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Effectiveness of Silver Nitrate on the Removal of Bacteria in Ceramic Pot Filters

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***Abstract*— This research is aimed at comparing the effectiveness of silver nitrate application methods on ceramic filter pot for treating drinking water. Filter pots performance with and without colloidal silver nitrate application was determined based on total coliform removal efficiency. Significant impact of silver nitrate application in removing total coliforms were observed for all filter pots. All filters were produced using locally available materials –clay and sawdust. The application method of the silver nitrate was dipping method and surface coating with a removal efficiency of 100% and 99.8% of total coliform respectively. For the filter with the dipping method, the following properties for filtered water were recorded: BOD of 5.94 mg/l, COD of 2 mg/l, turbidity of 5.24 NTU and Nitrate of 5.7 mg/l. Whereas, the filtered waterfrom filter with surface coating have the following properties: BOD of 2.21 mg/l, COD of 2.13 mg/l, turbidity of 4.48 NTU and Nitrate of 5.2 mg/l. These values fall within the World Health Organization limits for water treatment. This study concludes that locally available raw materials can be utilized to produced ceramic filters.This surely will help especially the rural dwellers in accessing clean drinking water.**

***Index Terms*—Ceramicfilters, Silver Nitrate, Total Coliforms, Filtration process.**

I. Introduction

As essential as water is to life, it could be dangerous if not purified hence there is the need for water treatment to render it safe for drinking and domestic use. Most important, is the removal of pathogenic organisms and toxic substances such as heavy metals causing health hazards. The World Health Organization (WHO) reported that over 99.8% of death is caused by poor quality of drinking water in the developing countries such as Nigeria [1]. Ceramic filters are microscopic screening agents typically made from a fine clay material capable of removing particles as small as 0.5 micron in size such as bacteria and parasites [2].Ceramic filtersare essentiallymade from the combination of clay, a burn out material (usually saw dust or rice husk), and water. Ceramic filter pots are produced from a press, which are then allowed to cure in air, followed by firing in a kiln, and finally application of silver for effective removal of microbiological efficacy [3,4,5,6]. Household water treatment and safe storage systems (HWTS) are increasingly being promoted in both development and emergency contexts to improve the quality of drinking water and reduce exposure to water-borne pathogens. HWTS have been found to reduce the number of diarrheal episodes by 45% [7]. Household water storage and treatment options include ceramic filtration, chlorination with improved storage, solar disinfection, thermal disinfection and combination systems using chemical coagulation-flocculation, sedimentation, filtration and chlorination as the most promising, accessible and effective means of improving the microbiological quality of water [8,9].

Recently, Nigeria has made solid progress in reaching people with water – seven in ten people now have clean water to drink. Despite that, 59 million people still don't have clean water and about 59,500 children under 5 die every year due to poor water and sanitation [10]. Thus, ceramic filters have the potential of tackling such a menace [11,12,13], as it will provide a cheap and reliable alternative source of providing clean and safe drinking water to many residents especially in rural areas in Nigeria [14,15].

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II. Methodology

a. Material Preparation and Filter Media Production

The first step in the manufacture of ceramic pot filters (CPF) is the acquisition and preparation of the raw materials. One of the advantages of CPFs is the local availability of the raw materials necessary for their manufacture.

The three (3) major raw materials required are:

- Clay, which shall be obtained locally.
- Combustible materials (Rice husk or saw dust), which shall be obtained from local farmers (sawdust may as well be used).
- Water.

The methods described below was adopted in the development of the water filtration system [16]. Table 1 shows the materials required and their uses for the production of ceramic filters.

