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Treatment of Drinking Water for Rural Household using Moringa Seed Coagulant and Ultraviolet Disinfection

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***Abstract*:- This paper investigates the use of *Moringa oleifera (MO)* seeds and Utraviolet (UV) light as natural coagulant and disinfectant respectively in a laboratory-scale water treatment plant. It examined the potency of MO in replacing aluminium sulphate (Alum) which is used widely all around the world in water treatment. The plant consists of 50 L coagulation stainless steel tank with motorized stirring mechanism; 50 L stainless steel settling tank; a 0.5 hp pump; three carbon filters; a UV sterilizer, and 50 L stainless steel storage tank. Samples of raw water from three different sampling points were analysed to determine their physicochemical properties namely, temperature, pH, turbidity, conductivity, total dissolved solids (TDS), chlorides, nitrates, sulphates and dissolved oxygen. An optimum dosage of 5 mL MO extract was used in the 3 samples and the samples were manually agitated for 5 minutes and allowed to settle for an hour. The results show reasonable reduction in the level of bacteria which were in conformity with World Health Organisation (WHO) standards. Fecal coliform and clostridium perfringens spore were completely eliminated from 1.2 cfu/100 mL and 13.8 cfu/100 mL respectively to 0 cfu/100 mL. This indicates that the water samples contain no disease-producing organisms. E-coli and count were reasonably reduced from 5.03 cfu/100 mL to 1.2 cfu/100 mL while total coliform was reduced from 35.6 cfu/100 mL to 12.1 cfu/100 mL which are within the acceptable standard limits.**

Keywords: Coagulants, Moringa oleifera, water treatment, Laboratory-scale and turbidity.

1. INTRODUCTION

The level of purity of the water being consumed in the rural and urban communities in Nigeria is very crucial since it has direct effect on health. According to UNICEF 2021 report, more than 86 % of Nigerians lack access to clean water. The report also stated that approximately, one person dies every ten seconds due to diseases related to consumption of unsafe water. This sums up to 3,575,000 persons every year. The consequences of drinking unhealthy water are therefore enormous.

Water quality describes the physical, chemical and microbiological characteristics of water. These properties collectively determine the overall water quality and the fitness of the water for a specific use. The physical quality of water is determined by its temperature, viscosity, surface tension, electrical conductivity, colour, taste and odour. Chemical quality of water is determined by presence of dissolved organic and inorganic substances such as chromium, arsenic, calcium carbonate, sodium chloride, pH, hardness, chemical stability, and free available and combined chlorine species. The microbiological quality of water is determined by the type and numbers of microorganisms present in the water (Abiyu et al., 2018; Amanda, 2018 and Schutte, 2006).

Water is of two major sources namely surface and ground water. Surface water is often contaminated by microbes, dissolved substances, improper drainage of untreated industrial effluents directly into water bodies and agricultural fields, etc. On other hand, groundwater can be contaminated by harmful chemicals from human activities or the natural environment. The raw water needs to be subjected to treatment processes so that these organisms and substances are removed (Kumar, 2015). The conventional water treatment plant includes screening, coagulation, flocculation, sedimentation, filtration and disinfection units. High construction cost of conventional water treatment plant and distribution system in most developing countries makes it difficult to provide safe and adequate water for all households, especially for the rural communities.

Many coagulants are widely used in conventional water treatment processes for potable water production. These coagulants can be classified into inorganic coagulant, synthetic organic polymer, and naturally occurring coagulant. Synthetic polyelectrolytes are used as primary coagulant as well as coagulant aid to improve the strength of particle aggregates, enhance coagulation and deposition (filtration). Naturally occurring coagulants are usually presumed safe for human health while there is a fear by using aluminum salts that may induce Alzheimer's disease. Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from microorganisms, animals or plants.

