Ethiopian Journal of Environmental Studies & Management 17(1): 67 – 85, 2024
ISSN:1998-0507 doi: https://ejesm.org/doi/v17i1.6
Submitted: January 23, 2024 Accepted: March 15, 2024

TRACE METALS AND PATHOGENS IN WASTEWATERS ON SEDIMENTS OF OYO PROVINCE, SOUTHWESTERN NIGERIA

***AJIBADE, O.M.,[1] BANJO, O.A.,[2] IKHANE, P.R.,[1] POPOOLA, O.D.,[2] OLADIPUPO, S.D.[1] AND OLUFOWOBI, M.M.[1]**

[1]Department of Earth Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria

[2]Department of Microbiology, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria

*Corresponding author: ajibade.muyiwa@oouagoiwoye.edu.ng

Abstract

This study examines toxic metal concentration and bacteriological characteristics of effluents in some parts of southwestern Nigeria. Fourteen wastewaters were analyzed for their trace metal content using Inductive coupled plasma optical emission spectrometry (ICP-OES) while 72-samples were examined for the presence of bacterial load using Standard Microbiological methods (THC-Total viable count and TCC-Total coliform count). Isolates identities were confirmed with relevant biochemical tests. Elevated concentrations of Cu-0.299µg/l, Pb-0.10µg/l, Zn-4.62µg/l, Cr-0.20µg/l, As-0.3µg/l, Ni-0.192µg/l, Cd-0.02µg/l, Se-0.02µg/l, Co-0.099µg/l, V-1.71µg/l, U-0.50µg/l, Sr-1.81µg/l and Ba-0.82µg/l were observed in the cassava market/industry wastewater: signifying this as the most contaminated water in the area. Fe-24.8mg/l in the school wastewater may be geogenically sourced; indicating high degree of weathering with the presence of ferromagnesian minerals while Cu and As in cassava waste-water might be compositional based through bioavailability uptake/sources. Bacteriological analysis revealed Enterobacter spp. and Escherichia coli across all sampled sites; these were consistently present in the wastewaters and are primarily considered as indicators of faecal pollution capable of affecting human health via contamination of surrounding drinking water sources. These species have been associated with several clinical conditions such as pus formation, pneumonia, rheumatic fever and infections in immune compromised inhabitants while others cause severe illness such as respiratory and urinary tract infections in humans. Concentration of toxic metals in the cassava market/industry wastewater should be controlled or monitored and the wastewater made less toxic by constant treatment with adequate remediation facilities to remove the toxic constituents before discharging them to surface water bodies.

Key Words: *Effluents, Metal burdens, Microbiological activities, Faecal pollution, Infections*

Introduction

Wastewater or effluent is water that has been used for domestic or industrial processes and becomes non useful because of the chemical and biological loads already present during these operations. Such water may constitute a health hazard having been negatively affected in quality by anthropogenic influences arising from domestic use, commercial, industrial and agro with agro-allied activities. Bilge water is not exempted from this negative impact in terms of metal load and microbial activities (Corti-Monzon *et al*., 2020, Church *et al*., 2019). The resultant quality of wastewater is dependent on chemical and biological contaminants that are related to its initial use (Wu *et al*., 2012, Le *et al*., 2016, Nobi *et al*., 2010). Consequently, drastic increase and development from human activities over the years has added to the amplification of metal variation in effluents (Vallejuelo *et al*., 2010, Rezic, 2013, Mahdavi *et al*., 2013, Gopinath *et al.,* 2010). Various activity such as domestic, industrial and urbanization have significantly increased the metal loads in the environment especially in Nigeria (Olatunji and Ajayi, 2016). Wastewaters may consist of materials in liquid state, solid or both and may be present in the form of radioactive, chemical or biological and can also be related to unpleasant health distress that usually manifest in humans through contamination which can also affect both natural and ecological concerns (Nobi *et al*., 2010). The discharge of these unto the soil, sediment and different water bodies/environment often goes without any form of monitoring in Southwestern Nigeria, as with other parts of the country. Moreover, it is often erroneously regarded as fit for the purpose of irrigation and used for the propagation of food crops (Olatunji and Ajayi, 2016).

Potentially harmful elements (PHEs) existence in wastewaters were found to be above standard or background concentration levels in water bodies (Rutherford *et al*., 1994; MEQE 2001) and observed as major contaminants that make wastewater toxic based on different anthropogenic activities. Some substances are mainly water reliant and discharged as waste into water or drains rendering most water bodies around that vicinity hazardous and unsafe.

Generally, some of the substances in wastewater include dirt, chemicals, laundry powder, fabric conditioners, household cleaners and micro-organisms (germs) which endanger public health and damage the environment (Le *et al*., 2016) while trace metals derived from industrial processing and manufacturing of consumer goods, are the most common substances in wastewaters (Wongsasuluk *et al*., 2014). Various works indicating high concentration of metals in effluent/wastewater with adverse effects on the environment had been a source of agony. Therefore, studies on correlative and physicochemical parameters of industrial effluents and effects of high BOD and COD (Ajibade *et al*., 2009); concentration of heavy metals in wastewater (Dijana *et al*., 2012), trace metals in sewage sludge and wastewater (Milik *et al*., 2007) and heavy metals in urban run-offs (Vijayaraghavan *et al*., 2008, Adekola *et al*., 2002).

