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Efficacy of Chemical Methods and Plant Based Syntheses of Silver Nanoparticles for Water Purification

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Abstract The availability of clean drinking water in Makurdi metropolis, Benue State, Nigeria has remained one of the greatest urban challenge as water borne diseases are still on the rise within this vicinity. World Bank's intervention has recently been received but the risk has not been completely curtailed as a result of recurring water related ailments. In this research, silver nanoparticles were used to purify water samples gotten from River Benue. Silver nanoparticles were prepared via two common methods; by chemical methods using tri - sodium citrate and sodium borohydride reduction, secondly, by biological method using green synthesis. The prepared silver nanoparticles were characterized for stability using a UV-VIS spectrophotometry to evaluate their surface plasma resonance peaks. Physicochemical parameters for standard quality water were evaluated on five samples with different concentrations; 5 mM, 3 mM, 2 mM tri sodium citrate and 5 mM of sodium borohydride and green synthesis. The silver nanoparticles were used for water treatment and the results obtained proved to be very effective in the removal of unwanted contaminants. The green synthesis method was suitable for home, industrial and recreational use while the 3 mM concentration was suitable for aquatic organisms.

Keywords Silver Nanoparticles, Water Purification

1. Introduction

Over the years, researchers have been trying to improve human lives through nanotechnology and nanoscience. Nanotechnology is a science centered on atomic, molecular and supramolecular molecules aiming to create nanostructures with enhanced functionalities. This involves the manufacturing of particles at small or tiny sizes creating a wide range of physiochemical properties including durability, strength, reactivity and conductivity [1]. Nanoparticles have attracted much attention due to their application in biology, catalysis, computing, solar cells and optoelectronic devices [2, 3]. They are of great interest because of their unique optical properties in ink-jet printing, ammonia sensing, as well as application in cosmetics and so on. Nanoparticles are small units of particles between 1 and 100 nm in size, with a surrounding interfacial layer. The interfacial layer is an integral part of nanoscale matter, fundamentally affecting all its properties. The interfacial layer consists of ions, organic and inorganic molecules. Nanoparticles have a greater surface area per volume than larger particles and this causes them to be more reactive with some other molecules hence the properties of many conventional materials change when formed from nanoparticles. In recent years, nanoparticles of noble metals such as gold, silver and palladium have drawn immense attention due to the wide range of new applications in various fields of industry. Particularly, silver nanoparticles have significant interest in medical applications such as very effective antibacterial agents without toxic effects, and industrial application. It is important that the silver nanoparticles require not only the particles to be of nano-size, but also synthesis of the nanoparticles be carried out easily and at low cost.

Nanoparticles

A nanoparticle is a microscopic particle with at least one dimension less than 100 nm [3]. Nanoparticle research is currently an area of intense scientific research, due to a wide variety of potential applications in biomedical, optical, and electronic fields. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures [4]. A bulk material should have constant physical properties regardless of its size, but at the nano-scale this is often not the case. Size-dependent properties are observed such as quantum confinement in semiconductor particles, surface plasmon resonance in some metal particles and super paramagnetism in magnetic materials [5]. The properties of materials change as their size approaches the nanoscale and as the percentage of atoms at the surface of a material becomes significant. For bulk materials larger than one micrometer, the percentage of atoms at the surface is minuscule relative to the total number of atoms of the material [6]. Nanoparticles exhibit a number of special properties relative to bulk material. For example, the bending of bulk copper (wire, ribbon, etc.) occurs with movement of copper atoms/clusters at about the 50 nm scale [6].

2. Materials and Methods

Synthesis of Nanoparticles

Silver nanoparticles were prepared by two different chemical reduction methods and a biological method.
All solutions were prepared with distilled water.

Synthesis of silver nanoparticles using sodium borohydride reduction

This method of synthesis was adopted from [7]. 0.0169 g of silver nitrate (169.87 g mol^{-1}) was dissolved in 20 mL of distilled water in a 20 mL volumetric flask to give 5 mM concentration. 0.0113 g of sodium borohydride (37.83 g mol^{-1}) was dissolved in 30 mL distilled water in a 50 mL conical flask to give 10 mM concentration. It was placed in an ice bath and a magnetic stir bar was added to it. It was then stirred on a magnetic stirrer for 20 min. 2 mL of the 5 mM silver nitrate solution was added drop by drop at a rate of one drop per second. A change in colour from light yellow to dark brown occurred at the end of the addition of the silver nitrate solution. The process is shown in the reaction below