Table 1 Materials Required for Ceramic Filter Production

Material	Purpose
Clay	- Main source of material for ceramic mixture
Rice husks / Saw Dust	- Mixed into ceramic to create pores in order for water to flow through
Water	- Used in creating ceramic mixture
Silver nitrate (AgNO3)	- Coated for elimination bacteria

The ceramic media of the filter requires the incorporation of rice husks. Which will eventually leave behind pores of its size after being burnt off at high temperatures in a kiln. The pores those created allow water to flow through the ceramic filter. The clay was crushed into fines with a hammer. The next step is the crushing of the rice husks into small pieces of particle size averaging 0.9 mm.The bigger the husk size, the bigger the pore (not always re commended).Once the clay and rice husk have been prepared, they must be mixed to create a uniform composition [17].

The homogenized mixed materials are first fed to the mould. The mould is made up of a male mould resting inside the female mould which was mounted to the hydraulic press.

Once the filters have been pressed, they are allowed to be dried before they can be fired. Without this step, the filters will undergo dramatic volume change in the kiln, which will cause cracking and even shattered.

After drying process, firing follows. Firing the kiln is an eight-hour process. The produced filters were then fired in a kiln for 8 hrs at a temperature range of 800 to 900 ^{o}C.

b. Method of Applying silver nitrate

Two methods for the application of the silver nitrate were employed, viz: Surface coating and dipping method.

i. *Add 100g of AgNO3 (99.8% purity) to 500mL of de-ionized water and then mix well.*
ii. *Add 1L of de-ionized water and mix for 1 minute. Silver solution is complete.*
iii. *Dilution of Silver solution is done with a silver solution to distilled water ratio of 1:180. (i.e. For every 100mL of silver solution used, it should be diluted with 18L distilled water)*
iv. *Using a paint brush, silver solution was coated on the inside and outside of the filter.*
v. *For the dipping method, the prepared silver solution was poured in a big container of about 20L capacity. The filter was then completely dipped for 60s to ensure proper penetration of the solution.*
vi. *Prior to v. above, the filters to undergo dipping method were cured (fully immersed) in water for 24 hrs.*
vii. *The filters were left to dry in a clean and dust free environment.*

III. RESULTS

a. Sample collection

Raw water was collected from river Kaduna and was filtered using three different filters. This lead to four samples namely; raw water (A), filtered water without the application of silver nitrate on filter (B), filtered water from surface coated filter (C) and filtered water from dipping method filter (D). The four samples were taken for physicochemical and bacteriological analysis immediately after treatments (filtration) were done.

b. Results and Discussion

pH: pH value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia also affect the pH of water.

From Table 2, the pH values recorded in this work were 7.7,8.6, 7.7 and 7.3 for sample A, B, C and D respectively. These values fallwithin the (6.5 to 8.5) WHO permissible limit for portable water. pH value is aparamount index of acidity or alkalinity and the concentration of hydrogen ion in ground water.pH lower than 4 will produce sour taste and higher value above 8.5 bitter taste. Higher values of pH hasten the scale formation in water heating apparatus and reduce the germicidal potential of chlorine.

Colour

Colour in drinking-water may be due to the presence of coloured organic matter, metals such as iron and manganese, or industrial wastes. The colour values realized from Table 2 were 112, 23, 15 and 12 mg/l for sample A-D respectively. Drinking-water should be colourless with a limit of 15 mg/l according to World health organization. Samples A and B were above standard limit, but C and D fall within and even below the limit. This showed that the Sample D treatment was more effective for sample D.

Turbidity: The Turbidity in water is the reduction of transparency due to the presence ofparticulate matter such as clay or silt, finely divided organic matter, plankton or other microscopic organisms. These cause light to be scattered and absorbed rather than transmitted in straight lines through the sample. The colloidal materials which bring about turbidity provide adsorption sites for substances that may be harmful to human and aquatic life.

The turbidity values of the samples from Table 2 were found to be in the range of 21.3 to 4.48 NTU in the order D<C<B<A. The values indicate that sample D got the best treatment and compared with the WHO permissible limit for portable water which is 5.0 NTU.

