

Characterization Adsorption and Antibacterial Properties of Silver-Modified Kaolinite Clay from Kwi, Plateau State Nigeria

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Abstract
Clay samples from Kwi, Barkin Ladi Local Government Area of Plateau State, Nigeria was purified and characterized using XRF, FT-IR and XRD. Silver-modified clay was prepared in order to develop an antibacterial and adsorptive material. The modified and purified clays were tested for antimicrobial activity against *Staphylococcus aureus, Enterobacteriae, pseudomonas aureus* and *salmonella typha* by microbiological test as well as adsorptive properties against Chromium (III), Nickel (II), and Lead(II) from leather ternary effluent. From the results the silica content (SiO_2) was found to be 56.12%, followed by alumina (Al_2O_3) 23.90%, iron (III) oxide 2.31% among others. The X-Ray diffraction studies showed that the clay deposit consist predominantly of kaolinite with d-spacing of 7.14639Å and 3.57632Å respectively and traces of quartz with d-spacing of 3.34520Å as well as orthoclase. The FT-IR spectral analysis of the clay samples reveals wave number and absorption band at 3688.02 and 3618.58cm^{-1} which arise from the internal surface OH group indicative of kaolinite and also deformation band at 1003.02 and 910.43cm^{-1}. Results have shown a strong antimicrobial activity of the Ag modified clay, which considerably inhibited the growth of ordinary microorganisms, including Gram-positive and Gram-negative bacteria. The Ag-clay reacted positively to organisms that had hitherto shown resistance to common antibiotic drugs. Also upto 64% of Cr ions and 94% of Ni ions were removed from ternary wastewater by Ag-modified and purified clays respectively. The results have confirmed the strong anti-bacterial activity of Silver ion.
Keywords: Clay characterization, adsorption, anti-microbial Properties, ternary wastewater
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1.0 INTRODUCTION

Clay is a term used to describe either the size of the individual particles present in a deposit or the specific minerals of a size less than 0.002mm in dimension (Fábio *et al*, 2009; Nwosu *et al*, 2013 and Abuh *et al*, 2014). Understanding the distinction between clay size and clay minerals is important because two samples of clay having identical particle size may have varying behaviours based on the clay minerals present (Gray *et al*, 2013). As a result of the substantial differences in behaviour of the various types of clay minerals, determining the type and proportion of clay minerals in a particular clay deposit is one of the first and most important steps necessary in screening a source material.

The application of nanotechnology in the purification and treatment of wastewater may potentially revolutionize water treatment processes (Zhang, 2006; Vishnu and Bibi 2013; Gil *et al*,2011; Bhattacharya *et al*, 2013). Characteristics such as large surface area, high specificity, high reactivity, catalytic potential and the absence of internal diffusion resistance make nano-particles excellent candidates for water treatment applications (Bergaya *et al*, 2006). According to Vishnu and Bibi (2013), nanoscale has stimulated the development and use of novel and cost effective technologies for remediation, pollution detection and pollution monitoring.

Among natural available nanoporous materials, clay minerals have several important advantages over alternative adsorbents. Clays are inexpensive, abundantly available and non-toxic, and have good sorption properties and ion exchange potential for charged pollutants. (Gil *et al*,2010). Clays possess a wide range of pore size distribution ranging from micro to mesopores (Haydel *et al*, 2008). Added to these is the fact that clay mineral platelets are truly nano-particulate and usually have very large surface area in the region of between 10 and 700m^2/g together with its multifunctional properties. The second is the fact that clay mineral's expansive surface often has an electrical charge that results in accumulation of inorganic and organic cations; coupled with its availability, low cost and ease of modification, chemical and mechanical stability, layered structure, high cation exchange capacity (CEC) (Falkinham *et al*, 2009). Thirdly, incorporation of various species and nanoparticles into the interlayer space allows clay minerals to be utilized as new functional materials (Li *et al*, 2002; Oya *et al*, 1991). These clay based functional materials and nano-composites demonstrate a great variety of applications such as adsorption and environmental remediation due to their variety in structural and surface properties, high chemical stability, high specific surface area and high adsorption capacity (Bergaya *et al*, 2006). Such features allow the clays to be tailored to suit specific decontaminating purposes which can bring about considerable advantages from industrial application point of view (Haydel *et al*, 2008).