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The use of natural materials in water treatment is not new as their use dates back to the ancient time. However, lack of knowledge on how they work has impeded their wide application (Ali *et al*, 2008). Recently many researchers such as Yongabi *et al*, (2011) and Yahaya *et al* (2011), have investigated the use of plant seeds as coagulants and disinfectants that could provide useful insight in water treatment. A number of plant materials studied are *Moringa oleifera, Magnifera indica, Prunus armeniaca Jatropha curcas, Hibiscus sabdarifa, Pleurotustuberregium; Azardiratica indica, Solanum melongena, Cynodon dactylon, Alternanthera sessilis, Anisochilus carnosuss,* Among these plant species, *Moringa oleifera* species have received good attention due to their extraordinary nutritional values and their excellent coagulation property.

The most important part used for water treatment is the waste product of the seed i.e. the defatted cake which can be obtained at a very low cost. The crude extract of Moringa oleifera seed is commonly used in water treatment and purification. Exhaustive literature reviews have shown the usefulness of the seed for water treatment. Earlier researches have revealed its ability to treat high, medium and low turbidity water. It can also be used as a softening agent as well as been as a dewatering agent, hence, its importance cannot be overemphasized in water treatment.

When Moringa oleifera is compared with conventional chemical coagulants, it has the following advantages such as cost effectiveness, availability, biodegradable sludge, eco-friendly, low sludge volume, non-production of harmful by-products, ease of handling as it is not corrosive, and it does not affect pH of water. In the light of the above advantages, Moringa oleifera is environmentally friendly and available at low cost which can be good alternative to chemical coagulants with a potential application in water treatment in developing countries.

Water treatment at the source such as solar disinfection using UV radiation in water treatment domain can be the best alternative and most important renewable energy applications and is ideal for any community. Ultraviolent light is characterized by wavelengths between 100 and 400 nm, but the most effective disinfection wavelengths are in the range of 200 to 280 nm. Furthermore, the UV source of radiation used is usually a low-pressure mercury arc lamp that generates short-wave ultraviolent in the region of 253.7 nm powered by alternative current source through electronic ballast which generates high energy consumption depending on the amount of water to be disinfected (Brahmi, and Abdennaceur, 2012).

2. RESEARCH METHODOLOGY

2.1 General Description of the plant

The Water Treatment Plant consists of the following units:

i. **Water intake:** This is a sump from which water is drawn for the plant. The suction line is fitted with a foot valve which screens out debris from entering the line. The sump 200 L cylindrical stainless steel tank.

ii. **Coagulation unit:** This is a 50 L stainless steel cylindrical water tank fitted with a mechanical stirrer to facilitate mixing of the Moringa *Oliefera* coagulant with water.

iii. **Stirrer motor:** It is an AC powered actuator for driving the mechanical stirrer in the coagulation tank.

iv. **Primary and Secondary settling tanks** consist of two 50 L cylindrical stainless-steel tanks for the coagulated water to freely settle down in order to attain effective filtration.

v. **Water filter:** This involves the use of filter cups for filtration.

vi. **Water pump:** This is to pump water from one tank to another.

vii. **Treated water tank:** This is a 200 L cylindrical stainless-steel tank for storage of treated water.

viii. **UV Lamp:** A device used to disinfect water.

ix. **Power house:** This house the control unit and power supply for the entire plant.

x. **Solar panel:** This converts sunlight energy to electric energy for the purpose of power supply.

Figure 1 shows the schematic diagram of the plant.