Total dissolved solids (TDS)

Total dissolved solids is the residue remaining in a weighed dish after the sample has been passed through a standard fibre glass filter and dried to constant mass at 103 – 105^{o}C or 179 – 181^{o}C. Many dissolved substances are undesirable in water. In this research work, the TDS values from Table 2 realized were 455 mg/l for raw water, 354, 385 and 147 mg/l for the filtered sample B, C and D respectively. According to WHO, the standard limit value for TDS is 500 mg/l. Dissolved minerals, gases and organic constituents may produce aesthetically displeasing colour, taste and odor. Some dissolved organic chemicals may deplete the dissolved oxygen in the receiving waters and some may be inert to biological oxidation, yet others have been identified as carcinogens. The sample C was higher in TDS compare to sample B which was treated without Silver nitrate, but D showed the best of all treatment in TDS at 147 mg/l.

Water with higher solids content often has a laxative and sometimes the reverse effect upon people whose bodies are not adjusted to them. High concentration of dissolved solids about 3000 mg/l may also produce distress in livestock.

Conductivity

Specific conductance yields a measure of water capacity to convey an electric current. This property related to the total concentration of the ionized substances in water and the temperature at which the measurement is made, the nature of the various dissolved substances, their actual and relative concentrations, and the ionic strength of the water sample vitally affect the specific conductance.

Conductivity measures the ionic content of the water and it is linked directly to total dissolved solids. The conductivity of the samples ranged between (0.20 – 0.64mS/cm). This is due to high dissolved inorganic minerals. All the filtered samples gave values below the WHO permissible limit of 1mS/cm. As the ionic concentration increases the conductance of the solution also increases. Therefore, conductivity measurement provided an indication of ion concentration.

Chlorides: Chloride is one of the major inorganic anion in water. In potable water, the salty taste is produced by the chloride concentrations is variable and dependent on the chemical composition. The concentration of the chloride was lowest in sample A (101mg/l) and highest in sample D (61.60mg/l). it was noticed that as the treatment level increases, the chloride level increases too. This could due to the amount of Silver nitrate doped. However, the values were within the WHO (200mg/l) limit for chloride. Chlorides occur in natural water at varying concentrations depending on the geographical condition. It may also get into surface water from several sources including: rocks containing chlorides, agricultural run-off, waste water from industries, oil well wastes, and effluent waste water from waste water treatment plants. High chloride content may harm metallic pipes and structures as well as growing plants. Small amounts of chlorides are required for normal cell functions in plant and animal life.

Hardness: Hardness of water is caused by the presence of multivalent metallic cations and is largely due to calcium, Ca^{+2}, and magnesium, Mg^{+2} ions. Hardness is reported in terms of $CaCO_3$. Hardness is the measure of capacity of water to react with soap, hard water requiring considerably more soap to produce lather. It is not caused by single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. The low and high value of Hardness has advantages and disadvantages. The total hardness of each samples were observed to be in the range (112 – 1,137mg/l). The concentration of each of the filtered sample was below the 500mg/l which is the WHO maximum permissible limit for drinking water except for the raw water, which was 1,137 mg/l. Hardness is the property that makes water form an insoluble curd with soap and primarily it is due to the presence of calcium and magnesium. Based on the hardness value ground water may be classified as soft (<75 mg/l), moderately soft (75-150 mg/l), hard (150-300 mg/l) and very hard (>300 mg/l). Hard waters have no known adverse health effects and may be more palatable than soft waters. Total hardness less than 80 mg/l may result in corrosive water, while hardness above 100 mg/l may result in the need for more soap during bathing and laundering, forms scum and curd, causes yellowing of fabrics and toughens vegetables cooked in the water. Excessive hardness may also lead to scale deposits in pipes, heaters, and boilers.

Alkalinity: Alkalinity is primarily due to carbonate, bicarbonate and hydroxide contents. The maximum and minimum alkalinity concentrations were found to be 29.02, 9.30, 3.60 and 2.31mg/l for samples A-D. These values are below the WHO acceptable limit of 250 mg/l. Excessive alkalinity may cause stomach upset and encrustation of utensils, pipes, and water heaters. High levels can also give a flat taste to the water and cause ―itchy‖ skin when bathing.