$$2AgNO_3 + 2NaBH_4 \rightarrow 2Ag + H_2 + B_2H_6 + 2NaNO_3 \quad (1)$$

Synthesis of silver nanoparticles by citrate reduction

This method was adopted from [8]. 0.0849 g, 0.0510 g and 0.0340 g of silver nitrate were dissolved in 100 mL distilled water each to give a 5 mM, 3 mM and 2 mM solutions respectively. 1 g of tri sodium citrate (258.06 g mol^{-1}) was dissolved in 100 mL to give 1 % tri sodium citrate solution. The silver nitrate solution was heated to boiling. 2 mL of the 1 % tri sodium citrate solution was added to each of the boiling mixtures drop by drop at a rate of one drop per second. Yellowish - brown AgNPs were formed after about 10 minutes of the addition of tri-sodium citrate. The equation for the citrate reduction of silver nitrate is shown below:

$$2Ag^+ + C_6H_5O_7^{3-} \rightarrow 2Ag + C_5H_4O_5^{2-} + H^+ + CO_2 \quad (2)$$

Preparation of silver nanoparticles through green synthesis

This method was adopted from [9]. Fresh leaves of *Carica papaya* were collected and washed. The leaves were then dried at room temperature (25 ^oC) for 10 days to remove moisture. The dried leaves, 5 g were mixed with 100 mL of distilled water. The mixture was boiled for 10 min and allowed to cool. The mixture was then filtered and centrifuged using K3 series centurion scientific Centrifuge at 2000 rpm for 1 h. 0.0849 g silver nitrate was dissolved in 100 mL distilled water to give a 5 mM concentration. The mixture was then boiled using a hot plate. The silver nitrate solution was added to the boiling extract and the colour change was monitored.

Characterization of Nanoparticles

The prepared silver nanoparticles were characterized using UNICO 2800P UV/Vis spectrophotometer at a wavelength range of 400 to 700 nm to evaluate the surface plasmon resonance peaks so as to ascertain the stability of the silver nanoparticles.

Water Treatment

The raw water was collected from river Benue, Makurdi, Benue state and stored at room temperature, 25 ºC for further use. 200 mL of the raw water was collected in five (5) different beakers labeled A- E and 20 mL of the silver nanoparticles was added to each of them. The samples were allowed to stand for 30 min in order to settle after which they were filtered using glass funnels and no 12 Whatman filter papers. The samples were then stored in the refrigerator at 15 ^oC and used for water analysis.

Water Analysis

The water parameters analyzed include turbidity, suspended particles, total dissolved solids, colour, taste, odour, conductivity, salts, temperature, pH, iron, sulphate. All methods used for the determination of analysis of parameters were adopted from [9].

The results obtained from these tests were recorded and compared with the WHO and NAFDAC water quality standards.

Determination of pH

The electrode and temperature probes of the HANNA HI98107 pH meter were rinsed with distilled water. A 50 mL beaker was filled with the raw water and the electrode and temperature probes of the pH meter were inserted into the beaker such that it was about 1cm above the bottom and the MEASURE button was pressed. The meter showed READY following which the pH and temperature were read and recorded. The same procedure was carried out for the treated samples.

Determination of turbidity

The cuvette was filled with the raw water sample to a marked point and inserted into the HANNA HI88703 turbidimeter such that the mark on the turbidimeter corresponded with the mark on the cuvette. The turbidimeter was switched on and the READ/ENTER button was pressed and the result was displayed on the screen in NTU (Nephelometric Turbidity units). The same procedure was repeated on other treated water samples and the results were recorded appropriately.

Determination of Odour

A conical flask was rinsed inside out until it was completely odourless and then rinsed with distilled water. The flask was half filled with raw water, stoppered and shaken for 3-5 seconds. The stopper was removed and the odour was determined taking the hand close to the opening of the flask and brought close to the nose. The result was recorded to be objectionable or unobjectionable. The same procedure was followed for the treated water.

Determination of Taste

The beaker was rinsed with 4 M HCl solution until it was odourless and then rinsed with distilled water. The raw water was poured into the beaker and tasted directly with the tongue. The result was recorded as either objectionable or unobjectionable. It was repeated on the treated water samples.

Determination of dissolved oxygen (DO)

The water sample to be tested for dissolved oxygen was poured into a 25 mL cell tube. The program number 445 was imputed and wavelength 532 nm was entered in the HANNA HI9146 oxygen meter. The water sample in the cell tube was inserted in the cell holder and the light shield was covered. The zero key was pressed and 0.0 mg L^{-1} was displayed. The ENTER key was pressed and the result was displayed on the screen. The procedures were repeated for other samples.

