (*Phoenix dactilyfera*) Seed – Dried with origin from Jibiya in Katsina State, Nigeria
iii. Laboratory Reagents as specified by the Standard Method for the Examination of Water and Wastewater by the American Public Health Association (APHA).
iv. Two (2) 150ml and nine (9) 75ml plastic bottles for Water Samples
v. Grinding Machine

vi. Distilled Water
vii. Pestle and Mortar
viii. Equipment: Equipment used includes Flocculator/Standard Jar Test Equipment, Magnetic Stirrer, Calorimeter, Turbidity Meter, Dissolved Oxygen Metre, pH Meter, Digital Weighing Balance and Burner. Laboratory Equipment used includes Titration Apparatus, Beakers, Conical Flasks, Measuring Cylinder, Spatula.

5.2 Methods

5.2.1. Raw Water Sample and Coagulants Sample Collection

The raw water sample to be subjected to treatment in this study was sourced from River Goroa, Minna-Bida Road, where local Gold mining occurs. All standard procedures for sample collection, storage, transportation and preservation stipulated by APHA was observed. The natural substrates to replace alum namely Date Palm seed *(Phoenix dactylifera)* was sourced carefully after engagement with relevant stakeholders such as the National Oil Palm Research Institute (NIFOR), Date Palm Sub-Station, Dutse, Jigawa State. Alum and *Phoenix dactylifera* Coagulants solutions were successively prepared using 10g/100ml of distilled water and added to the water samples at various doses for the conduct of Jar Test to determine the effect on flocculation and sedimentation as well as the optimum dose for the coagulants. The above process was repeated using a combination of Alum and each of the plant-based coagulants too in varying proportions. The raw water sample was also tested for physical, chemical and bacteriological characteristics in accordance with the procedures of the American Public Health Association (APHA), American Water Works Association (AWWA) and the World Environment Federation (WEF) standard for the examination of water and wastewater before the application of the artificial (Alum) natural coagulant (*Phoenix dactylifera)*Seed extract at the optimum dose of the natural substrates and the respective water quality index computed to validate the results of the water quality tests or otherwise

Plate i: Raw Water Samples

A. Alum Crystal

B. Date Palm Tree/Fruit

C. Date Palm Seed

D. Date Palm Seed Powder

Plate ii: Alum Crystal and Date Palm Value Chain

5.2.2. Preparation of Coagulant Solutions

(A) Alum Coagulant Solution

Alum was sourced from the Lower Usuma Water Treatment Plant Store and subsequently broken down into crystals and crushed in the laboratory into smooth powdered form. 10g of the powdered alum was measured on the weighing scale and mixed with 100ml distilled water and stirred properly by the aid of electric magnetic stirrer in the laboratory.

(B)*Phoenix dactylifera* Seed as Coagulant Solution

Phoenix dactylifera Seeds were sourced from Jibiya in Katsina State, Nigeria and subsequently sun dried for some days pounded and grinded to powdered form. It was then sieved several times through the least available domestic sieve. 10g of the powdered *Phoenix dactylifera* Seeds was measured on the weighing scale and mixed with 100ml distilled water and stirred properly by the aid of electric magnetic stirrer in the laboratory.

Figure 1.0: Research Flow Chart

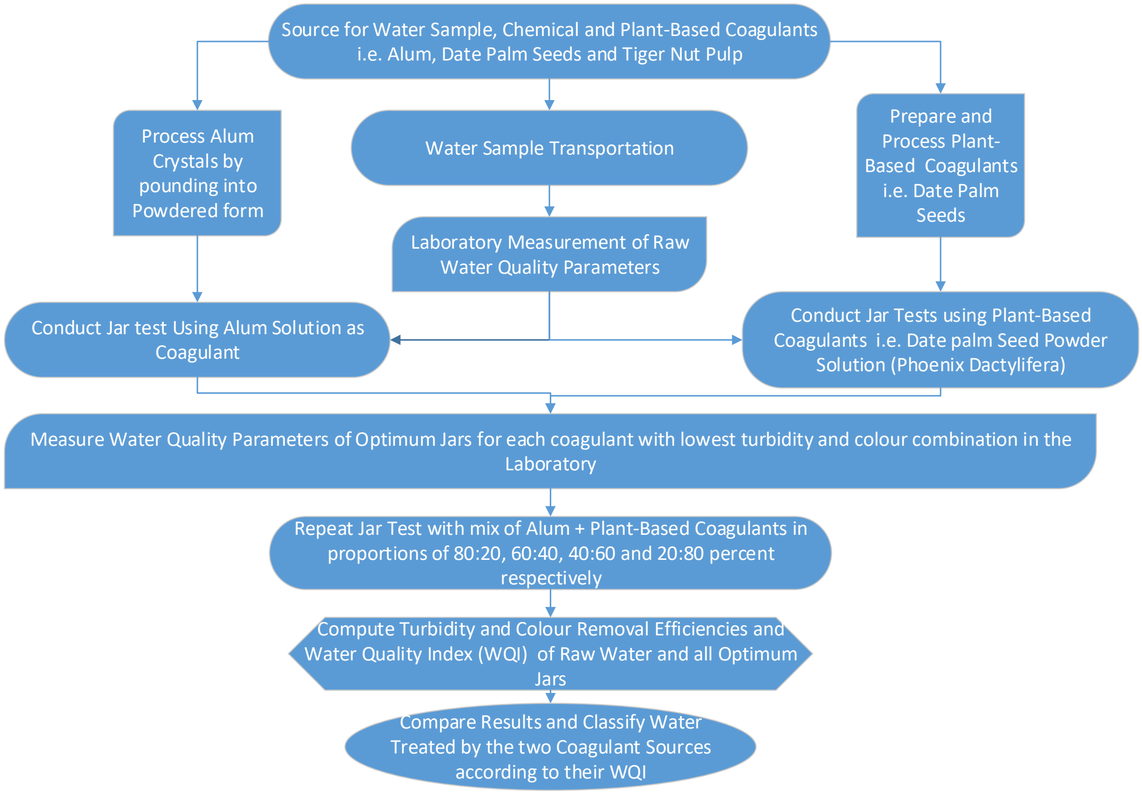
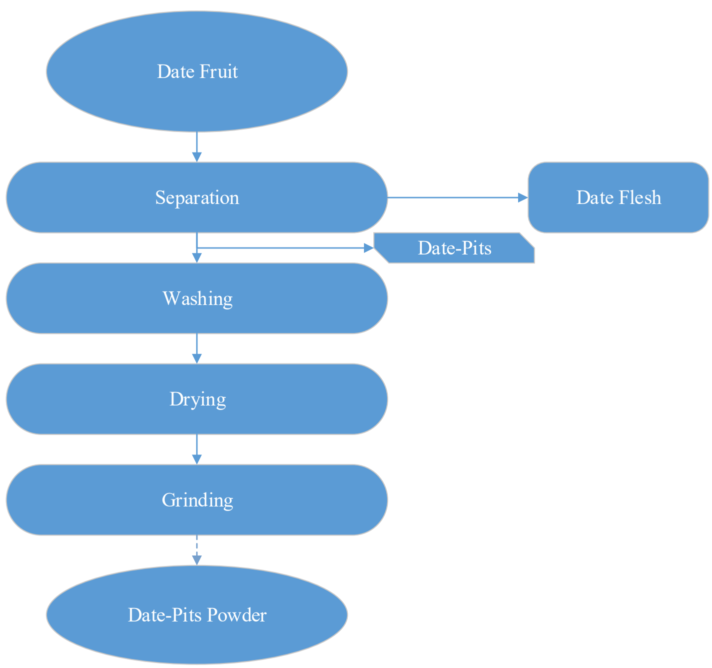