In and around urban centers, sewage water volume increases through household effluents, drainage water, commercial and business effluents, atmospheric deposition, traffic related emissions transported with storm water into the sewerage system (Adekola *et al*., 2002). Water running through mining sites may pick up metallic load into running water from tailings and other waste products from the mines. Heavy metals may be lost from their products by corrosion or through wear and tears during use. These may find their way either directly or indirectly through dusts into run-offs or sewage sludge (Vijayaraghavan *et al*., 2008). Toxicity may be the resultant process which may equally lead to several human body system disorders when wastewater is not properly handled and mismanaged (Khanitchaidecha *et al*., 2010, Wu *et al*., 2012, Le *et al*., 2016). In addition, 75% of shallow wells in southwestern Nigeria showed reports of pathogens, organic compounds from pesticides while about 35% of groundwater wells with high proximity to gullies, wastewater and sewage exceeded the permissible limit for nitrates. Also, deterioration of the environment through contamination processes can become manifested in the population of aquatic organisms (Hart, 1982). Suspicion and concerns on different undesirable health effects that allied with wastewater associated with bacterium and pathogens that connect public health hazard with risk factors in nearly all parts of the regions (Ali and Hashem, 2007). Incidences of waterborne disease outbreaks have been well reported in areas where sources of water contamination are largely uncontrolled. Production of overgrowth and excessive algae from these processes can lead to a decrease in dissolved oxygen and prevents light-rays from permeating through wastewater leading to the destruction of some important organisms, plant and animal life (Davies *et al*., 2003). Most major contaminants that are toxic which originate from domestic, municipal, industrial and agricultural processes can negatively impact and implicate ecosystem health status (Ikehata and Liu, 2011) but waste waters generated from cities and urban populations, holding different substances control the influence of pathogens, metals, biological and chemical oxygen demand. Dangerous microorganisms load in wastewater can be injurious to human body and make inhabitants around the neighbourhood susceptible to different exodermic and endodermic diseases (Ali and Hashem, 2007). Water borne diseases including wastewater load with bacteria can be devastating and cause death in humans. Both the old and young are at risk based on the presence of some harmful micro-organisms (Ali and Hashem, 2007) however, various microorganisms are present in wastewater resulting to an increase of viscosity of this contaminated water (Wu *et al*., 2012, Gerardi and Zimmerman, 2005). The presence of micro-organisms which include worms, fungi and some organic or inorganic toxins have been the bane of wastewater problems (Wu *et al*., 2012, Le *et al*., 2016). This has been found to increase viscosity of water, color and odour change and amplify its toxicity (Wu *et al*., 2012, Khanitchaidecha *et al*., 2010). Varying viruses such as Hepatitis and Norwalk virus are frequently found in wastewater while the most regular fungus is the *Candida* spp (Gerardi and Zimmerman, 2005). Common bacteria, such as *Salmonella* can cause food poisoning while other pathogens cause cholera (Gerardi and Zimmerman, 2005). There are some parasitic organisms

(*Cryptosporidium* and *Schistomsoma*) that are hazardous to human health which can inflict or cause diarrhoea and severe gastrointestinal and other infirmities that are significant and can cause death worldwide (Khanitchaidecha *et al*., 2010, Gerardi and Zimmerman 2005). Therefore, this study determines the toxic metal contents and microorganisms load in the effluent water derived from domestic and commercial sources and involve qualitative and quantitative assessment of the constituent with respect to antimicrobial susceptibility test on the wastewater organisms.

Oyo area consists of Apitipiti and Asipa Dams, river, streams and lakes characterized and engaged with fisheries and irrigation works (Fig 1). The area lies within the basement complex of southwestern Nigeria and consists of pre-Cambrian igneous and metamorphic rocks which formed part of the Migmatite-Gneiss Complex. The main lithologies include: the amphibolites, migmatites, gneisses, granites and pegmatites. Other rocks include biotite-schist and quartz-schists (Fig 1b).