Determination of iron concentration in water

A volume of40 mL raw water was poured into the vial. The program number 270 was set and appropriate wavelength of 450 nm was entered on the JENWAY 7200 spectrophotometer and the ENTER button was pressed and left to read for 5 minutes. The ferro reagent was poured into the vial containing the raw water and shaken for 10 s. it was then placed inside the spectrophotometer and the reading was taken. The same procedure was followed for the treated water samples.

Determination of sulphate concentration

A sub-sample of raw water was poured into the vial and sulphate powder pillows were added to the water sample and shaken for five second. The program number 685 was set and appropriate wavelength of 450 nm was entered on the JENWAY 7200 spectrophotometer and left to read for 5 min. The cell bottle was inserted in the spectrophotometer and the light shield was closed. The ENTER/READ button was pressed after which the results were displayed. The procedure was repeated for other water samples.

Determination of conductivity

A sample of raw water was taken in the beaker. The HANNA EC215 conductivity meter was switched on and inserted into the water in the beaker. It was left inside the beaker for 5 min. The result was displayed and recorded. It was repeated for the other samples.

Determination of total dissolved solids (TDS)

The raw water was poured into a 250 mL beaker. The HANNA HI8033 TDS meter was switch on and inserted into the beaker. It was left inside for 5 min and the reading was taken. It was repeated for the other samples.

3. Result and Discussion

3.1. Results

3.1.1. Nanoparticles formation

For the tri sodium citrate reduction, at 5 mM concentration, the SPR peak was 615 nm, at 3 mM concentration, it was 590 nm, and at 2 mM it was 585 nm. For sodium borohydride reduction, it was 435 at 5 mM concentration. For biological method, it was 410 nm. After 72 h, they were all evaluated again using the same spectrophotometer. All concentrations gave different SPR peaks. For tri sodium citrate reduction; 5 mM gave 590 nm, 3 mM gave 485 nm, and 2 mM gave 420 nm. For sodium borohydride reduction, it gave 540 nm at 5 mM concentration. For the biological method, it gave 540 nm. The change in the SPR peak indicates that aggregation/agglomeration took place after 72 h. There was not much change in colour.

Some of the UV-Vis spectra of the samples, when it was freshly prepared and after 72 h of preparation are shown in figures 1 to 4 below.

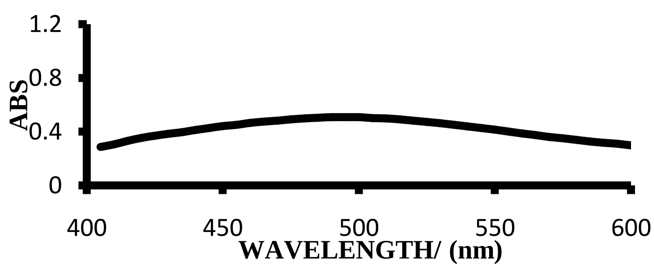

Figure 1: Plot of wavelength against absorbance for fresh 5mM citrate AgNPs

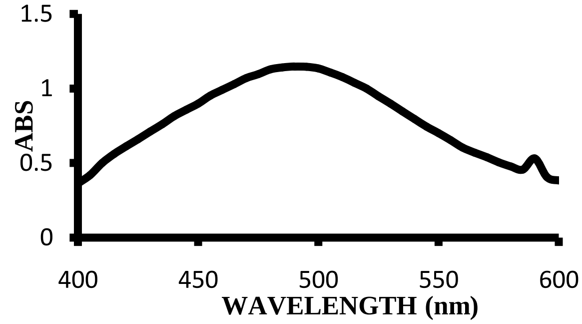

Figure 2: Plot of wavelength against absorbance for 3mM citrate AgNPs

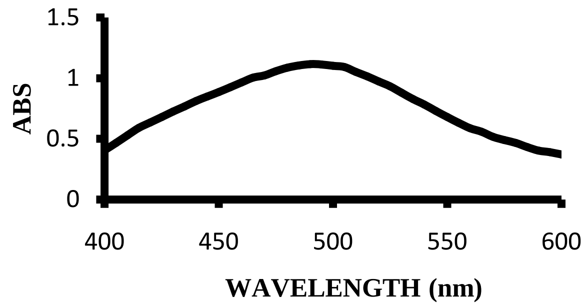

Figure 3: Plot of wavelength against absorbance for 3mM citrate AgNPs after 72 h

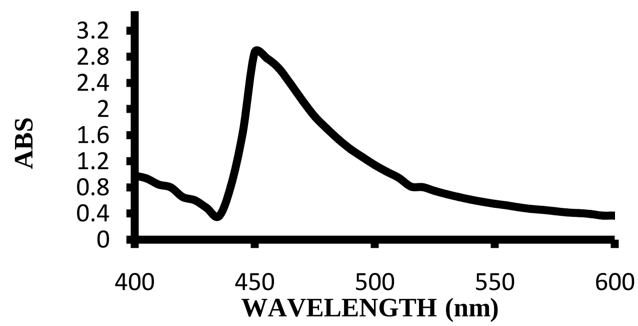

Figure 4: Plot of wavelength against absorbance of 5mM green synthesis AgNPs after 72 h

The difference in colour and SPR peak could be linked to difference in particles shapes and sizes. The SPR peak(s) depends on the size of the nanoparticles in that solution.