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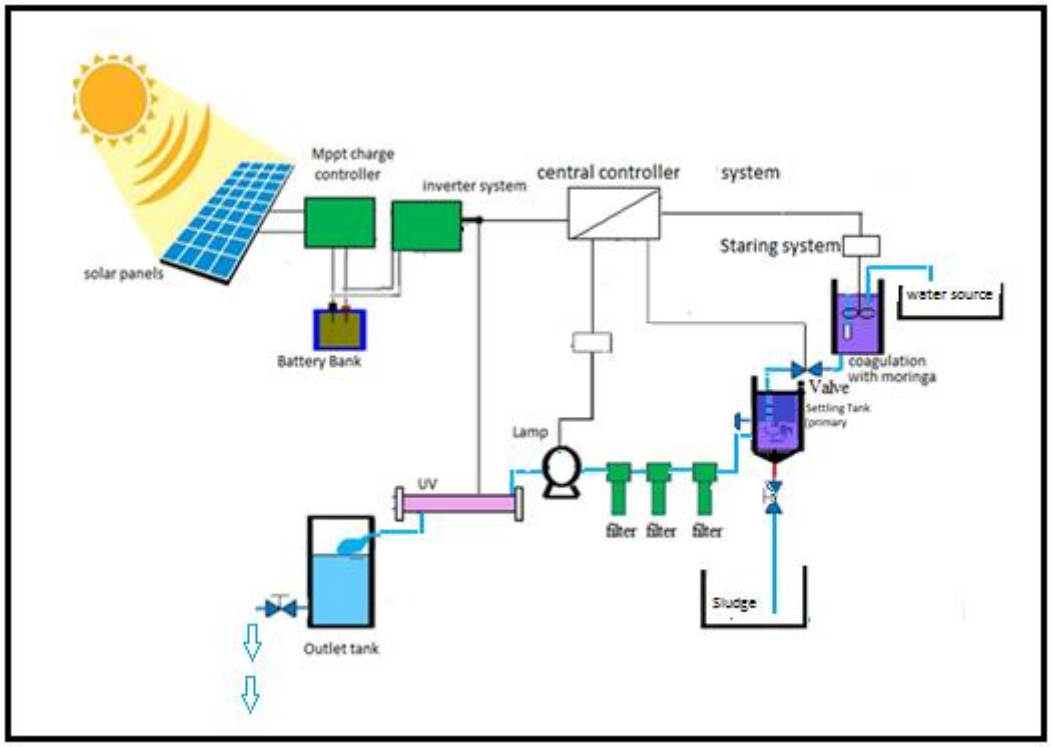

Figure 1: Schematic of the Water Treatment Plant

2.2 Preparation of Moringa *Oleifera* Coagulant

Moringa oleifera seed extract has proven to be effective at removing suspended material, soften hard water, removal of turbidity, chemical oxygen demand (COD), colour and other organic pollutant. The mechanism of the active coagulation components in Moringa oleifera seed protein is assumed that positively charged proteins attach to parts of surfaces of negatively charged particles through electrostatic interactions. This leads to formation of negatively and positively charged areas of the particle surface. Due to particle collision and neutralization, enmeshment of suspended particles which form flocs with a net-like structure take place. The coagulation active agent of moringa oleifera seeds have been established to be protein with cationic peptides of relatively low molecular weight. Some research have reported that coagulation efficiency of Moringa oleifera seeds can be greatly enhanced by extraction of its active agents with salt solution having one valence electron such as NaCl, KCl etc. In a research conducted, the coagulation capacity was greatly enhanced to about 7.4 times higher when the coagulative agent was extracted with 1M NaCl than that extracted by distilled water. This improvement was suggested to be apparently due to salting-in mechanism in proteins wherein a salt increases protein- protein dissociation, leading to increasing protein solubility as the salt ionic strength increases. Several studies have reported on the performance of Moringa oleifera seeds as an alternative coagulant or coagulant aid for various treatment of water such as turbidity, alkalinity, dissolved organic carbon (DOC), humic acid and hardness removal in raw water. Earlier studies have also recommended the use of MO seed extracts as coagulant for water treatment for the removal of various pollutants such as orange 7 dye, alizarin violet dye in water. Recent study carried out colour reduction studies on distillery spent wash using Moringa oleifera seeds and optimum colour reduction was found to be 56% and 67% using NaCl and KCl salt respectively.

2.2.1 Oil Extraction using Ethanol

The oil extraction technique adopted for the Moringa oleifera was as described by Gidde *et al.* (2012). Pod shells were removed; kernels ground and sieved through required sieve size (µm). Oil was removed by mixing the seed powder in ethanol. This was mixed with a magnetic stirrer for 30-45 min, and subsequently, separation of the residue from the supernatant was done by centrifuging for 10 min at 4000 rpm. The supernatant was decanted and the residual solid was dried (seed cake) at room temperature for 24 h.