Living Clay is known to have been used historically as an effective antibacterial in the treatment of dysentery, and as a means of decontaminating water. Presently it is being used internationally to clarify and balance small and large bodies of water. This is so because Living Clay particles are smaller than many bacteria; when bacteria encounter an environment abundant in clay it becomes surrounded by the clay, and are imbedded in it. The immediate result is that the bacteria are unable to receive nourishment and cannot survive (Haydel *et al*, 2008.

A recognized detoxifying agent, nutrient and bactericidal Calcium Montmorillonite Clay is in the smectite group of clays. Its power as a detoxifying substance comes from its inherent ability to adsorb and absorb. Its unique ability to grow and adsorb is the reason for its classification and recognition as a Living Clay (Haydel *et al*, 2008 While there is more than one Montmorillonite, the red Calcium Montmorillonite Clay of the smectite group remains a favourite for human use. For example, Iron-rich smectite and illite clay (Montmorillonite/Bentonite type of clay) is effective in killing bacteria *in vitro.* The authors reported that the clay mineral exhibited bactericidal activity against *E. coli*, ESBL (Extended-Spectrum Beta-Lactamases); *S. enterica serovar Typhimurium, P. aeruginosa*, and *M. marinum*, and significantly reduces growth of *S. aureus*, PRSA, MRSA, and nonpathogenic *M. smegmatis* approximately1,000-fold compared to cultures grown without added mineral products (Haydel *et al*, 2008). Similarly, Falkinham et al. (2009) have also studied the antibiotic and antimicrobial activity of red clays from the Kingdom of Jordan (Jordan's Red Soil). The authors concluded that the antibiotic activity of Jordan's red clays is likely due to the proliferation of antibiotic-producing bacteria, which is induced by the clay.

Antimicrobial materials are classes of materials that have the ability of inhibiting the growth or even killing some kinds of microorganisms. This property is very important at certain industry segments, normally those that require large purity and hygiene, along with a partial or complete removal of noxious microorganisms (Li *et al*, 2002

Researches have shown that montmorillonites intercalated with metallic ions with bacteriostatic nature, such as silver, copper, zinc, mercury, tin, bismuth, cadmium, chromium and thallium provide a strong antimicrobial activity to the clay (Oya *et al*, 1991; Ohashi and Oya, 1992; Zhou *et al*, 2004). . It has been shown that these ions can inhibit birth and growth, or even kill harmful microbes, by altering the metabolisms of bacterium and fungus (Hu and Xia, 2006; Frost *et al*, 2006).

Clay minerals may be administered either orally as antacids, gastrointestinal protectors, anti-diarrhoeic, osmotic oral laxatives, homeostatic, direct emetics, antianemics and mineral supplements, or parentally as antianemics and haemostatics. They may also be used topically as antiseptics, disinfectants, dermatological protectors, anti-inflammatories, local anaesthetics and keratolytic reducers (Carretero and Pozo, 2010).

Inorganic antibacterial products are usually in the form of a composite, in which the metallic ions are impregnated in or covered on a carrier (Li *et al*, 2002). Silver ions are extensively used in the synthesis of antibacterial agents because it is a very effective specimen in killing bacteria, at relatively low concentrations, and with a low toxicity. In water treatment and food industry, silver as antimicrobial agent is considered safer and relatively inert, and consequently, the most appropriate for such applications (Oliveira and Oliveira, 2004).

This work reports the results of the characterization, antibacterial and adsorption properties of silver modified clay from Kwi, Plateau State, Nigeria.

2.0 MATERIALS AND METHODS

Clay samples were obtained from Kwi, Barkin Ladi Local Government Area of Plateau state, Nigeria. The wastewater used for this work was collected from Naraguta Leather Work, Jos North Local Government Area of Plateau State, Nigeria.

2.1CLAY PURIFICATION

The clay samples were crushed and dispersed in a plastic container with large volume of water. The clay was then filtered to remove stone and the filtrate was allowed to sediment for 24hours. The clay was re-suspended in water again and allowed to stand overnight. The top fraction was removed and purified as follows. The clay obtained was re-dispersed in de-ionized water and heated at 75^{o}C in the presence of solutions containing sodium salts of bicarbonate (1M), citrate (0.3M) and chloride (2M) as described by Mecabih and Bouchikhi [22]. This process will eliminate organic and inorganic compounds including Al, Fe, and other free cations.