Table 1: Surface plasmon resonance (SPR) peaks of AgNPs by different methods of reduction.

	Tri sodium citrate AgNPs			**Sodium borohydride AgNPs**	**Green synthesized AgNPs**
SPR peak (nm)	5 mM	3 mM	2 mM	5 mM	5 mM
Fresh (sample)	615	590	585	435	410
After 72 h	595	485	420	540	450

Water analysis

The water analysis parameters have been divided into physical and chemical parameters. The result of analysis done on the treated water is provided in tables 2 to 4 below. The results were also compared with World Health Organization (WHO), National Agency for Food and Drug Administration and Control (NAFDAC) and Nigerian Industrial Standard (NIS) as shown in table 5.

Table 2 Results of the physicochemical parameters tested of the treated water

	Raw water	**Tri sodium citrate AgNPs**			**Sodium Borohydride AgNPs**	**Green Synthesized AgNPs**	**ANOVA**
Parameters		5 mM	3 mM	2 mM	5 mM	5 mM	
pH	8.1±0.070[a]	7.8±0.070[a]	7.7±0.000[a]	7.8±0.141[a]	7.7±0.565[a]	7.6±0.070[a]	0.435
Turbidity (NTU)	13.8±1.583[c]	3.7±0.212[a]	5.0±0.070[ab]	7.5±3.535[ab]	8.5±0.480[b]	3.6±0.141[a]	0.005
DO (ppm)	8.6±0.777[b]	6.4±0.176[a]	5.5±0.028[a]	5.8±0.926[a]	6.3±0.000	6.1±0.021[a]	0.007
Conductivity (μs cm^{-1})	118±8.485[b]	382±2.828[a]	362±2.828[a]	390.5±2.162[ab]	385.0±5.656[3\a]	360.5±2.121[a]	0.020
Iron (mg L^{-1})	1.4±0.763[b]	0.5±0.000[a]	0.1±0.070[a]	0.3±0.212[a]	0.3±0.000[a]	0.2±0.141[a]	0.056
TDS (mgL^{-1})	95.0±1.414[b]	54.1±0.212[a]	93.3±0.494[b]	90.7±8.909[b]	52.0±0.070[a]	52.1±0.070[a]	0.001
Sulphate (mg L^{-1})	77±2.828[e]	63±0.707[c]	70±0.707[d]	50±4.949[b]	38±1.414[a]	71±1.414[d]	0.001
Salinity (mg L^{-1})	0.4±0.070[b]	0.1±0.070[a]	0.3±0.000[ab]	0.1±0.000[a]	0.2±0.000[a]	0.2±0.212[ab]	0.086
Temperature (^{o}C)	25.6±0.070[c]	25.5±0.070[c]	25.4±0.070[bc]	25.1±0.212[ab]	25.4±0.141[bc]	25.0±0.070[a]	0.014
Taste	NA	ND	ND	ND	ND	ND	
Odour (Threshold)	NA	ND	ND	ND	ND	ND	

Means ± Values of Standard deviation are of two replications. Means within a row with the same superscript across columns were not significantly different (p>0.05).

NA= Objectionable, ND= Unobjectionable

Table 3: Results of the physical physicochemical parameters of the treated water

	Raw water	**Tri sodium citrate AgNPs**			**Sodium Borohydride AgNPs**	**Green Synthesized AgNPs**	**ANOVA**
Parameters		5 mM	3 mM	2 mM	5 mM	5 mM	
Conductivity (μs cm^{-1})	118±8.485[b]	382±2.828[a]	362±2.828[a]	390.5±2.162[ab]	385.0±5.656[a]	360.5±2.121[a]	0.020
TDS (mg/L)	95.0±1.414[b]	54.1±0.212[a]	93.3±0.494[b]	90.7±8.909[b]	52.0±0.070[a]	52.1±0.070[a]	0.001
Temperature ($^{\circ}$C)	25.6±0.070[c]	25.5±0.070[c]	25.4±0.070[bc]	25.1±0.212[ab]	25.4±0.141[bc]	25.0±0.070[a]	0.014
Turbidity (NTU)	13.8±1.583[c]	3.7±0.212[a]	5.0±0.070[ab]	7.5±3.535[ab]	8.5±0.480[b]	3.6±0.141[a]	0.005
Taste	NA	ND	ND	ND	ND	ND	
Odour (Threshold)	NA	ND	ND	ND	ND	ND	

Values are Means ± Standard deviation of two replications.