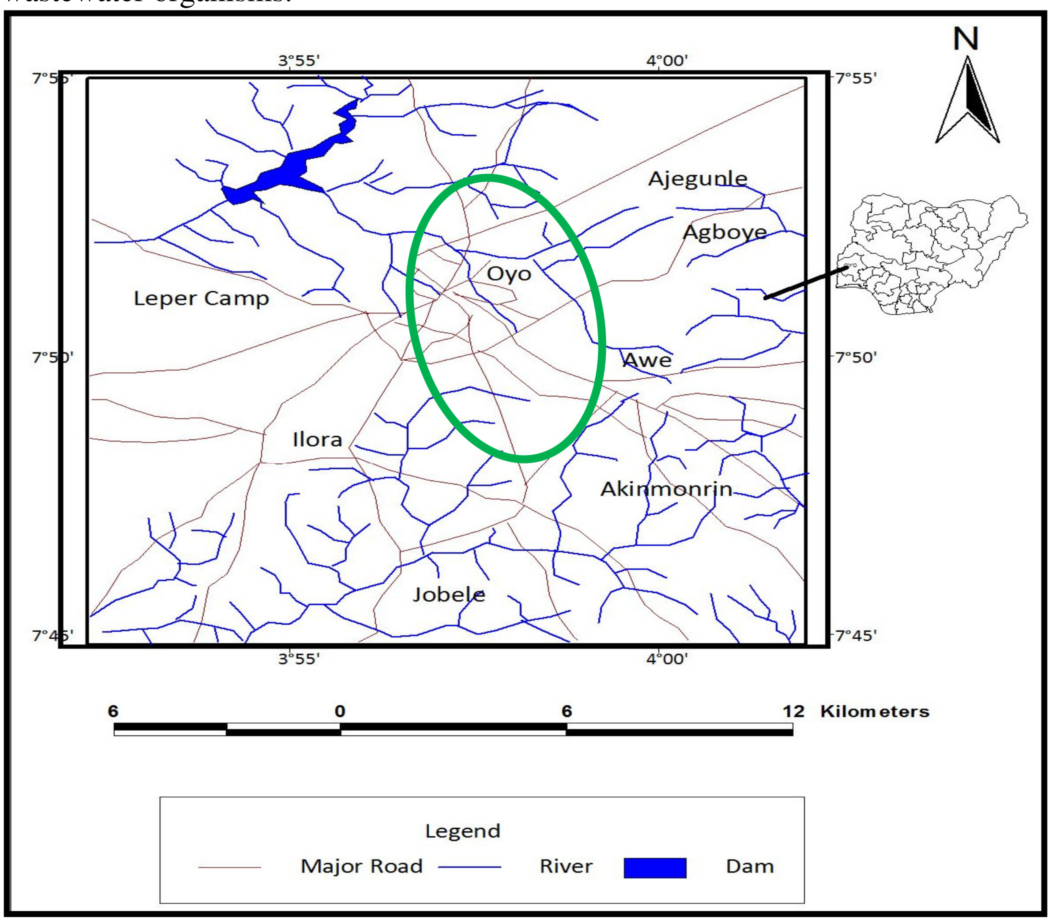

Fig. 1a: Map of Oyo town (extracted from topo-sheet - 241)

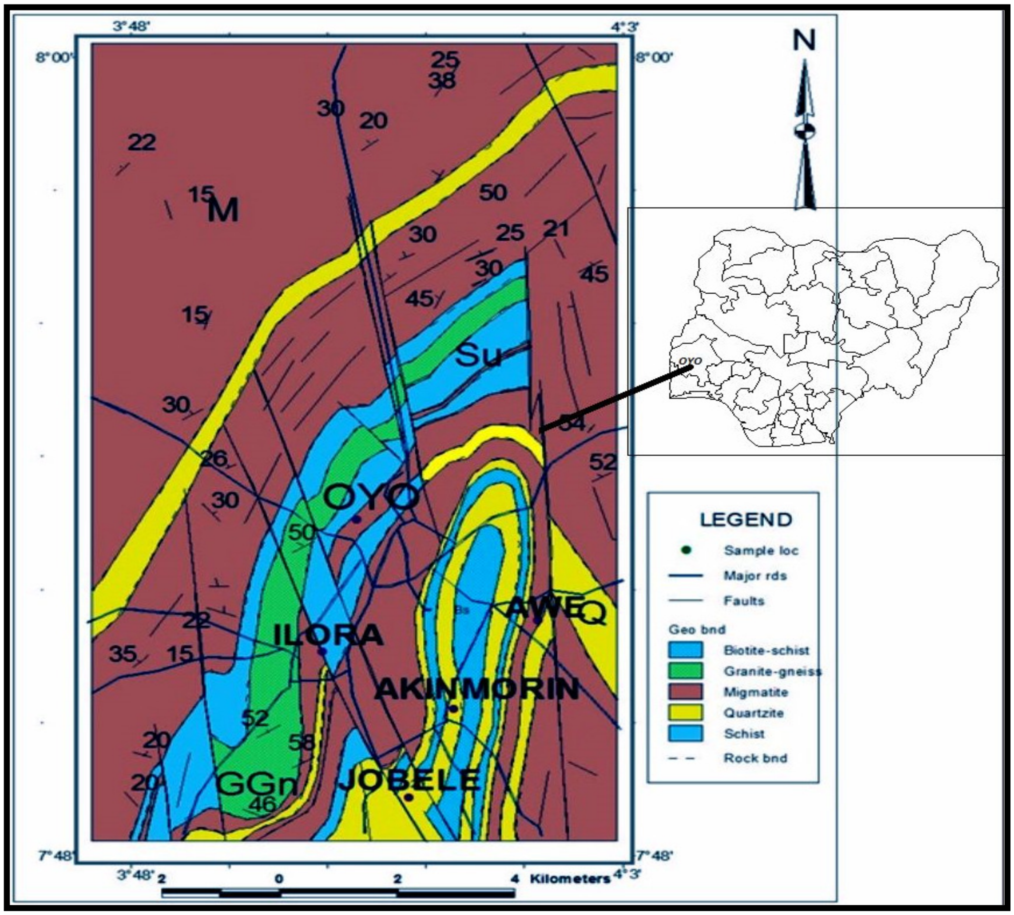

Fig. 1b: Geological map of the study area

Materials and Method

Fourteen (14) wastewater samples were analyzed for their chemical components with Inductive Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Hydrogen ion index (pH), electrical conductivity (EC) and total dissolve solids (TDS) tests were carried out on the effluents. The geochemical elements and micro-biological load in the wastewater were examined and interpreted to know the amount of pathogens in the samples from different anthropogenic locations while fifteen (15) trace elements analyzed were also examined.