Carbonates in the clay were removed by treatment with 0.5M HCl; this was followed by treatment with 30% v/v H_2O_2 at 70^{o}C to remove all organic matter. After several washings with water to remove chloride, the sample were treated with 1M NaCl to convert the clay to its Na^+ form to enhance swelling before drying at 110^{o}C. This sample was labeled purified clay (PC). The purified clay was subjected to XRF, FT-IR and XRD analyses to ascertain the nature and composition of the clay.

2.2PREPERATION OF SILVER MODIFIED CLAY

Silver modified clay was prepared by adding 6.0g of sodium hydroxide (NaOH) into 125ml of deionized water followed by 3g of silver nitrate ($AgN0_3$) with constant stirring until all the silver nitrate has dissolved. About 10g of purified clay was added in to $AgNO_3$/NaOH solution and aged for 72hours. It was then filtered and calcined at

400^0C for 2hours, pounded in to powdered form by the use of glass mortar. This sample was labeled silver modified clay.

2.3ADSORPTION STUDIES

In adsorption studies, 2g of each of the sample clay was added into 100ml of wastewater separately and was allowed to stand for 2hours, the clay were filtered out and the water was analyzed in each case, for the purified clay and silver modified clay by the use of atomic adsorption spectrophotometer.

$$\text{Removal efficiency (\%)} = \frac{C_0 - C_f}{C_0} \times \frac{100}{1}$$

Where C_o and C_f are the initial and final concentration of the metal ion (mg/L) in the wastewater.

2.4ANTIMICROBIAL STUDIES

The wastewater sample was taken to Department of Microbiology, University of Jos for microbial count and susceptibility test before and after treatment with the clay samples. Bacterial identification test includes; catalase test for streptococci, coagulase test for staph aureus, citrate utilization test for entero-bacteria, indole test for gram negative bacilli, oxidase test for pseudomonas and gram staining which is a method of differentiating bacteria species into two large groups (gram positive and grain negative).

2.5Characterization of Clay Samples

X-Ray Fluorescence Spectrophotometer (XRF) and X-Ray Diffraction Spectrophotometer (XRD) was made available by National Geological Research Agency (NGRA), Kaduna, Nigeria while Fourier Transform Infra-Red Spectroscopy (FT-IR) was made available by National Research Institute for Chemical Technology (NARICT), Zaria Nigeria.

3.0PRESENTATIONOF RESULTS

3.1CHARACTERIZATION OF KWI CLAY

Table 1: XRF RESULT ANALYSES FOR KWI CLAY

OXIDES COMP.	%
SiO_2	56.12
TiO_2	1.58
Al_2O_3	23.90
Fe_2O_3	2.31
CaO	0.28
MgO	0.17
Na_2O	1.287
K_2O	1.863
MnO	0.01
V_2O_5	0.22
Cr_2O_3	0.199
NiO	0.02
CuO	0.059
ZnO	0.059
SrO	0.13
BaO	0.85
PbO	0.045
L.O.I	10.89

The results of the XRF analysis of Kwi clay is shown on Table 1.The result shows the major constituents of the samples to be silica and alumina. Other elemental constituents' present includes Na_2O, Fe_2O_3, TiO_2, and K_2O. The 56.12% SiO_2 and 23.90% of Al_2O_3 suggest that the clay sample belongs to the kaolinite family.