2.2.2 Moringa *Olefeira* Extract

Traditionally, Moringa oleifera seed extracts are prepared by manually removing the dry seeds from their shells, grinding in mortar and pestle then soaking in water, and finally sieving the solution using a sieve of a particular mesh size. The resulting extract is then used in treating water. This is considered as a low technology of Moringa oleifera seed processing because it is only suitable for households and the sludge produced can be used as a bio-compost. Over the time, the removal of the seed oil

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either by organic solvent extraction (by using normal hexane or ethanol), cold pressing, or steam extraction gained popularity after which the defatted (removal of oil) seed cake extract is used in purifying water. This type of seed processing is considered as medium technology because it is suitable for medium to large communities and there are other by-product such as the oil which can be processed as edible oil, the seed shells can be processed to become activated carbon, and the sludge produced can be used as bio-fertilizer. Ali *et al.*, (2010), introduced an innovative method of processing the seed by further treating the defatted seed cake extract with microfiltration to enhance more isolation of bioactive compounds from the extract before using it to treat water. This is regarded as high technology because extracts obtained from the defatted seeds can further be purified by using ion exchange, membrane system, etc. The solid by-products from these processes can be used as animal feeds, the resulting permeate from membrane system can be freeze dried leading to longer shelf life for the seed. To date, most research focus on the use of the crude extract for treatment of water, while very few research have been done using the defatted seed extract and membrane processed seed extract for water treatment. Figure 2 shows the flow diagram on the stages involved in preparation of MO coagulant.

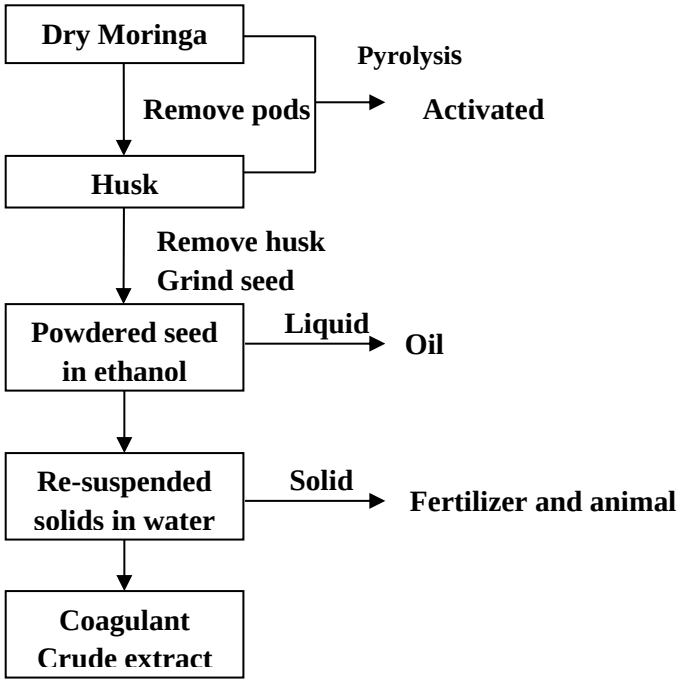

Figure 2: Typical extraction of the MO coagulant compound

2.3. Tests Procedures for Physico-chemical properties

Moringa olefera seed was dehusked, dried in an oven at 105ºC for an hour, ground and sieved to 250µm. The MO powder (20 g) was soaked in 1M Sodium chloride (NaCl), solution for 30 minutes and then filtered. Raw water samples (river) from different sampling points were analysed to determine their physicochemical properties, which include temperature, pH, turbidity, conductivity, total dissolved solids (TDS), chlorides, nitrates, sulphates and dissolved oxygen. An optimum dosage of 5ml MO extract was used in the 3 samples, and the samples were manually agitated for 5 minutes and allowed to settle for an hour. The treated sample were decanted and analysed. The procedures for the tests are presented as Appendix 3.

a) ***Conductivity and TDS***

These were measured using a Hanna HI pH, conductivity and TDS meter. The meter was calibrated in (μ S/cm) for conductivity and mg/l for TDS. It was switched on and its probe immersed into the water sample, the parameters were clicked one after the other to get their respective values read from the screen.