Filtered samples from different segments, such as domestic sectors, residential houses, churches, mosques, agricultural, schools, hospitals and mechanic sites were collected and analyzed at the Activation Laboratory Limited, Ontario, Canada. These samples were acidified with 3-drops of nitric acid while the other parts were sent for microbial analysis and antimicrobial susceptibility testing. Statistical software packages were used for data interpretation to represent geochemical trend and patterns with the use of Excel-2007 and SPSS-16. These evaluate the waste-water quality since its assessment can be carried out in various conducts that can reveal different degrees of contaminants (Vallejuelo *et al*., 2010, Singh *et al*., 2003,).

Microbiological Analysis

Sample Collection and Isolation of Bacteria

Wastewater samples were collected between November and December 2018 into sterile sample bottles. Three samples each were collected on each stretch of wastewater flow and pooled into one composite sample at each sample point per time. These were transported to the Laboratory and analysis within 8hr of collection. The samples were prepared by serial dilution into appropriate volumes of sterile saline peptone water. Using the surface spread method, 0.2 ml of each sample, plated on the surface of selective agars Eosin Methylene blue agar EMB, Mac Conkey agars and the use of selective enrichment broths (Rapparportvas siliadis soya peptone) followed by plating on Xylose lysine deoxycholate agar (Oxoid Basingstoke UK) for the isolation of Enterobacteriaceae. Plates were incubated aerobically at 37ºC for 24-48 hours and distinct colonies sub-cultured until pure colonies were obtained. The identities of the isolates were confirmed with relevant biochemical tests using the protocol of Cowan and Steel, (1984) and Barrow and Feltham, (1999). Confirmed isolates were stored on nutrient agar slants for further analysis. These determine the microbial load such as determination of Total viable count (THC) and Total coliform count (TCC) of the wastewater samples: these were estimated on nutrient agar and MacConkey agar plates respectively. This was done by plating 1ml aliquots of appropriate dilutions of the wastewater samples on the agars and inoculated plates were in duplicate and incubated at 37ºC for 24 hr after which the colony-forming units were estimated.

Results and Discussion

Physicochemical Properties of Wastewater

The geochemical analytical results (Table 1) of wastewater from Oyo area were presented. The wastewater pH assessment recorded diverse values which ranged from 4.99 to 8.42 with an average value of 7.12 indicating elevated occurrence of the cations (Rao et al; 1982). Areas around cassava market (pH-4.5) are usually marked with high acidity, exceeding the standard of pH-6.5 while some areas such as hospital and fish farm areas are slightly alkaline-pH8.9. These might have been as a resultant or occurrence of Na, Ca and Mg in the wastewater (Rao et al; 1982). However, other areas within the standard/limits; accounted for about 57%, indicating 43% challenging areas. Electrical conductivity values varied between 252 to 1998uS/cm with an average value of 725 uS/cm; this is also an indication of presence of high Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} salts with C2 and C3 ratings specifying medium to high salinity (Sharma1 and Chaudhari, 2012). Significantly, 71% of the wastewater falls within the standard-750 uS/cm.

At the cassava market, Total Dissolved Solids (TDS) values recorded in the wastewater were observed to be slightly high above the recommended limit signifying elevated TDS which could be a sign of both the presence of anions and cations: this covered about 14.28% of the study area while the remaining 85.72% was within limit of fresh water.

Sodium (Na) content in wastewater ranged between 8.7-174 mg/l with an average value of 80.1 mg/l (Table 1). This element is known as the most significant nutrient for plants growth improvement. Its involvement within the geochemical environment is important in total ionic mass balance while some areas are not appropriate or suitable for Irrigation purposes because they are above the standard mark of 40 mg/l (Argawal *et al*., 1982).

Table 1. Statistical Results of Elements in Oyo Wastewater

mg/l	Range	Min	Max	Mean	mg/l	Range	Min	Max	Mean
As	0.270	0.030	0.300	0.069	Na	165.30	8.70	174.00	80.10
Cd	0.018	0.002	0.020	0.005	K	6467.60	2.40	6470.00	970.84
Cr	0.180	0.020	0.200	0.046	Ca	265.60	10.40	276.00	107.61
Cu	0.297	0.002	0.299	0.046	Al	10.50	0.00	10.50	2.53
Co	0.089	0.099	0.010	0.031	P	426.96	0.04	427.00	63.22
Ni	0.187	0.005	0.192	0.038	S	177.00	16.00	193.00	118.29
Pb	0.090	0.010	0.100	0.023	Fe	24.73	0.07	24.80	6.32
Se	0.180	0.020	0.200	0.046	Mg	745.40	3.60	749.00	129.37
Sr	1.740	0.070	1.810	0.646	Si	57.50	11.70	69.20	27.87
V	1.700	0.010	1.710	0.257	Mn	4.44	1.44	5.88	3.50
Zn	4.615	0.005	4.620	0.949	Ti(mg/l)	0.23	0.01	0.24	0.09
Ba	0.800	0.020	0.820	0.159	U(mg/l)	0.45	0.05	0.50	0.11