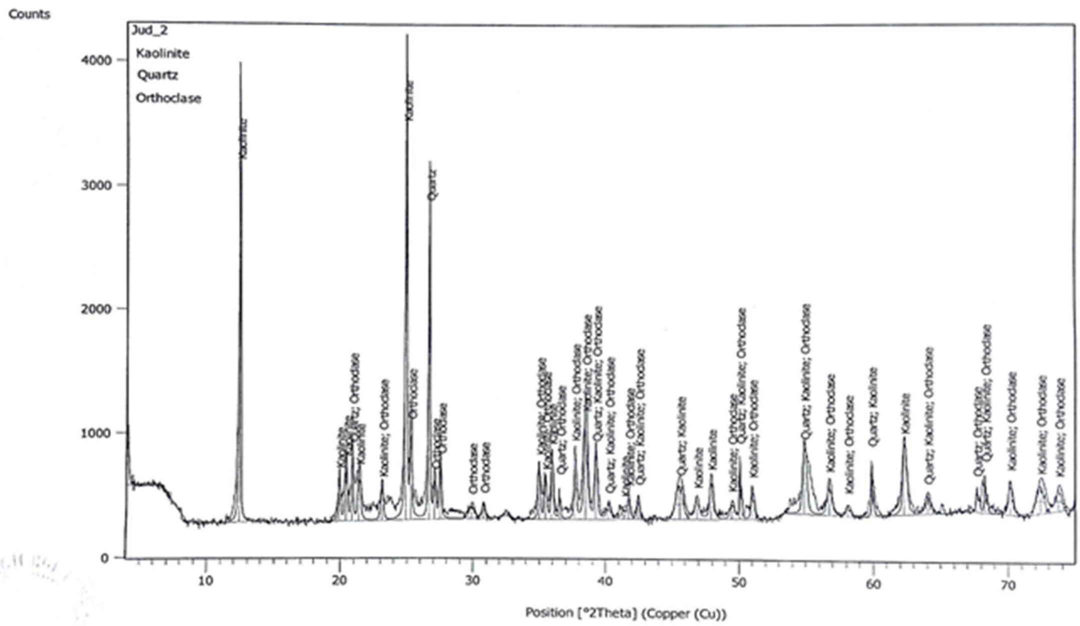

Fig 1: XRD pattern of Kwi clay

Table 2:TOP 3 PEAK LIST OF THE XRD RESULT

Pos.[°2Th.]	Height [cts]	EWHMLeft[°2Th.]	d-spacing[Å].	Rel. Int. [%]	Clay Type
12.3860	2873.57	0.1023	7.14639	90.28*	Kaolinite
24.8976	3182.92	0.1279	3.57632	100.00*	Kaolinite
26.6484	2522.22	0.1023	3.34520	79.24*	Quartz

3.2 X-RAY DIFFRACTION (XRD) OF KWI CLAY

XRD measurements were employed to determine the mineral present in the clay sample (Figure1and Table 2). It was found that the main mineral in the clay sample was kaolinite and quartz. With a principle reflection of Kaolinite having $2\theta_{CuKa}$ = 12.3860 °2Th., d-spacing = 7.14639Å, Rel. Int. = 90.28% and $2\theta_{CuKa}$ = 24.8976 °2Th., d-spacing = 3.57632Å, Rel. Int. = 100% and quartz at $2\theta_{CuKa}$ = 26.6484 °2Th., d-spacing =3.34570Å and Rel. Int. = 79.24% and other pattern were observed which indicate other mineral in small fractions are present in the clay sample.

3.3 FT-IR RESULTS FOR KWI CLAY

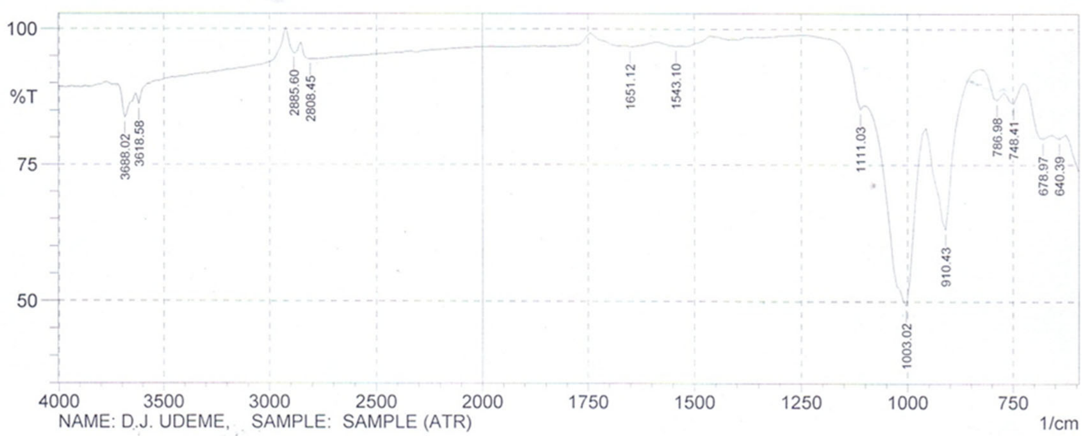

Figure 2: FTIR Spectra of KWI Clay

Table 3: Major bands and Assignment in Kwi Clay

Peaks	Assignment
640.39	Si-O
678.97	Si-O perpendicular
748.41	OH bending towards the surface of clay sheet
786.98	Si-O
910.43	AlAlOH deformation
1003.02	in plane Si-O stretching
1111.03	stretching vibrations of Si-O bonds
1651.12	OH deformation of water
3618.58 3688.02	Stretching vibrations of surface hydroxyl groups for kaolin

The spectrum in figure 2 demonstrates well crystalline kaolinite. The sharp doublet at 3688.02 and 3618.58 cm^{-1} is characteristic for the kaolin group in general. The bands at 3688.02 cm-1, and near 3618.58 arise from the internal surface OH groups. The OH deformation bands of kaolinite are situated at 1003.02 and 910.43cm-1. Supporting bands at 786.98 (Si-O) and 678.97 cm^{-1} (Si-O) are diagnostic for kaolinite.