Figure 2.0: Flow Diagram of Preparation of Date-Pits Powder



Source: Hossain *et al.*, (2014).

5.2.3. Experimental Procedure – Water Quality and Jar Tests

Physico-Chemical and Bacteriological water quality parameters where determined in the laboratory on the raw water and coagulants treated water in line with the standard procedures for the examination of Water and waste water stipulated by the American Public Health Association (APHA) and American Water Works Association (AWWA). Jar Tests were conducted to determine optimum or effective dosage of a coagulant to be applied in treatment of the raw water. In this case, alum was replaced by prepared Date Palm Seeds and Tiger Nut Wastes respectively to determine the optimum dose. A Stuart Flocculator equipped with a six (6) number of paddles for rapid and slow mixing is used. A Turbidimeter is used for turbidity measurements in the process after a given settling time. 100ml of the raw water were measured in six number 100ml beakers each and the paddles inserted in each. The flocculator was switched on at a speed of 250rpm for 3 minutes for rapid mixing. After 3 minutes, the speed was reduced to 25rpm for slow missing and this continued for 17 minutes for coagulation/flocculation. 30 minutes settling time was allowed before the residual turbidity and other water quality parameters were measured.

Plate 3: Jar Test Equipment (Flocculator)

5.5.4. Water Quality Tests

The quality of the Raw Water/Wastewater is tested before and after treatment with the optimum dose obtained from the jar test (after filtration) for it's physico-chemical and Bacteriological parameters in line with the APHA Examination of Water and Wastewater guidelines and compared with native or WHO water quality standards for conformity or otherwise. For the Purpose of this study, we shall use twenty-one (21) Physico-chemical water quality parameters were employed in the determination of Water Quality Indices. They are ***pH, Turbidity, Colour, Electrical Conductivity,TDS, Aluminium, Iron, lead, Calcium, Magnesium, Manganese, Sulphate, Chloride, Nitrate, Nitrite, Chromium, Hardness, Alkalinity, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO).***

5.5.6. Methods for Determination of Water Quality Parameters.

The Methods for the determination of Water Quality parameters in the laboratory are as stipulated by the American Public Health Association Handbook for the Examination of Water and Wastewater. The methods are tabulated below:

Table 3.0: Methods of Laboratory Determination of Water Quality Parameters

S/No.	Parameter	Chemical Notation	Unit	Method Reference	Method
	A. Physical Parameters				
1	Colour	Colour	Pt-Co	APHA 2120D	Spectrophotometric Method
2	Odour	Odour			
3	Taste	Taste			
4	Temperature	T	^{o}C	APHA 2550B	Laboratory Measurement
5	Turbidity	Tur.	NTU	APHA 2130B	Nephelometric Method
6	pH	*pH*		APHA 4500H^{+}B	Electrometric Method
7	Electrical Conductivity	EC	µS/cm	APHA 2510B	Laboratory Measurement
8	Total Dissolved Solid (TDS)	TDS	mg/L	APHA 2510B	Laboratory Measurement
	B. Chemical Paramaters/Cations				
9	Aluminium	Al	mg/L	APHA 3500 - Al B	Eriochrome Cyanine R Method
10	Alkalinity		mg/L	APHA 2320B	Titration Method
11	BoD	BOD_5	mg/L	APHA 5210B (Calculation)	5-Day BOD Test
12	Dissolved Oxygen	DO	mg/L	DO Meter	Laboratory Measurement
13	Chloride	Cl	mg/L	APHA 4500Cl-B	Argentometric Method
14	Calcium	Ca	mg/L	APHA 3500 Ca-D	Calculation
15	Magnesium	Mg	mg/L	APHA 3500 Mg-D	Calculation
16	Manganese	Mn	mg/L	APHA 3500-Mn B	Persulfate Method
17	Chromium	Cr	mg/L	APHA 3500-Fe D	Calorimetric
18	CoD	CoD	mg/L	APHA 5220D (Calometric)	Closed Reflux, Colorimetric Method
19	Copper	Cu	mg/L	APHA 3500-Cu _B	Neocuproine Method
20	Zinc	Zn	mg/L	APHA 3500-Zn B	Zincon Method
21	Iron	Fe	mg/L	APHA 3500-Fe B	Phenanthroline Method
22	Lead	Pb	mg/L	APHA 3500-Pb B	Dithizone Method
23	Sulphate	SO_4	mg/L	APHA 4500SO_4^{2-}E	Turbidimetric Method
24	Flouride	F	mg/L	APHA 4500-F^{-}C	Ion-Selective Electrode Method
25	Nitrite	NO_2	mg/L	APHA 4500NO_2^{-}B	Colorimetric Method
26	Nitrate	NO_3	mg/L	APHA 4500NO_3^{-}B	Ultraviolet Spectrophotometric Screening Method
27	Hardness		mg/L	APHA 2340C	EDTA Titrimetric Method
28	Phosphate	PO_4^{3-}	mg/L		
	C. Bacteriological Parameters				
29	Total Coliform Count	TCC	MPN	APHA 9222B	Standard Total Coliform Membrane Filter Procedure
30	e-Coli (*Faecal* Coliform)	e-Coli	Cfu/100mL	APHA 9222E	Delayed-Incubation Thermotolerant (Fecal) Coliform Procedure