b) Turbidity

Hi33414 Turbidity and Chlorine meter by Hanna Instruments was used to analyse for the level of turbid of the water sample. Mode of the Turbidity/Chlorine meter was set to Turbidity (in NTU).The vial with standard were inserted into the sample chamber for calibration and was removed after calibration. Thereafter, one of the sample was poured to 10 ml Cuvette and was

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placed in the chamber then READ button was pressed and it began to scan until the result was displayed on the screen in NTU unit.

c) Chloride

Chloride method was selected and one cuvette (#1) was filled with 10 mL of deionized water. Another cuvette (#2) was filled with 10 mL of the sample (up to the mark). 0.5 mL of HI93753A-0 Chloride Reagent A was added to each cuvette using the 1 mL syringe. The caps were replaced and each cuvette was mixed by inverting for approximately 30 seconds. 0.5 mL of HI93753B-0 Chloride Reagent B was added to each cuvette using the second 1 mL syringe. The caps were replaced and each cuvette was mixed by inverting for approximately 30 seconds. The cuvette with the reacted deionized water (#1) was placed into the holder and the lid closed. Timer was started and the display showed the results in mg/L of chloride (Cl-).

d) Procedure for Bacterial Test

Each Positive presumptive fermentation tubes were paired with a fermentation tube containing EC broth. Each EC tube was labeled to match its paired presumptive tube. A portion of the liquid was transferred from each presumptive tube to its paired EC broth fermentation tube using a sterile transfer loop. The positive presumptive tubes were discarded after transferring using appropriate safety precautions. Place all of the inoculated EC broth tubes in a water bath incubator maintained at 44.5° +/-0.2°C. The EC broth tubes were incubated for 24 (+/-2) hours. The tubes were removed from the water bath, after gentle shaking, they were inspected for gas production. All fermentation tubes showing gas production were recorded positive on the test data sheet. Test results were calculated and recorded as Most Probable Number (MPN)/100 mL. The fermentation tube contents were discarded using appropriate safety precautions.

Isolation of Enterobacteriaceae using membrane filtration method Phenol red indicator, purified by adsorption chromatography was incorporated into lauryl sulphate broth (LSB) used in the membrane filtration method for the detection of Escherichia coli and other coliform bacteria. Relative to LSB containing the impure dye or its major contaminant, the purified phenol red provided clear visualization of discrete yellow colonies observed against a white background. The colonies remained stable for at least 24 h at 25 degrees (ºC) under standard laboratory lighting conditions. Pre-enrichment (non-selective enrichment) Water samples (100 mL) were filtered through a sterile (0.45 µm) milipore membrane filter. The membrane filter was lifted with a blunt edge forceps and transferred into 90 mL of buffered peptone water and gently mixed then incubated for overnight at 37 °C. Selective enrichment A1 ml volume of the pre-enrichment agar was transferred with a pipette into 10 mL Rappaport-Vassiliadis Soy Peptone (RVS) broth was incubated at 37 °C. Serial dilution and selective plating Serial dilution of 10−6 was prepared using normal saline and a loopful of culture was streaked on selective agar Salmonella-shigella agar (SSA) and incubated at 37 °C overnight. Colonies on the Salmonella-shigella agar were then counted and subjected to biochemical test. Coliform determination

The multiple tube fermentation method was used according to the methodology described in APHA (2001) beginning with 250 mL flasks and using lactose broth for the presumptive test and brilliant green and EC (E. coli) broth for the confirmation tests. The most probable number (MPN) of total coliform counts was calculated using the Hoskins table (APHA, 2001). Aliquots of the positive tubes of brilliant green broth were collected and streaked onto MacConkey (MC) agar. Colonies with different morphotypes were collected and transferred into tubes containing tryptic soy agar (TSA) and incubated at 37 °C for 24–48 h for subsequent biochemical identification.

For biochemical identification, oxidase-negative bacteria were selected, and the colonies were subjected to biochemical tests using IMVIC characterization reaction from the nutrient slant used in completed test. The bacterial isolates were viewed with microscopic and characterized using colonial, morphological and biochemical identification methods that were further identified using Bergey's manual of Determinative Bacteriology.