3.4ADSORPTION OF METAL IONS

The results and comparison of the concentrations in mg/L of Chromium (II), Cadmium (II), Lead (II), and Nickel (II) found in Leather Works waste effluent before and after adsorption with Ag-modified as well as purified clay are reported in tables 4and 5 below.

TABLE 4: Concentrations of Chromium (III), Lead (II), and Nickel (II) in Tannery Wastewater before and after treatment with purified Kwi clay

HEAVY METALS	Cr^{3+}	Pb^{2+}	Ni^{2+}	Cd^{2+}
Initial metal concentration (mg/L)	0.0629	0.9298	0.1483	ND
Final metal concentration (mg/L) after treatment	0.0503	0.8759	0.0079	ND
Amount removed (mg/L)	0.0126	0.0539	0.1404	ND
Removed efficiency	20.03%	5.79%	94.67%	ND

$Ni^{2+} > Cr^{3+} > Pb^{2+}$

TABLE 5: Concentration of Chromium (III), Cadmium (II), Nickel (II) and Lead (II) found in Tannery wastewater before and after treatment with silver (Ag) modified Kwi clay.

HEAVY METALS	Cr^{3+}	Pb^{2+}	Ni^{2+}	Cd^{2+}
Initial metal concentration (mg/L)	0.0629	0.9298	0.1483	ND
Final metal concentration (mg/L) after treatment	0.0226	0.8624	0.1191	ND
Amount removed (mg/L)	0.0403	0.0674	0.0292	ND
Removed efficiency	64.06%	7.24%	19.68%	ND

$Cr^{3+} > Ni^{2+} > Pb^{2+}$ NB: ND means not detected

3.5ANTI-BACTERIAL STUDIES

The total microbial count (TMC) and identification in raw leather works wastewater as well as the Biochemical and Susceptibility test results, the Drug Abbreviations and Full names in susceptibility test are shown in tables 6-

Table 6: Microbial count and identification in Leather works wastewater

S/N		Waste Water Before Treatment (Raw water)	After Treatment with Purified Clay	After Treatment with Silver Modified Clay
1	Total plate Microbial count	106	96	16
	Coliform count	76	33	12
2	Identified micro-organisms present in raw and treated wastewater.	*Staphylococcus aureus, E. coli, proteus spp, Enterobacteriae, pseudomonas aureus salmonella typha*	*Staphylococcus aureus, Enterobacteriae, E. coli*	E. coli, proteus spp
3	Gram Reaction	Gram positive cluster, gram negative short rods, gram negative long rods, gram positive rods	*Staphylococci aureus*, Gram negative short rods, Gram positive rod, Gram negative long rods	Gram negative short rod, Gram positive rods

Table 7: Biochemical Test Results

S/No	Sample	Catalase	Cuagulase	Indole	Citrate	Oxidaze	Motility	Glucose	Lactose	Sucrose	Triple sugar ion agar slant butt slope gas H_2S
1	Waste water sample	+	+	+	+	+	+	+	+	+	Y Y + +
2	After treatment with purified clay	+	+	+	+	-	+	+	-	-	R Y - -
3	After treatment with silver modified clay	-	-	+	-	-	+	+	-	-	R Y - -

NB: YY means glucose, lactose and sucrose are fermented
RY means only glucose fermented