5.5.6 Method for Water Quality Index Determination

The Weighted Arithmetic Water Quality Index was employed in the determination of the water quality indices for the raw water, chemical and plant-based coagulated water samples.

Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables. The method has been widely used by the various scientists and the calculation of WQI was made by using the following equation:

$$WQI = \frac{\sum QiWi}{Wi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

The quality rating scale (Qi) for each parameter is calculated by using this expression:

$$Qi = \frac{100(Vi - Vo)}{(Si - Vo)} \qquad \text{……1a}$$

Where,

Vi is estimated concentration of *i*th parameter in the analysed water

Vo is the ideal value of this parameter in pure water

Vo = 0 (except pH =7.0 and DO = 14.6 mg/l)

Si is recommended standard value of *i*th parameter

The unit weight (w_i) for each water quality parameter is calculated by using the following formula:

$$Wi = \frac{K}{Si} \qquad \text{……1b}$$

Where,

K = proportionality constant and can also be calculated by using the following equation:

$$K = \frac{1}{\sum (1/Si)} \qquad \text{……1c}$$

K is equal to unity (Armah*et al*, 2012).

6.0 Results and Discussion

The results derived from the laboratory investigation of the raw water sample in relation to the World Health Organisation guidelines for drinking water quality and the use of Alum, and *Phoenix dactylifera* consecutively and in varying proportion in coagulation are presented in this section. The results were further analysed to ascertain the efficiencies of turbidity and colour removal for the three coagulants for the purpose of comparison. Water Quality Indices were also computed to classify the water obtained after coagulation with the various coagulants to corroborate the results so obtained.

Table 4.0: Average Raw Water Quality Parameters

S/No.	Parameter	Chemical Notation	Unit	Concentration		Average Conc.	Maximum Limit (WHO)
				25th Feb., 2020	19th March, 2021		
1	Colour	Colour	Pt.Co	405	1383	894	15
2	Odour	Odour		Unobjectionable	Unobjectionable		
3	Taste	Taste		Unobjectionable	Unobjectionable		
4	Temperature	T	^oC	27.7	27.8	27.75	
5	Turbidity	Tur.	NTU	50	192	121	5
6	pH	*pH*		7.22	7.05	7.135	6.5 - 8.5
7	Electrical Conductivity	EC	µS/cm	286	222	254	250
8	Total Dissolved Solid (TDS)	TDS	mg/L	251	144	197.5	1000
				B. Chemical Parameters			
9	Aluminium	Al	mg/L	22.4	32.4	27.4	0.2
10	Alkalinity		mg/L		106	106	120
11	BoD	BOD_5	mg/L	102	1.9	51.95	6
12	Dissolved Oxygen	DO	mg/L	5.5	7	6.25	5
13	Chloride	Cl	mg/L	24.9	31.9	28.4	250
14	Calcium	Ca	mg/L	32.1	30	31.05	75
15	Magnesium	Mg	mg/L	17.1	22	19.55	50
16	Manganese	Mn	mg/L		1.2	1.2	0.1 to 0.5
17	Chromium	Cr	mg/L	0.08	0.05	0.065	0.1
18	CoD	CoD	mg/L	4	11.00	7.5	10
19	Copper	Cu	mg/L	0.016	0.86	0.438	1 to 2
20	Zinc	Zn	mg/L		0	0	2
21	Iron	Fe	mg/L	3.11	1.62	2.365	0.3
22	Lead	Pb	mg/L	0.001	0.003	0.002	0.01
23	Sodium	Na	mg/L	40		40	200
24	Potasium	K	mg/L	14		14	
25	Sulphate	SO_4	mg/L	7	7.00	7	250
26	Flouride	F	mg/L	0.7	0	0.35	1.5
27	Nitrite	NO_2	mg/L	0.139	0.091	0.115	3
28	Nitrate	NO_3	mg/L	7.46	12.5	9.98	50
29	Hardness		mg/L		120	60	200
30	Phosphate	PO_4^{3-}	mg/L			0.26	0.26
				C. Bacteriological Parameters			
31	Total Coliform Count	TCC	MPN	84	1530	807	0
32	e-Coli (*Faecal* Coliform)	e-Coli	Cfu/100mL	14	645	329.5	0

Note: *All measurements requiring measuring devices were repeated at least three times.*

6.1. Coagulated Water Test Results - Alum

Two jar tests were conducted using Alum as coagulant in 2020 and 2021 respectively. The test carried out in 2020 was a trial test. The results of Jar Tests carried out using Alum solution as coagulant in 2020 and 2021 are presented in Appendix F and G respectively. The computation of turbidity and colour removal efficiencies arising from the results of the jar tests are presented in tables 4.2, 4.3, 4.4 and 4.5 below.