Nitrate and Nitrite: The concentration of nitrate in water samples depends on the nitrification activities of micro-organisms. The results of nitrate were 15, 10, 5.7 and 5.2 mg/l for sample A-D. The values were well below 50mg/l for WHO permissible limits of nitrate in drinking water. In general, vegetables are the main source of nitrate intake when level in drinking water is below 10 mg/l. When nitrate level in drinking water exceeds 50 mg/l, drinking water becomes the main source of total nitrate intake. High level of nitrate in drinking water due to excessive use of agriculture fertilizers, decayed vegetable water, domestic effluent, sewage disposal industrial discharges, leachable from refuse dumps, and atmospheric precipitation has become a serious problem. Water that is contaminated with nitrate proves harmful especially to infants causing methaemoglobinaemia otherwise called infantile cyanosis or blue baby syndrome if consumed.

Nitrite in water is either due to oxidation of ammonium compounds or due to reduction of nitrate. Nitrites generally occur in trace quantities in surface waters but may attain high levels in some ground waters. The values were 0.5, 0.3, 0.3 and 0.1 for sample A-D. It can be toxic to certain aquatic organisms even at concentration of 1 mg/l.

Sulfates

Water containing high levels of sulfates, particularly magnesium sulfate (Epson salts) and sodium sulfates (Glauber's salt) may have a laxative effect. These effects vary among individuals and appear to last only until they become accustomed to using the water. The values of sulfate in the samples as presented in Table 2 were 49, 33, 26 and 24 mg/l for samples A-D respectively. The upper limit recommended for sulfates is 250 mg/l. Treatment include filtration and reverse osmosis.

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

BOD and COD are the two important parameters to indicate the degree of pollution in raw water. From Table 2 of result BODvalues for the raw sample was 129.2 mg/l and reduced after filtration to 32.1, 5.94, and 2.21 mg/l, for the filtered samples B,C and D respectively. The higher BOD value at the initial stage was mainly contributed to the presence of organic matter since industrial and aquatic wastes consist of a lot of organic compounds. These organic materials will then decompose by bacteria and caused high BOD level. High BOD reading indicates low dissolved oxygen (DO) level in water body which is unfavorable for aquatic ecosystem. Hence, a decline in BOD value of the raw water due to filtration process is necessary to improve the raw water quality.

COD is used to measure the amount of organic pollutants present in water body. The raw sample which COD value was 171.33 mg/l after treatment showed lower COD value which were 9.1, 2and 2.13 mg/l for sample B, C and D as compared to the raw water which was 171.33 mg/l. COD value reduced after filtrations treatment as organic compounds had been removed from raw water. Low concentration of organic compounds will result in low COD value.

Bacteriological analysis

The principal risk associated with water in small-community supplies is that of infectious disease related to faecal contamination. Hence, the microbiological examination of drinking-water emphasizes assessment of the hygienic quality of the supply. This requires the isolation and enumeration of organisms that indicate the presence of faecal contamination. In certain circumstances, the same indicator organisms may also be used to assess the efficiency of drinking-water treatment process, which is an important element of quality control. Other microbiological indicators, not necessarily associated with faecal pollution, may also be used for this purpose. The isolation of specific pathogens in water should be undertaken only by reference laboratories for purposes of investigating and controlling outbreaks of disease. Routine isolation in other circumstances is not practical

TABLE 2: PHYSICOCHEMICAL AND BACTERIOLOGICAL PARAMETERS OF WATER SAMPLES (A= raw water, B = filtered raw water without the application of silver nitrate, C = filtered water from surface coated filter and D= filtered water from dipping method filter**)**