The K^+ contents ranged from 2.40 - 6470 mg/l with an average value of 970.8 mg/l specifying high alkaline wastewater (Table 1). This contributed about 10.2% to the total ionic mass balance with suggested standard value of K^+ in irrigation water as 2.0 mg/l. However, with reference to recommended value, about 87% of the wastewater could pose a big challenge when irrigating cultivated soils.

Ca concentration in wastewater collected from different anthropogenic areas range from 10.4 - 276mg/l with a mean of 107.6 mg/l; this added 30% to the total cation mass balance signifying the controlling powers of Ca in the effluents. Furthermore, it contributes significantly to the alkalinity and the solubility of Ca-salts into the wastewater (Sharma1 and Chaudhari, 2012). Ca-salts supports irrigation processes especially in water containing less than ≤ 800 mg/l is apposite for irrigating farmlands. Wastewater had been reported to be dangerous for irrigating cultivated land or some crop plants because of its high salinity and sodicity (Ayers and Westcot, 1985). In view of this standard (≤ 800 mg/l), all the wastewater samples are within the safe limit of irrigation and would not affect soils in any form (Table 1).

Mg concentration in wastewater samples varied from 3.60 to 749.0mg/l with an average value of 129.40mg/1 and its contribution to the total ionic mass balance of 11.0% indicating alkalinity influence in the water (Table 1). Furthermore, the standard of Mg in irrigating water could be ≤ 121.5 mg/l before it can be suitable for irrigation purposes. At this level, 86% of the wastewater samples could safely be applied for irrigation without any dreadful or appalling impact on farmlands while the remaining 14% are dangerous to soils. Mg in irrigation water is 5.0 mg/l (Ayers and Westcot, 1985).

The phosphorus contents varied from 0.04 to 427.0mg/l with the mean value of 63.22mg/l (Table 1); this immensely added to the total ionic mass balance especially from cassava processing industry. The PO_4^{3-} value in the wastewater samples was high and above the recommended value of 2.00mg/l for irrigation purposes; indicating its presence in cassava industry wastewater, dam and mechanic effluents. Very high concentration value was recorded at the cassava processing industry/market which specify phosphorous as an important nutrient in cassava. Considering this standard, the PO_4^{3-}contents in the three locations are harmful for irrigation purposes based on its toxicity (Islam *et al*., 2015). Also, the presence of excess phosphorous in solution will lend support to algae growth (Khanitchaidecha *et al*., 2010) thereby causing nuisance in the stream, channel which finally create high effect of biological oxygen demand (BOD) with death of various biota as the resultant outcome. About 85.71% of wastewater samples were above the standard and not suitable for irrigation works demonstrating its harmfulness.

Aluminium elemental concentration in wastewater revealed high Al^{3+} (10.5mg/l) content in the school area signifying leaching from soils directly into wastewater. This ranged from 0.7-10.5mg/l with the average of 3.54mg/l observed in the effluents (Table 1). However, Al contents in the dam and mechanic workshop wastewater was leached into the soil and not detectable, revealing <0.1mg/m values. Also, flocculation might have affected water from the dam. Fe is a product of weathering and varied from 0.07-24.8mg/l with an average of 6.328mg/l. The highest value was recorded at the school area implying geogenic concentration, devoid of any anthropogenic inputs. This element could be sourced from weathered ferro-magnesian minerals with high Fe-content contained in metamorphic minerals of various metamorphic rocks origin.

The sulphur in solution (SO_4^{2-}) ranged from 16.0 to 193.0mg/l with an average value of 118.0mg/l. Its involvement in the total ionic mass balance is 4.0% with 20.00mg/l as the standard for irrigation works. It had been reported that about 33% of sulphur was derived from minerals in rocks through weathering processes while other considerable sources which amount to 67% might come from both anthropogenic and other geogenic sources (Singh *et al*., 1999, Singh *et al*., 2003; Alhello and Al-Saad, 2020).

Si-content in the effluent samples varied from 11.7-69.2mg/l with an average of 27.870mg/l. The highest concentration recorded at the school area, suggested high silica mineral in solution. This also indicated the degree of weathering of silicate and alumino-silicate minerals; at the school area while the hospital wastewater recorded lowest values. The presence of Si^{4+}in solution at the mechanic-33.3mg/l and dam-38.2µg/ml waters signify moderate weathering of silicate minerals.