Table 5.0: TrialTurbidity Removal Efficiency for 100% Alum 2020

Jar	Alum Dose	Initial Turbidity (T_o) (NTU)	Final Turbidity (T_f)	Turbidity Removal Efficiency $T_e = (T_o - T_f)/T_o *100$
1	10	121.00	2.74	97.74
2	20	121.00	2.30	98.10
3	30	121.00	2.67	97.79
4	40	121.00	2.73	97.74
5	50	121.00	3.17	97.38
6	60	121.00	2.74	97.74
			Average Te	**97.75**

Table 6.0: Turbidity Removal Efficiency for 100% Alum 2021

Jar	Alum Dose	Initial Turbidity (T_o) (NTU)	Final Turbidity (T_f)	Turbidity Removal Efficiency $T_e = (T_o - T_f)/T_o *100$
1	10	121.00	4.95	95.91
2	20	121.00	5.41	95.53
3	30	121.00	5.78	95.22
4	40	121.00	6.64	94.51
5	50	121.00	7.16	94.08
6	60	121.00	6.91	94.29
			Average T_e	**94.92**

Average Turbidity Removal Efficiency for Alum = (97.75 + 94.92)/2 = **96.34**

Table 7.0: Trial Colour Removal Efficiency for 100% Alum 2020

Jar	Alum Dose	Initial Colour (C_o) (Pt. Co)	Final Colour (C_f)	Colour Removal Efficiency $C_e = (C_o - C_f)/C_o *100$
1	10	894.00	1.00	99.89
2	20	894.00	BR	
3	30	894.00	BR	
4	40	894.00	BR	
5	50	894.00	15.00	98.32
6	60	894.00	6.00	99.33
			Average C_e	**99.18**

BR – Below Range

Table 8.0: Colour Removal Efficiency for 100% Alum 2021

Jar	Alum Dose	Initial Colour (C_o) (Pt. Co)	Final Colour (C_f)	Colour Removal Efficiency $T_e = (C_o - C_f)/C_o *100$
1	10	894.00	215.00	75.95
2	20	894.00	154.00	82.77
3	30	894.00	65.00	92.73
4	40	894.00	BR	
5	50	894.00	BR	
6	60	894.00	BR	
			Average C_f	**83.82**

Average Colour Removal Efficiency for Alum = (99.18 + 83.82)/2 = **91.50**

6.2. Coagulated Water Test Results – 100% *Phoenix dactylifera*

Similarly, Jar test was conducted using *phoenix dactylifera* seed powder solution as coagulant in place of alum. The results of Jar Tests carried out were used in the computation of turbidity and colour removal efficiencies arising from the results of the jar test are presented in tables 9 and 10 below.

Table 9.0: Turbidity Removal Efficiency for 100% *Phoenix dactylifera*

Jar	Phoenix Dactylifera	Initial Turbidity (T_o) (NTU)	Final Turbidity (T_f)	Turbidity Removal Efficiency $T_e = (T_o - T_f)/T_o$ *100
1	10	121.00	12.80	89.42
2	20	121.00	13.30	89.01
3	30	121.00	13.40	88.93
4	40	121.00	12.80	89.42
5	50	121.00	12.50	89.67
6	60	121.00	11.60	90.41
			Average Te	**89.48**

Turbidity Removal Efficiency Ratio = *T_e(Phoenix dactilyfera)/T_e(Alum) x 100*

= (89.48/96.34)x100 = **92.88%**

Table 10.0: Colour Removal Efficiency for 100% *Phoenix dactylifera 2020*

Jar	Phoenix Dactylifera	Initial Colour (C_o) (Pt. Co)	Final Colour (C_f)	Colour Removal Efficiency$C_e = (C_o - C_f)/C_o$ *100
1	10	894.00	299.00	66.55
2	20	894.00	275.00	69.24
3	30	894.00	280.00	68.68
4	40	894.00	301.00	66.33
5	50	894.00	325.00	63.65
6	60	894.00	340.00	61.97
			Average C_e	**66.07**

Colour Removal Efficiency Ratio = (66.07/91.50)x100 = **72.21%**

6.3. Combination of Alum and Plant-Based Coagulants

6.3.1 Coagulated Water Test Results – Combination of Alum and *phoenix Dactylifera*in Varying Percentages.

Jar Test was conducted at the optimum *Phoenix dactylifera* coagulant dose of 40 mg/L and second best optimum dose of 30 mg/L for the purpose of comparison using a combination of alum and *phoenix dactylifera*coagulants at proportions of Alum: *Phoenix dactylifera* of 80%:20%, 60%:40%, 40%:60% and 20%:80% respectively. This step was predicated on the fact that the turbidity and colour removal efficiencies of *phoenix dactylifera* even though close to that of alum did not exceed it. 80% alum and 20% *phoenix dactylifera* coagulant was found to produce the optimum jar with turbidity of 8.71 NTU and colour of 51 Pt.Co at a temperature of 29.9^{o}C.

6.4. Summary of Results for Turbidity and Colour Removal Efficiencies and Optimum Dose and Combination of the Plant-Based Coagulants with Alum

The summary of the Turbidity and Colour removal efficiencies as well as the optimum dose and percentage coagulant combination with Alum are presented in table 11 below.

Table 11.0: Summary of Turbidity, Colour Removal Efficiencies, Optimum Dose and Proportion of Coagulant Combination with Alum.