Means within a row with the same superscript across columns were not significantly different (p>0.05)

NA= Objectionable

ND= Unobjectionable

Table 4: Results of the chemical physicochemical parameters of the treated water

	Raw water	**Tri sodium citrate AgNPs**			**Sodium Borohydride AgNPs**	**Green Synthesized AgNPs**	**ANOVA**
pH	8.1±0.070[a]	7.8±0.070[a]	7.7±0.000[a]	7.8±0.141[a]	7.7±0.565[a]	7.6±0.070[a]	0.435
DO (ppm)	8.6±0.777[b]	6.4±0.176[a]	5.5±0.028[a]	5.8±0.926[a]	6.3±0.000	6.1±0.021[a]	0.007
Iron (mg L^{-1})	1.4±0.763[b]	0.5±0.000[a]	0.1±0.070[a]	0.3±0.212[a]	0.3±0.000[a]	0.2±0.141[a]	0.056
Sulphate (mg L^{-1})	77±2.828[e]	63±0.707[c]	70±0.707[d]	50±4.949[b]	38±1.414[a]	71±1.414[d]	0.001
Salinity (mg L^{-1})	0.4±0.070[b]	0.1±0.070[a]	0.3±0.000[ab]	0.1±0.000[a]	0.2±0.000[a]	0.2±0.212[ab]	0.086

Values are Means ± Standard deviation of two replications.

Means within a row with the same superscript across columns were not significantly different (p>0.05)

Table 5: Comparison of the physicochemical parameters with WHO, NAFDAC and NIS standards

Parameters	Unit	Raw water	Tri sodium citrate AgNPs 5 mM	Tri sodium citrate AgNPs 3 mM	Tri sodium citrate AgNPs 2 mM	Sodium boro-Hydride AgNPs 5 mM	Green synthesis AgNPs 5 mM	WHO	NAFDAC	NIS
pH	-	8.1±0.070^{a}	7.8±0.070^{a}	7.7±0.000^{a}	7.8±0.141^{a}	7.7±0.565^{a}	7.6±0.070^{a}	6.5-8.5	6.5-8.5	6.5-8.5
Turbidity	NTU	13.8±1.583^{c}	3.7±0.212^{a}	5.0±0.070^{ab}	7.5±3.535^{ab}	8.5±0.480^{b}	3.6±0.141^{a}	19	19	19
DO	Ppm	8.6±0.777^{b}	6.4±0.176^{a}	5.5±0.028^{a}	5.8±0.926^{a}	6.3±0.000^{a}	6.1±0.021^{a}	5-9	5-9	5-9
Conductivity	$\mu s\ cm^{-1}$	118±8.485^{b}	82±2.828^{a}	62±2.828^{a}	90.5±2.162^{ab}	85.0±5.656^{a}	360.5±2.12^{a}	100	100	100
Iron	$mg\ L^{-1}$	1.4±0.763^{b}	0.5±0.000^{a}	0.1±0.070^{a}	0.3±0.212^{a}	0.3±0.000^{a}	0.2±0.141^{a}	0.3	0.3	0.3
TDS	$mg\ L^{-1}$	95.0±1.414^{b}	54.1±0.212^{a}	93.3±0.494^{b}	90.7±8.909^{b}	52.0±0.070^{a}	52.1±0.070^{a}	500	500	500
Sulphate	$mg\ L^{-1}$	77±2.828^{e}	63±0.707^{c}	70±0.707^{d}	50±4.949^{b}	38±1.414^{a}	71±1.414^{d}	250	250	250
Salinity	$mg\ L^{-1}$	0.4±0.070^{b}	0.1±0.070^{a}	0.2±0.000^{ab}	0.1±0.000^{a}	0.2±0.000^{ab}	0.2±0.212^{ab}	0.1-0.2	0.1-0.2	0.1-0.2
Temperature	^{o}C	25.6±0.070^{c}	25.5±0.07^{c}	25.4±0.070^{bc}	25.1±0.212^{ab}	25.4±0.141^{bc}	25.0±0.070^{a}	5-50	5-50	5-50
Taste	-	NA	ND	ND	ND	ND	ND	ND	ND	ND
Odour	Threshold	NA	ND	ND	ND	ND	ND	ND	ND	ND

Values are Means ± Standard deviation of two replications.
Means within a row with the same superscript across columns were not significantly different (p>0.05)
NA=Objectionable, ND=Unobjectionable

3.2. Discussion

Although prolonged exposure of silver nanoparticles to the body could have adverse effect on human health and the environment at large [11], they are still considered being able to help improve human life, making it easier and better. The acceptability and use of potable water for recreation, agricultural, industrial and domestic uses are influenced by the following physicochemical parameters.