Barium concentrations in wastewater ranged from 40 µg/litre) to 820µg/l, with mean value of 214 µg/l; in 71.42% of all locations surveyed. This is in line with lowest Ba-content (50 µg/l) in drinking water in the Netherlands (Fonds et al; 1987). Ba is present in both igneous and sediments and occurred in some compounds especially in $BaSO_4^{2-}$ (barite) and $BaCO_3^{2-}$ (Witherite). About nine Ba-salts/compounds was found common in water especially barium sulphate and barium carbonate: These compounds are largely used by rubber, plastics, electronics and textile industries, in glassmaking, brick-making and paper-making; as a lubricants, additives, pharmaceuticals and cosmetics case-hardening of steel, oil and gas industry and as a wetting agent for drilling mud (Kravchenko *et al*., 2014; Brooks, 1986). Barium in water comes primarily from natural sources (Rocks) but it possesses great danger to the environment because of its varying solubilities. The halides, nitrates and acetates are soluble whereas; the carbonates, chromates, fluorides, phosphates and sulphates are less soluble (USEPA 1985a, 1985b).

The highest Ba-levels were observed in wastewater at areas where low pH was recorded (granite gneiss), this is in support of USEPA 1985a. The environmental implications of Ba had been found to be positively great/high in relation to the Ba in water with mortality from cardiovascular disease (Schroeder and Kramer, 1974). $BaCO_3^{2-}$ dust (22.6 µg/m^3) negatively affected male reproductive organs in humans (Tarasenko *et al*., 1977).

This Mn^{2+} concentration ranged from 1.44-5.88mg/l with the average of 3.50mg/l at Oyo area (Table 1). However, Mn^{2+} recorded the highest values in the dam and mosque wastewater indicating its low mobility. Concentrations of Fe^{2+} and Mn^{2+} in water have been found to support bacteria growth with energy derived from chemical reactions which involve oxidation of these elements. The amount of Mn^{2+}in wastewater can also cause possible health risk with obnoxious taste through seepages into underground water systems. Mn^{2+} recommended level in water is 0.05 mg/l (USEPA 1985a, 1985b).

Trace metals which include Zn, As, V, U and Sr are the most prevailing and dominant metals that might likely cause environmental issues. Occurrence and increasing incidence of elevated concentration of these metals could likely be injurious to the environment (Singh *et al*., 2009). The highest concentration of Cu-0.299µg/l, Pb-0.10µg/l, Zn-4.62µg/l, Cr-0.20µg/l, As-0.3µg/l, Ni-0.192µg/l, Cd-0.02µg/l, Se-0.02µg/l, Co-0.099µg/l, V-1.71µg/l, U-0.50µg/l, Sr-1.81µg/l and Ba-0.82µg/l was observed in the cassava market wastewater (Tables 1 and 2; Figs 2, 3 and 4): this indicated that cassava market wastewater is the most contaminated. Fe varied from 0.07mg/l - 24.8 mg/l from mechanic to school effluents respectively revealing the highest (Fe-24.8mg/l) concentration in the school wastewater which was above the standard limit (5.00 µg/ml). This could be geogenically sourced from the presence of ferromagnesian minerals. The presence of Cu and As in cassava waste-water might be compositional through bioavailability sources and uptakes (Kribek *et al*., 2014a). Zn, Pb, Ni and other toxic metals (Table 2; Figs 3 and 4) may be anthropogenically introduced from farm implements and machineries used in this cassava processing market / industry into the environment.

The concentration of Pb in wastewater samples ranged from 0.01 - 10 µg/ml with an average value of 2 µg/ml (Tables 1 and 2; Fig 4). These values were above the standard (Pb-0.05 mg/l) for irrigation and unsuitable for these purposes (Fig 4).

U^{2+} recorded the highest concentration value of 0.5mg/l at the cassava processing market/industry: this also confirmed that cassava market wastewater is the most contaminated since Uranium standard is 0.03-0.04mg/l (Abida and Haq, 2013).

Table 2: Results of Elemental Compositions in Oyo Wastewater

Elements	Cassava	School	Hospital	Mechanic	Dam	Mosque	Fish farm
Ba	0.82	0.07	0.08	0.02	0.02	0.04	0.6
As	0.3	0.03	0.03	0.03	0.03	0.03	0.03
Cd	0.02	0.002	0.002	0.002	0.002	0.002	0.002
Cr	0.2	0.02	0.02	0.02	0.02	0.02	0.02
Co	0.099	0.029	0.012	0.013	0.045	0.01	0.011
Cu	0.299	0.062	0.008	0.002	0.002	0.005	0.006
Fe	3.6	24.8	1.14	0.07	5.75	5.01	3.88
Pb	0.1	0.01	0.01	0.01	0.01	0.01	0.01
Ni	0.192	0.021	0.005	0.015	0.018	0.008	0.005
Se	0.02	0.002	0.002	0.002	0.002	0.002	0.002
Zn	4.62	1.77	0.063	0.005	0.073	0.04	0.069
Mn	5.23	1.86	1.6	2.61	5.88	5.88	1.44
V	1.71	0.04	0.01	0.01	0.01	0.01	0.01
U	0.5	0.05	0.05	0.05	0.05	0.05	0.05
Sr	1.81	0.5	0.2	0.68	0.91	0.035	0.07