S/No	Coagulant	Turbidity Removal Efficiency Te (%)	Colour Removal Efficiency Ce (%)	Te(Alum Average)/Te	Ce(Alum Average)/Ce	Optimum Proportion in Combination with Alum (Alum/Nature-Based Coagulant)	Optimum Combined Coagulant Dose D(%)
1	Alum	94.92 - 97.75	83.82 - 99.18	N/A	N/A	N/A	N/A
2	Phoenix Dactylifera	89.48	66.07	1.08	1.38	80/20	40

NOTE: Averages of Teand Ce for Alum are 96.34% and 91.50% respectively. Alum is 8% more efficient in Turbidity removal and 38% more efficient in colour removal than Phoenix dactylifera coagulant.

Table 12.0: Consolidated Experimental Results

S/No.	Parameter	Chemical Notation	Unit	Maximum Limit (WHO)	Raw Water	Alum Coagulation 2020	Alum Coagulation 2021	Average for Alum	*Phoenix Dactylifera* (P.D) Coagulation 100%	80% Alum + 20% PD@ 30mg/L	80% Alum + 20% PD@40mg/L
	A. Physical Parameters										
1	Colour	Colour	Pt.Co	15	1,383.00	BR	154	154	920	75	51
2	Odour	Odour		non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable
3	Taste	Taste		non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable	non-objectionable
4	Temperature	T	°C		27.80	27.70	27.80	27.75	27.00	29.80	29.90
5	Turbidity	Tur.	NTU	5	192.00	50.00	192.00	121.00	55.90	8.96	8.71
6	pH	*pH*		6.5 - 8.5	7.05	7.22	7.05	7.14	7.50	7.40	7.30
7	Electrical Conductivity	EC	µS/cm	250	222.00	286.00	222.00	254.00	210.00	223.00	238.00
8	Total Dissolved Solid	TDS	mg/L	1000	144.00	251.00	144.00	197.50	138.40	134.50	142.90
	B. Chemical Paramaters/Cations										
9	Aluminium	Al	mg/L	0.2	32.40	1.4	1.4	1.40	1.4	1.35	1.4
10	Alkalinity		mg/L	120	106.00	106	106	106	82	86	84
11	BoD	BOD_5	mg/L	6	1.90	0.80	0.80	0.80	0.80	0.80	0.60
12	Dissolved Oxygen	DO	mg/L	5	7.00	8.00	8.00	8.00	7.60	8.80	9.00
13	Chloride	Cl	mg/L	250	31.90	35.80	21.80	28.80	15.90	21.80	15.90
14	Calcium	Ca	mg/L	75	30.00	35.30	24.00	29.65	30.40	22.40	22.40
15	Magnesium	Mg	mg/L	50	22.00	10.20	10.90	10.55	18.10	22.90	21.70
16	Manganese	Mn	mg/L	0.1 to 0.5	1.20	2.50	1.60	2.05	4.60	1.50	0.50
17	Chromium	Cr	mg/L	0.1	0.05	0.01	0.01(BR)	0.00	0.00	0.00	0.00
18	CoD	CoD	mg/L	10	11.00	0.00	0.00	0.00	3.00	0.00	0.00
19	Copper	Cu	mg/L	1 to 2	0.86	0.004	0.004	0.004	0.004	0.004	0.005
20	Zinc	Zn	mg/L	2	0.00						
21	Iron	Fe	mg/L	0.3	1.62	0.07	0.07	0.07	1.93	0.15	0.06
22	Lead	Pb	mg/L	0.01	0.003	0.003	0.003	0.003	0.002	0.003	0.003
23	Sulphate	SO_4	mg/L	250	7.00	66.00	21.00	43.50	21.00	13.00	15.00
24	Flouride	F	mg/L	1.5	0.00						
25	Nitrite	NO_2	mg/L	3	0.091	0.005	0.008	0.0065	0.077	0.01	0.006
26	Nitrate	NO_3	mg/L	50	12.50	0.20	0.80	0.50	27.40	2.70	2.30
27	Hardness		mg/L	200	120.00	182.00	96.00	139.00	102.00	90.00	100.00
28	Phosphate	PO_4^{3-}	mg/L		0.26	0.32	0.39	0.355	0.56	0.31	0.20
	C. Bacteriological Parameters										
29	Total Coliform Count	TCC	MPN	0	1530.00	0.00	46.00	46.00	96.00	0.00	58.00
30	e-Coli (*Faecal* Coliform)	e-Coli	Cfu/100m	0	645.00	0.00	12.00	12.00	56.00	0.00	26.00

6.5 Water Quality Index Determination and Coagulated Water Classification:

Weighted Arithmetic water Quality Index was employed in the determination of the Water Quality Indices after the use of all coagulants in this research. WQI computations were done and that for the raw water is tabulated in table 13.0 below. The summary of the computations is tabulated in table 14 below.