Turbidity

Turbidity is the measure of cloudiness or haziness of a fluid caused by large number of individual particles that are generally visible to naked eyes, similar to smoke in air. It is the amount of suspended particles in water which vary in sizes. It is also a measure of water clarity, how much of these particles suspended in water decrease the passage of light. Turbidity was objectionable for almost all the applicable uses of water. Turbidity in water may be due to the presence of clay, silt or organic debris, the presence of these colloidal materials gives water a cloudy appearance which is unattractive and harmful. The measurement of turbidity is a key test of water quality [12]. From the result, green synthesis AgNPs-treated water was the most suitable for usage because of its low turbidity amount thereby having a significantly low amount of contamination(s). Although turbidity has no health effects, high turbidity can interfere with disinfection and provide a medium for microbial growth. High turbidity may indicate that there is presence of disease-causing microorganisms. These organisms include viruses, bacteria and parasite that can cause symptoms like nausea, cramps, diarrhea and headaches.

Total Dissolved Solids

Total dissolved solids are a measure of the dissolved combined content of all organic and inorganic substance present in a liquid in molecular ionized or micro- granular suspended form. This is the total amount of total charged ions including minerals, salts or metals dissolved in a given volume of water. These are caused by agricultural and residential run-offs and are directly related to the purity of the water and the quality of purification systems. Water with TDS more than500 mg/L but less than 1000 mg/L is poor and TDS more than 1000 mg/L is not recommended for drinking [13]. Sodium borohydride AgNPs-treated water was the most suitable for usage because water with high TDS is caused by the presence of potassium ions, chlorides and sodium ions. High TDS affects water taste such as bitter, salty or brackish taste and can also cause water hardness.

Electrical conductivity

Conductivity is a measure of water capacity to pass electrical flow. This ability is directly related to the concentration of the ions in water. The more ions are present the higher the conductivity of the water and the lesser the ions the lower the conductivity of the water [14]. Green synthesis AgNPs water sample was found to be the most suitable for usage. Although the electrical conductivity of water poses no health risks, it is advisable to go with water with low electrical conductivity concentration due to less presence of ions in it.

Dissolved oxygen

Dissolved oxygen refers to the level of free oxygen in water. Just as we need air to breathe so does aquatic organisms need dissolved oxygen to respire [15]. The dissolved oxygen concentration is constantly affected by diffusion and aeration. Based on the result, 5 mM tri sodium citrate AgNPs water is found to be most suitable for aquatic life because the lower the concentration of dissolved oxygen, the higher the stress the aquatic animals undergo. A high level of DO in water supply is good because it makes drinking water taste better however high DO level speed up corrosion in water pipes. For these reasons, industries use water with the least possible amount of DO. In this regard 3 mM tri-sodium citrate AgNPs arethe most suitable for industrial uses.

pH

pH is a measure of the acidity or basicity of water. Since pH can be affected by the chemicals in the water, it is an important indicator that water is changing chemically. The human body has a natural pH of 7, it needs this level to run efficiently and always seek to return to this state if it becomes overly acidic or alkaline. `Since pH of water can indirectly affect health, water with acidic pH level can corrode plumbing and leach metal [16]. Green synthesized AgNPs treated water samples were the most suitable because their pH values were below the equilibrium pH which is neitheracidic nor alkaline. Acidic water could cause metallic or sour taste of drinking water, stain laundry when washing, give blue green staining of sinks and other household fixtures while alkaline water could cause bitter taste, scale buildup in household plumbing, decreased efficiency of household heaters.

Salinity

It is the concentration of dissolved salt in a given volume of water. When the level of salt falls below a measurable limit, it shows that the water is good [17]. From the table of results above, 5 mM and 3 mM tri sodium citrate AgNPs treated water sample are most suited because salts in soil water may inhibit plant growth for two reasons; first, the presence of salt in the soil solution reduces the ability of the plants to take up water and this leads to reduction in growth rate. Secondly, if excessive amount of salt enters the plants in the transpiration stream, there will be injury to cells in the transpiring leaves and this may cause further reduction in the plant growth. Although it poses no health risk, a low level of salinity is the safest to drink because it shows they are lesser ions found in it.