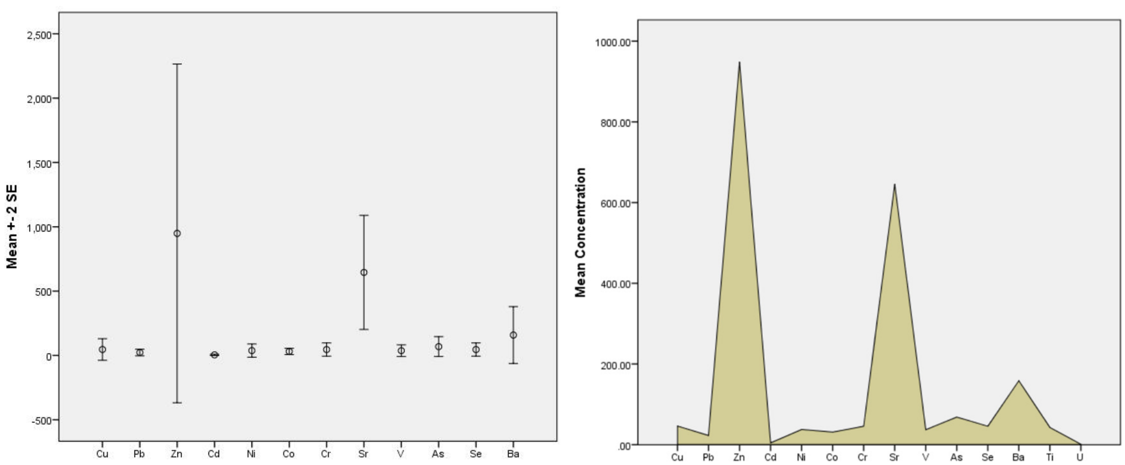

Fig 2: Mean concentration of trace elements in wastewater

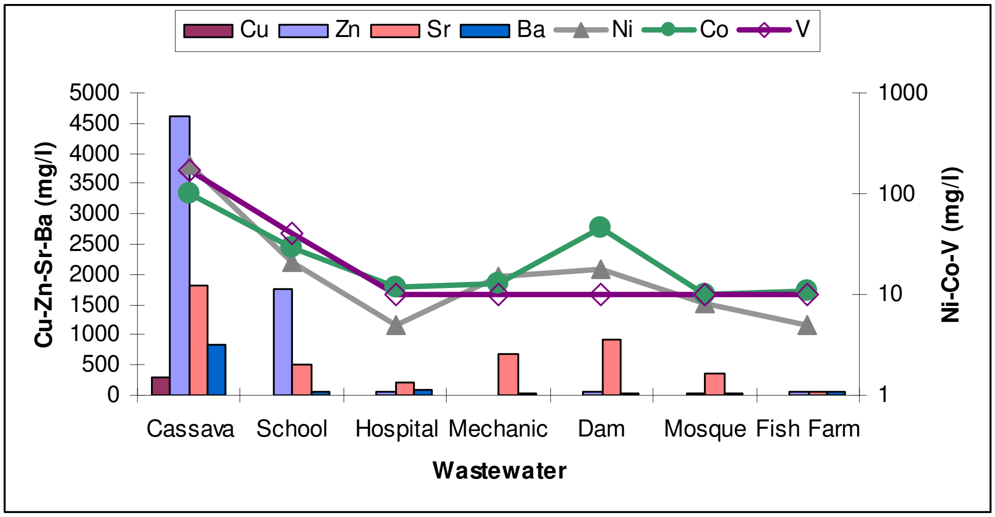

Fig. 3: Concentration of trace elements in Wastewater

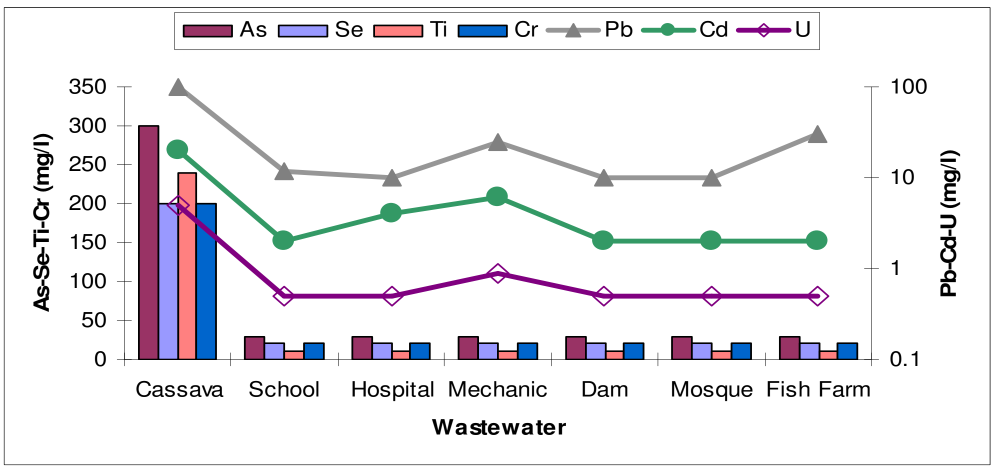

Fig. 4: Concentration of trace elements in Wastewater

These occurred within the acidic region with high pH levels; because reports had indicated that the occurrence of U^{2+} flourish in acidic environment especially in mines and smelting wastewater discharge of pH 2.0 or 3.0: this corresponds to the work of Abida and Haq, 2013. Considerable amount of U^{2+} in wastewater has caused devastating effects in humans and the environment based on its toxicity which can greatly threaten and damage the ecosystem at large. Its occurrence in water can possibly enrich and damage human organs. This has led to damage of the unique bioelectric current of human body system, leukemia, chronic mottle skin and paralysis. Wastewater containing U^{2+} can be treated with the use of coagulants (CaO-Calx, $AlCl_3$, $FeCl_3$), evaporation and absorption methods (Abida and Haq, 2013).