Table 13.0: WQI Computation for Raw Water

S/No	Parameter	Notation	Unit	Raw Water Sample	Standard Permissible Level as per WHO Guidelines	Ideal Value	Unit Weight (Wi)	Quality Rating Qi	Qi*Wi
				Vi	Si	Vo	(1/Si)	((Vi - Vo)/(Si - Vo))*100	
1	Calcium	Ca	mg/L	31.05	**75**	0.00	0.0133	41.40	0.55
2	Magnesium	Mg	mg/L	19.55	**50**	0.00	0.0200	39.10	0.78
3	Manganese	Mn	mg/L	1.20	**0.5**	0.00	2.00	240.00	480.00
4	Chromium	Cr	mg/L	0.07	**0.1**	0.00	10.00	65.00	650.00
5	Iron	Fe	mg/L	2.365	**0.3**	0.00	3.33	788.33	2,627.78
6	Lead	Pb	mg/L	0.002	**0.01**	0.00	100.00	20.00	2,000.00
7	Chloride	Cl	mg/L	28.40	**250**	0.00	0.00	11.36	0.05
8	Sulphate	SO_4	mg/L	7.00	**250**	0.00	0.00	2.80	0.01
9	Nitrate	NO_3	mg/L	9.98	**10**	0.00	0.1000	99.80	9.98
10	Nitrite	NO_2	mg/L	0.115	**3**	0.00	0.33	3.83	1.28
11	Dissolved Oxygen	DO	mg/L	6.25	**5**	14.60	0.20	86.98	17.40
12	Biochemical Oxygen Demand	BOD_5	mg/L	51.95	**6**	0.00	0.17	865.83	144.31
13	Chemical Oxygen Demand	COD	mg/L	7.50	**10**	0.00	0.10	75.00	7.50
14	Turbidity	Tur.	NTU	121.00	**5**	0.00	0.20	2,420.00	484.00
15	Colour		Pt-Co	894.00	**15**	0.00	0.07	5,960.00	397.33
16	Total Alkalinity		mg/L	106.00	**120**	0.00	0.01	88.33	0.74
17	Total Hardness	TH	mg/L	9.98	**200**	0.00	0.01	4.99	0.02
18	*pH*	*pH*		7.14	**8.5**	7.00	0.12	9.00	1.06
19	Total Dissolved Solids	TDS	mg/L	197.50	**1000**	0.00	0.00	19.75	0.02
20	Electrical Conductivity	EC	µS/cm	254.00	**250**	0.00	0.00	101.60	0.41
21	Aluminium	Al	mg/L	32.40	**0.2**	0.00	5.00	16,200.00	81,000.00
						ΣW_i =	**121.68**	**ΣQ_iW_i =**	**87,823.21**
							WQI = $\Sigma Q_iW_i/\Sigma W_i$	**721.77**	
								Grade E: Unsuitable for Drinking Purpose	

Table 14.0: Consolidated Results for Water Quality Index and Water Quality: Classification for the Coagulants/Coagulant mix Used

S/No	Description of Coagulant/Coagulant Mix	WQI	Water Quality Classification	WQ Interpretation as Per WAWQI Method
1	Raw Water	721.77	Grade E	Unsuitable for Drinking Purpose
2	100% Alum	68.21	Grade C	Poor Water Quality
3	100% Phoenix davtylifera	83.59	Grade D	Very Poor Water Quality
4	80% Alum + 20% Phoenix Dactylifera	56.26	Grade C	Poor Water Quality

6.6 Discussion of Results:

Colour: The initial average water colour was 1383 Pt-Co. while the least colour out of the coagulants used stands at 51Pt.Co using 100% Alum and 20% Phoenix dactylifera coagulant at 40mg/L. The W.H.O acceptable maximum standard for drinking water is 15Pt-Co. This indicates that the Phoenix dactylifera reduced the initial average colour of the raw water 27.12 times (2712%) to 51Pt.Co. Though above the W.H.O guideline by 36Pt.Co. The processes of filtration and disinfection is expected to improve the colour in a conventional water treatment facility.

Turbidity: The initial raw water turbidity was 192 NTU while the least turbidity out of both coagulants used stands at 8.71 NTU using 80% Alum and 20% Phoenix dactylifera at 40mg/L coagulant dose. The W.H.O acceptable maximum standard for drinking water is 5NTU. This indicates that the coagulant mix reduced the initial turbidity of the raw water 22.044 times (2204.4%) to 8.71 NTU. Though slightly above the W.H.O guideline by 2.71 NTU, the processes of filtration and disinfection is expected to bring the turbidity value within acceptable range in a conventional water treatment facility.

pH: The pH of the water in all the cases of the tests falls within the W.H.O guidelines of 6.5 to 8.5 with the least being 7.14 for alum coagulant. Using 8.5 as the maximum limit of pH gives 16% reduction in pH using 100% Alum coagulant.

Electrical Conductivity (EC): The initial average water electrical conductivity was 222 µS/cm. while the least EC out of the coagulants used stands at 210 µS/cm using 100% Phoenix dactylifera coagulant. The W.H.O acceptable maximum standard for drinking water is 250µS/cm. This indicates that the Phoenix dactylifera reduced the initial EC of the raw water 0.054 times (5.4%) to 12µS/cm. Both the EC for the raw water and the least EC above are within the W.H.O maximum acceptable limit of 250µS/cm.

Total Dissolved Solids: The initial average water Total Dissolved Solids (TDS) was 144mg/L. while the least TDS value out of the coagulants used stands at 134.5mg/L using 80% Alum and 20% Phoenixdactylifera coagulant at 30mg/L. The W.H.O acceptable maximum standard for drinking water is 1000mg/L. This indicates that the coagulant reduced the initial TDS of the raw water 0.066 times (6.6%) to 134.5mg/L. All TDS values obtained for the raw water, the least TDS and all the TDS above are within the W.H.O maximum acceptable limit of 1000mg/L.

Biochemical Oxygen Demand (BOD): The initial average water BOD was 0.8mg/L. while the least BOD out of the coagulants used stands at 0.6mg/L using 80% Alum and 20%Phoenix dactyliferaat 40mg/L dose coagulant. The W.H.O acceptable maximum standard for drinking water is 6mg/L. This indicates that the coagulant mixreduced the initial BOD of the raw water 0.25 times (25%) to 0.6mg/L. All BOD values obtained for the raw water, the least BOD and all others above are within the W.H.O maximum acceptable limit of 6mg/L as they range from 0.8 to 1.9mg/L.

Dissolved Oxygen (DO): The initial average water DO was 7.0mg/L. while the least DO out of the coagulants used stands at 7.6mg/L using 100% Phoenix dactylifera. The W.H.O acceptable maximum standard for drinking water is 5mg/L. All DO values obtained for the raw water, the least DO and all others above exceeds the W.H.O maximum acceptable limit of 5mg/L as they range from 7.2 to 9mg/L.