Temperature

Temperature is an important factor when assessing quality water. Temperature impacts both the chemical and biological characteristics of water. The solubility of oxygen and other gases decreases as temperature increases. Temperature is an important factor because of its influence in water chemistry and it influences other factors like dissolved oxygen, salinity and conductivity. Plants and aquatic animals are both affected by temperature based on the standard temperature for each of them [18]. Based on the green synthesized AgNPs treated-water temperature of 25^{o}C, the intensity of taste is greatest for water at room temperature and is significantly reduced by chilling or heating. An Increase in temperature also means increase in vapour pressure of trace volatiles in drinking water and that could lead to increased odour.

Iron

Environmental protection agency (EPA) considers iron as a secondary contaminant, which means it doesn’t have a direct impact on health. While a low level of iron is not harmful but excess of it is not recommended for digestion, it can lead to stomach ulcer. Some of the results obtained showed that in some samples, excess iron was found while in some it was below the standard as to not posing any health risk to human [19]. 3 mM tri sodium citrate AgNPs treated-water was found to be the most suitable for drinking and other uses because it contains iron within acceptable levels. Also, high iron content can lead to an overload which can cause diabetes, hemochromatosis, stomach problems, nausea and vomiting. High iron in water can also cause metallic taste, discoloured beverages, yellowish stains and stains in laundry.

Sulphate

Sulphate is one of the major dissolved components of rain. High concentration of sulphate in water we drink can have a laxative effect when combined with calcium and magnesiumwhich are major indicators of water hardness. The amount of sulphate in water has effect on the human body so it is advisable not to exceed the stipulated standard. The consumption of drinking water containing high amount of sulphate may result in intestinal discomfort, diarrhea and consequently dehydration [20]. From the result, water treated with sodium borohydride AgNPs was considered the most suitable since it contains the lowest amount of sulphate in water. Bacteria could attack the sulphate reducing it tohydrogen sulphide gas (H_2S), high concentrations of which lead to bad odour of breath in humans.

Taste and Odour

Taste is the sensation perceived by the tongue when it comes in contact with a substance. Odour on the other hand is the sensation due to the presence of substances having an appreciable vapour pressure and stimulates the human sensory organs in the nasal cavity. Before any water can be considered good and fit for drinking and other uses, it must be tasteless, colourless and odourless. The major organic causes of taste and odour are methyl isobomeol and geosmin often associated with algal blooms [21]. When water is said to have taste and odour, it is unfit for consumption and other uses.

From the results, comparing it with [22], although both studies of the physicochemical parameters have different standards, they both correspond with each other. This proves that impurities can contribute to the analysis of water and silver nanoparticles plays a good role in disinfecting water. It shows that water treated with green synthesized AgNPs is the most appropriate for household consumption because the water sample contains significantly low amount of residue or contaminants. For irrigation and agricultural uses, 3 mM tri sodium citrate AgNPs was found tobe the most suitable treatment agent because water used for this purpose has to contain averagely dissolved oxygen, a pH neither too acidic nor alkaline, a TDS of closely 100 mg L^{-1} and a temperature of 25^{o}C.

4. Conclusion

Water can support the growth of many types of microorganisms. The presence of disease-causing microbes in water is unhealthy and even life threatening. Microbiological contamination of water has long been a concern of the public. Safe drinking water plays a significant role in human health and well-being. Urgent development of effective and low-cost disinfecting technologies is needed to address the problems caused by an outbreak of harmful microorganisms. WHO estimates that 94 % of cases are preventable through modifications to the environment, including access to safe water and to improve sanitation and hygiene not just on the water but within the environment. This study revealed that those microorganisms could be removed with the aid of silver nanoparticles. Silver nanoparticles were prepared through two different methods: chemical methods via tri-sodium citrate reduction and sodium borohydride reduction methods as well as the biological method. After the treated water samples were analyzed based on physicochemical parameters using standards of regulatory agencies such as WHO, NAFDAC and NIS, 5 mM tri sodium citrate AgNPs was able to meet up with 10 parameters out of the 11 parameters tested, 3 mM tri sodium citrate AgNPs, 2 mM tri sodium citrate AgNPs, sodium borohydride AgNPs and green synthesized AgNPs were able to meet up with all of the 11 physiochemical parameters tested. From the statistics, it shows that green synthesized AgNPs are the most suitable for treating water meant for household consumption while 3 mM tri sodium citrate AgNPs is the most suitable to treat water supplies for aquatic organisms.

References

[1]. Sharma, B. D. and Bora, N. (2012). Green synthesis of silver nanoparticles using *Bryophyllum pinnatum* (lam) and monitoring their antibacterial activities. *Archives Applied Science Research*, 4, 2098- 2104.