Table 8: Susceptibility test

S/NO	Sample	ANTI-BIOTICS DISC ON MICRO-ORGANISM ISOLATED		Resistant
		Organism	Sensitive	
1	Raw Waste Water	*Pseudomonas*	CPX, AU, CN, PEF, OFX, CEP, PN, S	NA
		E.coli	SXT, AU, CN, S, CPX, OPX	PEF, NA, PN, CEP
		Staphylococcus aureus	CN, PEF, SXT, S, CPX, R	APX, Z, AM
		Bacillus spp	CPX, R, AMZ, APX, CN, PEF, S	SXT, E
		Proteus spp	CPX, SXT, S, PN, CEP, OFX	AU, CN, PEF, NA
2	After Treatment with Purified clay	*Staphylococcus aureus*	SXT, E, PEF, CN, R, CPX	APX, Z, AMS
		E. coli	SXT, S, PN, CEP, NA, PEF, CN, AU, CPX	—
		Enterobacteriae	SXT, E, PEF, CN, APX, Z, AM, R, CPX	—
3	After Treatment with Silver modified clay	*Proteus spp*	CPX, SXT, S, PN, CEP, OFX	—
		E. coli	CPX, SXT, S, PN, OFX, NA, PEF, CN, AU	—

Table 9: Drug Abbreviations and Full names in susceptibility test

Gram Negative Rods		Gram Positive Rods	
OFX	TARIFID	PEF	PEFLACINE
PEF	PEFLACINE	CN	GENTAMYCIN
CPX	CIPROFLOX	APX	AMPICLOX
AU	AUGUMENTIN	Z	ZINNACEF
CN	GENTAMYCIN	AM	AMOXACILIN
S	STREPTOMYCIN	R	ROCEPHIN
CEP	CEPOREX	CPX	CIPROFLOXACIN
NA	MALIDIXIC ACID	S	STREPTOMYCIN
SXT	AMPICILIN	SXT	SEPTRIN
		E	ERYTHROMYCIN

4.0DISCUSSIONS

4.1ADSORPTION PROPERTIES: The initial concentration of the heavy metals (Cr, Ni, and Pb) in Naraguta leather works waste effluent were analyzed to be 0.0629, 0.1483 and 0.9298mg/L respectively as shown in Table 4 above, which significantly decrease to 0.0503, 0.0079 and 0.8759 respectively after treatment with purified clay with a removal efficiency of 20.03%, 94.67% and 5.79%. Cadmium (Cd) was not detected in the water sample. This could be attributed to its presence in concentration below the detection limit of the instrument used. There was a high preference of Ni for the purified clay than other metal ions. As seen inTable 5, the concentration of Chromium (II), Nickel (II), and Lead (II) also decreased to 0.0226, 0.1191and 0.8624 after treatments with silver (Ag) modified clay which showed a removal efficiency of 64.06% for Chromium (II), 19.68% for Nickel (II) and 7.24% for Lead (II) respectively. The concentration of heavy metal decreased significantly in the treated wastewater when compared to the untreated water. The result also showed that purified clay had higher affinity for Ni^{2+} while silver modified clay had higher affinity for Cr^{3+}.

According to Bineesh and Park (2011), when the exchangeable cations in clay are replaced by polymeric and oligomeric hydroxyl metallic cations, calcined at 300-500ºC, a pillared clay with a stable pillar having increased inter-layer spacing possessing micro-pores capable of strong adsorption is formed. Gil et al. (2010) have also reported that pillaring improves the structural characteristics of the clay, increasing the accessibility of the reactant molecules to the interlayer active sites. These classes of materials possesses shape-selective properties due to their inter-layer and inter-pillar distances which control the diffusion rates of reactants, reaction intermediates and products according to Molina et al (2011). Similarly, Enoh and Wetpan (2015) have demonstrated that the modification of clay using acid enhanced the adsorption of metal ions from water by removing between 57 -100% of metal ions studied. According to Basak et al(2012), isomorphic substitution within the clay layer by Mg^{2+}, Fe^{3+}/Fe^{2+} or Al^{3+} generates negative charges that are normally counterbalanced by hydrated alkali or alkaline earth cations (Na^{+}, K^{+}, Ca^{2+}, etc.) residing in the interlayer. Because of the relatively weak Van der Waals forces existing between the layers, intercalation of various molecules is feasible. This is the basis of the adsorptive properties of silver and other modified clays.