Chemical Oxygen Demand (COD): The initial average water COD was 11mg/L. while the least colour out of the two plant-based coagulants stands at 0.0mg/Lusing all the coagulants/coagulant mix with the exception of 100% Phoenix dactylifera which was 3.0mg/L. The W.H.O acceptable maximum standard for drinking water is 10mg/L. This indicates that the coagulant reduced the initial COD of the raw water 1.0 times (100%) to 0.0mg/L.

Calcium: The initial average water Calcium concentration was 30mg/L. while the least Calcium value out of the coagulants used stands at 22.4mg/L using 80% Alum and 20%Phoenix dactyliferaat 40 and 40mg/L dose respectively The W.H.O acceptable maximum standard for drinking water is 75mg/L. This indicates that the coagulant mixreduced the initial Calcium of the raw water 1.3393 times (133.93%) to 22.4mg/L. All Calcium values obtained for the raw water, the least Calcium and all others above are within the W.H.O maximum acceptable limit of 75mg/L as they range from 22.4 to 30.4mg/L.

Magnesium: The initial average water Magnesium concentration was 22mg/L. while the least Magnesium value out of the coagulants used stands at 10.55mg/L using 100% Alum coagulant. The W.H.O acceptable maximum standard for drinking water is 50mg/L. This indicates that the coagulant (Alum) reduced the initial Magnesium content of the raw water 0.5245 times (52.45%) to 17.6mg/L. All Magnesium values obtained for the raw water, the least Magnesium and all others above are within the W.H.O maximum acceptable limit of 5mg/L as they range from 10.55 to 30.2mg/L.

Iron: The initial average water Iron concentration was 1.62mg/L. while the least Iron value out of the coagulants used stands at 0.06mg/L using 80% Alum and 20% Phoenix dactylifera at 40mg/L coagulant dose. The W.H.O acceptable maximum standard for drinking water is 0.3mg/L. This indicates that the coagulantreduced the initial Iron content of the raw water 27 times (2700%) to 0.06mg/L. The iron values obtained from the use of 100% Phoenix dactylifera exceeds the W.H.O maximum acceptable limit of 0.3mg/L.

Lead: The initial average water Lead concentration was 0.003mg/L. while the least Lead value out of the coagulants used stands at 0.002mg/L using 100% Phoenix dactylifera. The W.H.O acceptable maximum standard for drinking water is 0.01mg/L. This indicates that the coagulantreduced the initial lead content of the raw water 5 times (500%) to 0.002mg/L. All lead values obtained from the use of both coagulants were within the W.H.O maximum acceptable limit of 0.3mg/L.

Sulphate: The initial average water Sulphate concentration was 7.00mg/L. while the least sulphate value out of the coagulants used stands at 13.00mg/L using 80% Alum and 20% Phoenix dactylifera at 30mg/L coagulant dose. The W.H.O acceptable maximum standard for drinking water is 250mg/L. This indicates that Sulphate content of the water rather increased with the use of the coagulants in this instance.

Total Coliform Count: The initial raw water total coliform count was 1530MPN while the least total coliform count out of the two plant-based coagulants stands at 0.00 NTU using phoenix dactylifera coagulant at 30mg/L. The W.H.O acceptable maximum standard for drinking water is 0MPN. This indicates that the coagulant reduced the initial total coliform count of the raw water to meet threshold specified by the W.H.O guidelines in one instance. Other values for total coliform count were above the W.H.O specification.

E-Coli: The initial raw water e-coli was 645Cfu/100ml while the least e-coli out of the two plant-based coagulants stands at 0.00 NTU using phoenix dactylifera coagulant at 30mg/L. The W.H.O acceptable maximum standard for drinking water is 0Cfu/100ml. This indicates that the coagulant reduced the initial total coliform count of the raw water to meet the requirement specified by the W.H.O guidelines in one instance. Other values for e-coli were above the W.H.O specification.

6.7. Water Quality Index and Water Quality Classification

The computation of Water quality Index as summarized in table 14.0 shows that 100% Alum and 80% Alum + 20% Phoenix dactylifera at 40mg/L produced Grade C (Poor Water Quality) with WQI values of 68.21 and 56.26 respectively.100% Phoenix dactylifera coagulant solution produced Grade D (Very Poor Quality Water) with WQI value of 83.59. The raw water was established to have a water quality index of 721.77, Grade E and unsuitable for drinking purposes. While Phoenix dactyliferahas potentials as coagulant, it performs optimally in combination with alum and limited the usage of alum coagulant by at least 20%.

7.0 Recommendations

The recommendations arising from this research are as follows:

1. Further Investigation be carried out on other potential plant-based coagulants especially those that produces a lot of environmental wastes with the aim to having many option of plant-based coagulants at the disposal of end users. This will also enhance access to clean water in rural areas thereby helping to attain the sustainable development goal on water and sanitation.

2. The use of a combination of 80% Alum and 20% Phoenix dactylifera tends to have some disinfection properties as it reduced Total Coliform Count and e-coli to zero. Further investigation in this regard is strongly recommended.

3. Phoenix dactyliferais more effective as a coagulant aid for the water sample in question.

4. The colour of Phoenix dactylifera seed powder which is dark brown can be aesthetically improved by pigmentation without adversely affecting it’s coagulation ability. This area should be researched further too.

8.0 Conclusion

The conclusion arising from this research are drawn in the order of the objectives.

In the first instance, the results of the physical parameters prior to and after the conduct of jar tests and the resultant analysis of individual water quality parameters using the plant-based coagulant namely Phoenix dactylifera seed powder shows that it has potential to serve as coagulant.