[2]. Natsuki, J., Natsuki, T., and Hashimoto, Y. (2015). A review of silver nanoparticles: synthesis methods, properties and application. *International Journal of Material Science and Applications*, 4(5), 325-332. 10.11645/j.ijmsa.20150405.17

[3]. Khan, A., Shareen, A., Mahmood, T., Rehman, W. and Yaqoob, A. (2017). Novel synthesis and characterization of silver nanoparticles from the leaves extract of *Aloe vera* and their antimicrobial activity. *Journal of Nanoscience and Nanotechnology Application*, 1, 103- 111.

[4]. Tanya, M. and M. S. S. (2012). Green synthesis of silver nanoparticles. *International Journal of Pharmaceutical Medicine and Biological Science*, 1, 234- 241.

[5]. Suriati, G., Mariati, M. and Azizan, A. (2014). Synthesis of silver nanoparticles by chemical reduction method: effect of reducing agent and surfactant concentration. *International Journal of Automotive and Mechanical Engineering*, 10, 1920-1927. 10.15282/ijame.10.2014.9.0160

[6]. World Health Organisation monographs on selected medicinal plants (2002). Volume 4.

[7]. J.D.P. Khank (2005). Exposure related health effects of silver and silver compounds: a review. *Ann Occupied Hygiene.*, 49, 575- 585.

[8]. Panigrahi, T. (2013). Synthesis and characterization of silver nanoparticles using the leaf extract of *Adzadiracta indica.* 1, 1) pp?.

[9]. Ekiye, E. and Luo, Z. (2010). Water quality monitoring in Nigeria; case study of Nigeria's industrial cities. *Journal of America Science*. 6(4), 22- 28.

[10]. Zhang, Y., Peng, H., Huang, W., Zhou, Y. and Yan, D. (2008). Facile preparation and characterization of highly antimicrobial colloid Ag or Au nanoparticles. *Journal of Colloid Interface Science*, 325, 371–376.

[11]. Bhatia, S. (2016). Nanoparticles types, classification, characterization, fabrication methods and drug delivery application. *Springer International Publishing.* 2, 33- 93.

[12]. Singh, S., Singh, B. K., Yadav, S. M. and Gupta, A. K. (2015). Applications of nanotechnology in agricultural and their role and diseases management. *Research Journal of Nanoscience and Nanotechnology*, 5(1,) 1-5.

[13]. Ibrahim, K. Saeed, K. and Khan I. (2017). Nanoparticles: Properties, applications and toxicities. *Arabian Journal of Chemistry.* 1, 12-17.

[14]. Uddin, M. N., Alam, M. S., Moni, M.N. and Milah, M. A. (2014). An assessment of river quality parameters: a case study of Jamuna River. *Journal of Environmental of Science and Natural Resources*, 7(1), 249- 256.

[15]. Chinedu, S. N., Nwinyi, O. C., Oluwadamisi, A. Y. and Eze, V.N. (2011). Assessment of water quality in Canaanland, Ota, southwest Nigeria. *Agriculture and Biological Journal of North America*, 2(4), 577-583.

[16]. Zielinka, A., Skwarek, E., Zaleska, A., Gazda, M. and Hupka J. (2009). Preparation of silver nanoparticles with controlled particles size. *Elsevier Procedia Chemistry*. 1(17), 1560-1566.

[17]. Sondi, A. and Salopek-Sondi, B. (2004). Silver nanoparticles as antimicrobial agent; a case study of *E. coli* as a model for gram negative bacteria. *Journal of Colloid and Interface and Science*, 2(75), 177-182.

[18]. Mohammedinejad, R., Pourseyedi, Sh., Baghizaden, A. Ranjbar, Sh. and Mansoori, G. A. (2013). Synthesis of silver nanoparticle using Silybummarianum seed extract. *International Journal of Nanoscience and Nanotechnology*, 9, 221- 226.

[19]. Qasim, M., Udomluck, N., Chang, J., Park, H. and Kim, K. (2018). Synthesis and characterization of silver nanoparticles. *International Journal of Nanomedicine,* 13, 235–249. 10.2147/IJN.S153485

[20]. Salomoni, R., Léo, P., Montemor, AF. Rinald, BG. and. Rodrigues, MFA. (2017). Antibacterial effect of silver nanoparticles in *Pseudomonas aeruginosa. Nanotechnology of Science Applied*, 10, 115–121. 10.2147/NSA.S13341

[21]. Theivasanthi, T. and Alagar, M. (2011). Antibacterial study of silver nanoparticles.

[22]. Rajawat, S. and Qureshi, M. S (2012). Comparative study on bactericidal effect of silver nanoparticle synthesized using green technology, in combination with antibiotics on *salmonella typhoon*. *Journal of Biomaterials and Nano biotechnology*, 3, 480-485. 10.4236/jbnb.2012 34049