3. RESULTS AND DISCUSSIONS

The following results were obtained:

Figures 3, 4 and 5 show the values of some physico-chemical parameters of raw and treated water samples from different water sources: river, pond and earth dams.

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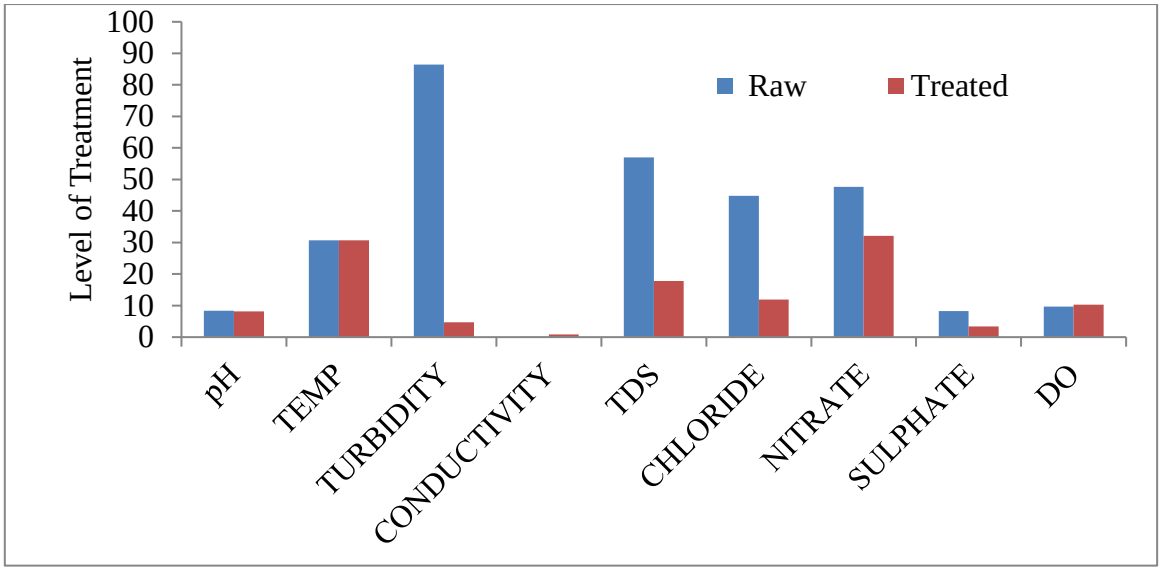