Secondly, the Water Quality Index was computed for the raw water, alum andphoenix dactylifera seed powder as well as combination of alum and the plant-based coagulant at effective dose. The result obtained classified the water in each case as indicated accordingly. The raw water and the 100% Phoenix dactylifera coagulated water were classified as grade E (Unsuitable for drinking purpose) and grade D (Very Poor Water Quality) with WQI of 721.77 and 83.59 respectively. Similarly, 100% Alum and 80% Alum + 20% Phoenix dactyliferacoagulant mix were classified as Grade C (Poor Water Quality) with WQI of 62.21 and 56.26 respectively.

Thirdly, Phoenix dactyliferarecorded turbidity and colour removal efficiencies of 89.48% and 86.71% respectively in comparison to alum. Comparatively, the turbidity and colour removal efficiencies of Alum from the research was 97.75% and 99.18% respectively. This implies that alum if more effective than phoenix dactyliferacoagulant but the turbidity removal efficiency of Phoenix dactyliferacoagulants is more than 80% which is also good.

Finally, a combination of alum and the plant-based coagulant reveals that the optimum dose of 40mg/L suffices for a combination of 80% Alum and 20% Phoenix dactyliferaas coagulant. The plant-based coagulants functions optimally and effectively in combination with alum rather than when acting alone. Therefore, Phoenix dactyliferahasthe capacity to limit the use of alum coagulant by at least 20%.

REFERENCES

Al.Sameraiy M. (2012). A Novel Water Treatment Approach for Turbidity Removal Using Date Seeds and Pollen Sheath. Journal of Water Resource and Protection 04(02):79 – 82. January, 2012. DOI:10.4236/jwarp.2012.42010

Amagloh, F.K. and Benang, A. (2009). Effectiveness of MoringaOleifera Seed as Coagulant for Water Purification. African Journal of Agricultural Research Vol. 4 (1), pp. 119-123, February 2009. Available online at http://www.academicjournals.org/AJAR. ISSN 1991-637X © 2009 Academic Journals.

Armah F.A, Luginaah I. &Ason B. (2012). "Water Quality Index in the Tarkwa Gold Mining Area in Ghana", The Journal of Transdisciplinary Environmental Studies vol. 11, no. 2, 2012.

Arnoldsson E., Bergman M.,Matsinhe N. and Persson K.M (2008) ."Assessment of drinking water treatment using MoringaOleiferanatural coagulant". VATTEN 64:137–150. Lund 2008. www.foreningenvatten.se

Bakare B.F. (2016). An Investigation of MoringaOleifera Seed Extract as a Natural Coagulant in Water Treatment. Proceedings of the World Congress on Engineering and Computer Science 2016 vol II., October 19 – 21, 2016, San Francisco, USA. ISBN: 978-988-14048-2-4, ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online).

HDRA. 2002. MoringaOleifera: A Multi-Purpose Tree. HDRA - The Organic Organisation. Coventry, UK.

Hossain M.Z , Waly M.I, Singh V., Sequeira V.,Rahman M.S (2014).Chemical Composition of Date–Pits and Its Potential for Developing Value–Added Product – a Review, Polish Journal of Food and Nutrition Science, 2014, Vol. 64, No. 4, pp. 215–226, DOI: 10.2478/pjfns-2013-0018. http://journal.pan.olsztyn.pl

Mehdi J. , Masoud S. , Younes S. , Alireza A. , Hamid Z.andTizazu M. (2019). A Review on Date Palm Tree: Properties, Characterization and Its Potential Applications. Journal of Renewable Materials. January 2019. DOI: 10.32604/jrm.2019.08188

Muhammad I.M, Abdulsalam S., Abdulkarim A. and Bello A.A (2015). Water Melon Seed as a Potential Coagulant for Water Treatment. Global Journal of Researched in Engineering: C Chemical Engineering, Volume 15, Issue 1, Version 1.0. Published by Global Journals Inc. 9USA), Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Ogunlela, A.O and Famakinwa, J.O (2016). The Use of MoringaOleifera Seed Powder for Treating Recirculatory Aquaculture System (RAS) Discharge. The International Journal of Science and Technoledge, Vol. 4, Issue 9, September, 2016, pp 77 - 81. ISSN 2321 – 919X. www.theijst.com.

Oria-Usifo E. E., Anyata, B.U. and Ekenta, E.O. (2014). Use of MoringaOleifera seed extracts as alternative natural material for water purification. Journal of Engineering and Applied Sciences 10 (2014), 41 – 53.

Saleem M., Sami A.J. and Bachmann R.T., Characterisation and coagulant activity screening of fractionated water-soluble seed proteins from MoringaOleifera, Materials Today: Proceedings (4th International Conference on Green Chemical Engineering and Technology: Materials Science), 2214-7853/ 2020 Elsevier Ltd. https://doi.org/10.1016/j.matpr.2020.03.700

Sulaiman M., Zhigila D.A., Mohammed K., Umar D.M., Aliyu B., Manna F.A (2017). MoringaOleifera seed as Alternative Natural Coagulant for Potential Application in Water Treatment: A Review. Journal of Advanced Review on Scientific Research 30, Issue 1 (2017) 1-11. Pernebit Academia Baru. ISSN: 2289-7887. www.akademiabaru.com/arsr.html

Saharudin N.F.A. and Nithyanandam R. (2014). Wastewater Treatment by Using Natural Coagulant, Chemical Engineering Department, School of Engineering, Taylor's University, Malaysia. 2nd eureka 2014.

United Nations World Water Development Report (WWDR, 2018). Nature Based Solutions for Water. World Water Assessment Programme of UNESCO financially supported by the Government of Italy. p.2, 4.

WHO (2012). Guidelines for Drinking-Water Quality, Fourth Edition. ISBN 978 92 4 1548151.

Yisa J., Jimoh T.O, Oyibo O.M (2012). "Underground Water Assessment Using Water Quality Index", Leonardo Journal of Sciences, Issue 21, July – December, 2012, pp. 33 – 42.ISSN 1583 – 0233.