S/N	PARAMETERS	UNIT	SAMPLE				
	PHYSICOCHEMICAL		**A**	**B**	**C**	**D**	**WHO**
1	pH		7.7	8.6	7.7	7.3	6.5-8.5
2	ALKALINITY	mg/l	29.02	9.3	3.6	2.31	250
3	SALINITY	mg/l	0.4096	0.314	0.282	0.128	-
4	COLOUR	mg/l	112	23	15	12	15
5	TOTAL DISSOLVED SOLID	ppm	455	354	385	147	500
6	ELECTRICAL CONDUCTIVITY	mS/cm	0.64	0.49	0.44	0.20	1
7	CHLORIDE	mg/l	101	112	140	140	250
8	FREE CHLORINE	mg/l	0.34	0.25	0.25	0.25	-
9	TOTAL CHLORINE	mg/l	0.37	0.34	0.34	0.30	-
10	TURBIDITY	NTU	21.3	5.79	5.24	4.48	5
11	DISSOLVED OXYGEN	mg/l	2.77	5.15	6.12	6.22	-
12	BIOLOGICAL OXYGEN DEMAND	mg/l	129.2	32.10	5.94	2.21	-
13	CHEMICAL OXYGEN DEMAND	mg/l	171.33	9.1	2	2.13	
14	HARDNESS	mg/l	1,137	281	115	112	150
15	AMMONIUM	mg/l	1.70	1.11	ND	ND	
16	SULPHATE	mg/l	49	33	26	24	100
	BACTERIOLOGICAL TEST	mg/l					
18	TOTAL COLIFORM COUNT	cfu/100ml	500	240	0	1	10
19	COLIFORM COUNT	cfu/100ml	24	10	0	0	1
20	NITRITE	mg/l	0.5	0.3	0.3	0.1	0.2
21	NITRATE	mg/l	15	10	5.7	5.2	50

Coliform organisms (Total Coliforms)

Coliform organisms have long been recognized as a suitable microbial indicator of drinking-water quality, largely because they are easy to detect and enumerate in water. The term "coliform organisms" refers to Gram-negative, rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties and able to ferment lactose at 35–37°C with the production of acid, gas, and aldehyde within 24–48 hours. They are also oxidase-negative and non-spore-forming and display b-galactosidase activity.The total coliformrealized were 500, 240, 0 and 1cfu/100 ml for sample A-D respectively with the limit set by WHO being 10cfu/100 ml respectively.

Although coliform organisms may not always be directly related to the presence of faecal contamination or pathogens in drinking-water, the coliform test is still useful for monitoring the microbial quality of treated piped water supplies. If there is any doubt, especially when coliform organisms are found in the absence of thermotolerant coliforms and *E. coli*, identification to the species level or analyses for other indicator organisms may be undertaken to investigate the nature of the contamination. Sanitary inspections will also be needed.

Faecal streptococci (Coliform Count)

Faecal streptococci are those streptococci generally present in the faeces of humans and animals. All possess the Lancefield group D antigen. The coliform count values recorded in this work are 24 cfu/100 ml for raw, 10 cfu/100 ml for filter without silver nitrate, then 0 cfu/100 ml for the coated and dipped silver nitrate filter with the limit set by WHO being 1 cfu/100 ml of water. These values fall within the (6.5 to 8.5) WHO permissible limit for portable water.

Their primary value in water-quality examination is therefore as additional indicators of treatment efficiency. Moreover, streptococci are highly resistant to drying and may be valuable for routine control after new mains are laid or distribution systems are repaired, or for detecting pollution of groundwaters or surface waters by surface run-off.

IV. Conclusion

Considering the results of water quality analysis, it is evident that both methods of silver nitrate application i.e surface coating and dipping methods are highly effective in the treatment of bacteriological content of the raw water collected.

The filters are also effective in the reduction TDS and Turbidity as all the values recorded fall below the WHO standard.

High level of COD and BOD reduction from the filters are also recorded.

On a general note, the filters (ceramic pot filters) can serve as a means to deliver safe clean drinking water for people in the rural areas in Nigeria who suffers from the lack of safe drinking water.

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