Figure 3: Physico-chemical Properties of Raw and Treated River Water

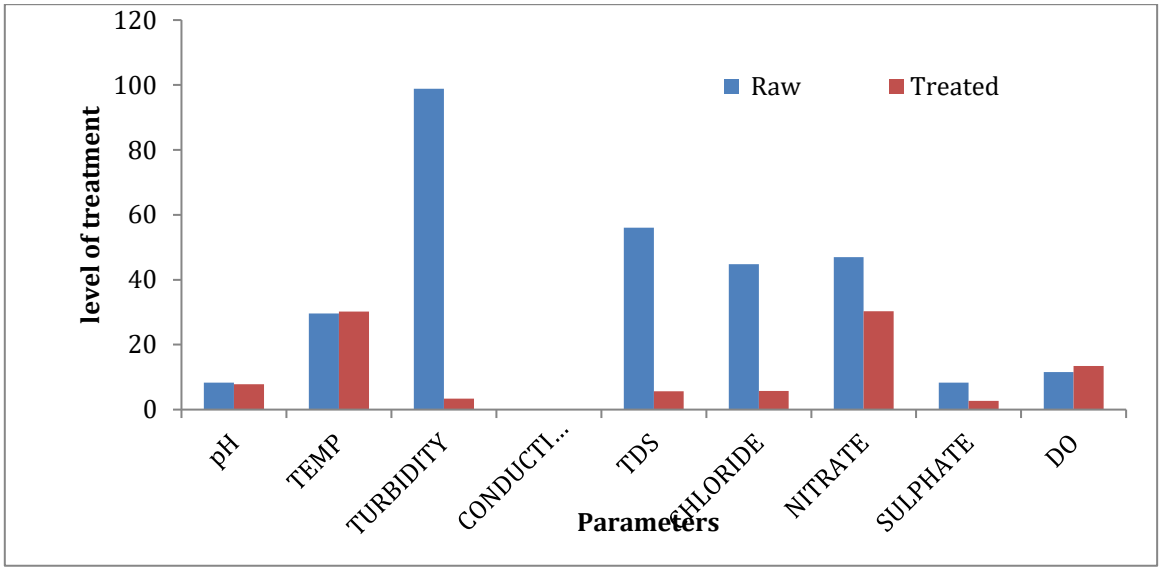

Figure 4: Physico-chemical Properties of Raw and Treated Pond Water

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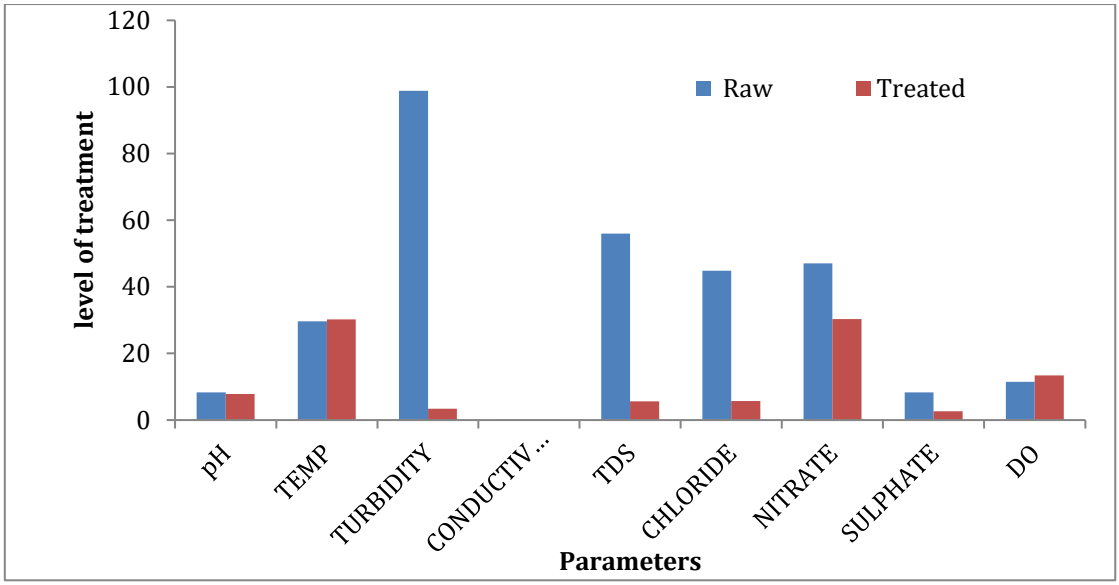

Figure 5: Physico-chemical Properties of Raw and Treated Earth Dam Water

The physico-chemical properties of the raw water samples fall below the minimum water quality standards as recommended by the World health Organization and Nigeria Institute of Standards (NIS), hence the need for their treatment.

The results for the treated water samples show significant improvement from those of the raw water samples and are within the permissible levels for good drinking water. The temperatures of raw samples and the treated samples are dependents on the ambient condition. The acceptable temperature limits of potable water is relative and depends on individual preference. The pH of the raw samples are more alkaline than the treated water samples. The treatment processes dropped the pH from 8.4 to 8.1; 8.3 to 7.9 and 8.3 to 7.8 respectively. The pH of all the treated samples fall within the NIS (2015) acceptable limit of 6.5- 8.5. The pH values, which quantify acidity and alkalinity of water show that the water samples are safe not only for drinking but are also suitable for agricultural, recreational and other domestic uses. This result is in agreement with similar studies by Oluyemi *et. al*., 2010; Esemikose and Akoji, 2014 and Oluyege *et al*, 2014.

The conductivity levels indicate the total concentration of ionized dissolved substances in the samples. There are substantial increases in the conductivities of Raw 1 and Raw 3 samples by 92 % and for raw 2 by 77 %.