4.2ANTIMICROBIAL PROPERTIES

Table 6 shows the microbial count, microorganisms that were present in raw wastewater and the gram reaction of bacterial. The total plate count and coliform count of micro-organic before treatment were 106 and 76, which reduces to 96(9.43%) and 33(56.6%) after treatment with purified clay and 16(84.9%), 12(84.2%) after treatment with silver modified clay. Also the identified micro- organisms that were present in the wastewater include: Staphylococcus aureus, pseudomonas, enterobacteria, proteus spp, E.coli and salmonella typhi which reduces to staphylococcus aureus, enterobacteria, E.coli after treatment with purified clay, and after treatment with silver modified clay reduced to proteus spp and E.coli only. According to the result, there were Gram positive cluster, Gram negative short rods, Gram negative long rods and Gram positive rods which reduce to staphylococcus aureus, Gram negative short rods, Gram positive rod and Gram negative long rods after treatment with purified clay. Treatment with silver modified clay reduced the micro- organism to Gram negative short rod and gram positive rods only.

Table 7 shows Biochemical test of the micro-organism before and after treatment with purified and silver modified clay. The wastewater gave a positive test for catalase (staphylococcus), oxidase (pseudomonas), motility, glucose, Lactose, sucrose, while after treatment with purified clay it gave a negative test to oxidase, lactose, sucrose and treatment with silver modified clay give a negative test to catalase, coagulase, citrate, oxidase, lactose and sucrose.

Table 8 shows susceptibility test of the micro- organism which is all about sensitivity and resistant of micro-organism before and after treatment of wastewater with purified and silver (Ag) modified clay. From the results, all the micro-organisms found in the raw wastewater showed high sensitivity to most of the common antibiotic drugs and resistance to some few drugs. However, after treatment with purified clay, only Staphylococcus aureus showed resistance to three of the drugs (APX, AM, Z) while others were sensitive to all the other drugs tested. The ability of raw clay to remove micro-organisms from water have been attributed to the presence of Iron(III) ions (Haydel *et al*, 2008). Similarly, after treatment with silver modified clay, the two micro-organisms identified were sensitive to all the drugs tested and there was no resistance. This further confirms that silver-nanoclay could serve as a strong and potent antibiotic drug especially in areas where resistance to common drugs have been reported, although more research is required to ascertain the effect of this type of material in humans. This claim is supported by the work of Shalini *et al*. (2012) who reported that Silver (Ag) nanocatalyst is highly efficient for the degradation of microbial contaminants in water and are reusable as well. It is important to note that heating the clay to a temperature of 400^{o}C ensures that every form of micro-organisms that were present inside the clay was destroyed.

Clay's ability to attract toxins, bacteria, heavy metals, and other noxious substances have been reported to come from its positive electrical charge (Haydel *et al*, 2008). With toxic and unhealthy substances tending to have a negative electrical charge, they are irresistibly attracted to the radiantly positive pole of the clay. Nano-Ag is currently the most widely used antimicrobial nanomaterial. Its strong antimicrobial activity, broad antimicrobial spectrum, low human toxicity, and ease of use make it a promising choice for water disinfection and microbial control. It is now well accepted that the antimicrobial activity of nano-silver largely stems from the release of silver ions (Xiu *et al*., 2011, 2012). Also, as the size of silver particles decreases to the nano-scale, their antibacterial efficiency increases due to their large surface area per unit volume. Silver ions generated from the silver surface bind to the reactive group in the target cell or organism, resulting in their precipitation and inactivation. The destruction of bacterial life is dependent on the physical-chemical factors that affect the ability of a cell to grow and multiply. Antimicrobial agents either inhibit growth (bacteriostatic) or destroy cells (bactericidal). The most important factors for impeding bacterial viability are temperature, pH, osmotic pressure, oxidation state, and concentrations of nutrients and wastes (Nolte, 1982). Homeostasis (internal stability) of the cell depends on the action and interaction of a number of physiological systems, and therefore, the effect of the clay mineral surface and related aqueous solution chemistry on the functioning of the whole cell must be considered. Bactericides function by impeding nourishment, disrupting essential metabolic activities, suffocation (precipitation of a solid phase rendering the cell wall impermeable), poisoning (delivery of a toxin), or physical disruption (cell lysis by bursting or penetration) (Nolte, 1982).

5.0CONCLUSION

Although natural clay possesses antibacterial properties, the study have shown that the purification of clay and the introduction of silver ion into clay inter-layer enhances its adsorptive and anti-bacterial properties. The research has demonstrated that silver modified clay has a broad-spectrum in vitro antibacterial activity against antibiotic-susceptible and antibiotic-resistant bacterial pathogens and could be used for such purpose especially given the fact that antibiotic resistance is on the rise in most developing countries, the need for new therapies to combat dangerous bacterial infections cannot be over emphasized. This could be exploited in several products such as paint, cream, and powder.

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