The Turbidities (NTU) of raw 1, raw 2 and raw 3 samples decreased substantially from 86.4 to 3.42; 94.9 to 4.37 and 98.8 to 4.7 mg/L respectively. The values obtained are within the WHO acceptable limit of 5 mg/L. Also, the dissolved oxygen (DO) increased from 9.70 to 10.34; 8.72 to 11.07 and 11.52 to 11.42 mg/L respectively. WHO did not specify DO limit for drinking water, however, some researchers suggested that values from 0 to 18 mg/L are safe for human consumption (www. Atlas.scientific.com). This improvement is due to aeration process during water treatment as Eswari, Amala and Poonguzhali (2015) observed. The total dissolved solids TDS of the raw water samples recorded significant drops from 57 to 17.82; 56 to 6.3 and 56 to 5.6 ppm after treatments. The values fall within the WHO acceptable limit of 300 ppm. These results are in agreement with that of Oluyemi *et al* (2010) and Ibrahim and Ajibade (2012).

The high average nitrate content (47.5 mg/L) of the raw water samples can be attributed to the use of chemical fertilizers, indiscriminate animal grazing and improper disposal of animal and human wastes. All the treated water samples had their nitrate level reduced to within acceptable limits of NIS and WHO standards of 45 mg/L).

A bacterial test was carried out to determine the physico-chemical parameters of the water samples before and after passing through UV-Sterilizer. Four bacterial tests : Faecal Coliform- its presence indicates recent faecal contamination; E-coli- its presence causes urinary tract infections, bacteraemia, meningitis, diarrhea, (one of the main cause of morbidity and mortality among children), acute renal failure and haemolytic anaemia; total coliform count- its presence indicates indication of faecal contamination; and clostridium perfringens spore- Index of intermittent faecal contamination) were conducted on both the raw and treated water samples. All the tests showed the elimination or reasonable reduction in the level of bacteria which are in conformity with standards. Fecal coliform and clostridium perfringens spore were completely eliminated from 1.2 cfu/100 mL and 13.8 cfu/100 mL respectively to 0 cfu/100 mL. This indicates that the water samples contain no disease-producing organisms. E-coli and count were reasonably reduced from 5.03 cfu/100 mL to 1.2 cfu/100 mL while total coliform was reduced from 35.6 cfu/100 mL to 12.1 cfu/100 mL which are near to the acceptable standard limits.

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4. CONCLUSION

This study revealed that *Moringa Oleifera* coagulant has proved to be effective in water treatment because the desirable physico-chemical properties of the raw water samples after treatment, have been noticed to fall within acceptable standards by WHO and NIS. Similarly, the UV sterilizer has effectively eliminated all phatogenic enteric substances in the raw water sample. Therefore *Moringa Oleifera* and UV sterilizer can be considered to have the potency of being effective in water treatment plants for human consumption.

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Appendix 1: Physio-chemical Parameters of Raw and Treated Water Samples

Test Water Sample	Temp (°C)	pH	Electrical Conductivity (ms)	Total Dissolved Solid (ppm)	Turbidity (mg/L)	Dissolved Oxygen (mg/L)
Raw 1	30.7	8.4	0.07	57.00	86.4	9.70
Raw 2	29.8	8.3	0.07	56.00	94.9	8.72
Raw 3	29.6	8.3	0.07	56.00	98.8	11.52
Treated 1	30.7	8.1	0.87	17.82	3.42	10.34
Treated 2	30.6	7.9	0.86	6.30	4.37	11.07
Treated 3	30.2	7.8	0.89	5.60	4.70	13.42

Appendix 2: Bacterial test of Raw and Treated water samples

S/No	Parameters	Unit	Untreated	Treated	Max. Permitted Limit
1	Faecal Coliform	cfu/100 mL	1.3	0	0
2	E-Coli	cfu/100 mL	5.03	1.2	0
3	Total Coliform Count	cfu/100 mL	35.6	12.1	10
4	Clostridium Perfringens Spore	cfu/100 mL	13.8	4.6	0