However, all the wastewater samples contained non-detectable trace amount of Cd but with the exception Cd-20μg g^{-1} from the cassava processing market/industry (Table 2; Fig 4): this also confirmed that cassava market wastewater is the most contaminated. This designates toxicity to 14% of the study area while 86% observed no toxicity effects. However, the major causes of Cd^{2+} intake by inhabitants might have come from agricultural products (Ansari and Malik, 2007). The average intake of $Cd^{2+}$was 367-382 µg day^{-1} (Ansari and Malik, 2007) signifying low susceptibility of the inhabitants to Cd^{2+} around the cassava processing market/industry. The presence of Cu in wastewater varies from 299μg/l, 8μg/l, 6μg/l and 5μg/l for cassava, hospital, fish farm and mosque effluents respectively. This specifies cassava processing market/industry as the most contaminated effluent. The presence of Cu in this market/industry might be compositional based, through bioavailability sources or uptakes (Ansari and Malik, 2007).

Wastewater samples from different anthropogenic sites in the town contained significant amount of Zn^{2+}at the cassava processing market/industry-299μg/l, school-299μg/l, hospital-299μg/l, dam-299μg/l, mosque-299μg/l and fish farm-299μg/l effluents respectively (Table 2; Fig 3). With respect to this, propel of heavy metal contamination derived from siting of small-scale industries around water bodies without any conventional remediation strategies has been connected with Zn-toxicity and its easy availability in water bodies (Mishra and Patel, 2009). Since Fe or Cu-299μg/l comes along with Zn-4620μg/l in wastewater, hence they recorded their highest concentration levels in the cassava processing market/industry effluents (Table 2; Fig 3). This is supported by Mishra and Patel, (2009) on surface and wastewater sources. In the classification of toxic metals in wastewater (Wang and Chen, 2009; Srivastava *et al*., 2007), described Zn as one of the most significant metals encountered in wastewater based on its occurrence in plants and animals (Pejic *et al*., 2008; Sengil and Ozacar, 2009). Disproportionate level of Zn intakes has been studied to be deadly because it is not bio-degradable and bio-accumulation in organisms/human body from the food chain (Ucun *et al*., 2009). The tolerable limit (Zn-5mg/l) from different water standards has been fixed but potable type as exception (Bathia, 2013) but concentration levels above this standard impinge critically on the soil fertility (Agorboude and Navia, 2009). This was observed at the cassava processing market/industry which indicates that; this water is not safe and cannot be used for irrigation purposes with reverence to Zn and Cu contents. Furthermore, Zn concentration values from other areas, are within the standard and were found suitable for irrigation use. Zinc is one of the significant elements in enzymes (Mukhopadhyay *et al*., 1998) and its toxicity can cause different effects that can be linked to gastrointestinal disturbance and muscular rigidity (Vilar *et al*., 2007, Pérez *et al*., 2009, Lesmana *et al*., 2009, Bhattacharya *et al*., 2006).

The contamination factor is used to classify the level of contamination of metals in water while the contamination index of a metal is the ratio of concentration of the metal with the world health organization standard/guidelines.

All the metals were very high and strongly correlated with each other such as As-Cu ($r = 0.98$), Cu-Zn ($r=0.93$) but the exception of Ba-Sr ($r=0.50$) and Ba-Co ($r=0.63$) are moderately correlated. Factor analysis of metals in the sampled wastewater also indicated that most of the metals exist in the same agrarian geochemical environment (Fig. 5).

Seventy-two (72) bacterial strains with isolated organisms fitted into nine genera of public health concern namely; *Pseudomonas, Serratia, Bacillus, Escherichia, Enterobacter, Citrobacter, Salmonella, Klebsiella, Proteus* and *Aeromonas* (Tables 3 and 4, Fig 6). Generally, the most frequently isolated genera were *Escherichia coli*, (detected in all sampled wastewaters) closely followed by *Enterobacter*. Isolation of these organisms may have public health implications for inhabitants of the area. In general, most of the organisms especially *Enterobacter* spp. and *Escherichia coli* which were consistently present in the wastewaters are primarily considered as indicators of faecal pollution capable of affecting human health via contamination of surrounding drinking water sources (Surendraraj *et al.*, 2009). Species of organisms isolated have been associated with several clinical conditions such as pus formation, pneumonia, rheumatic fever and infections in immune compromised patients (Lesmana *et al.*, 2009). The Serratia family is particularly interesting in that, until recently, they were considered relatively harmless to humans.

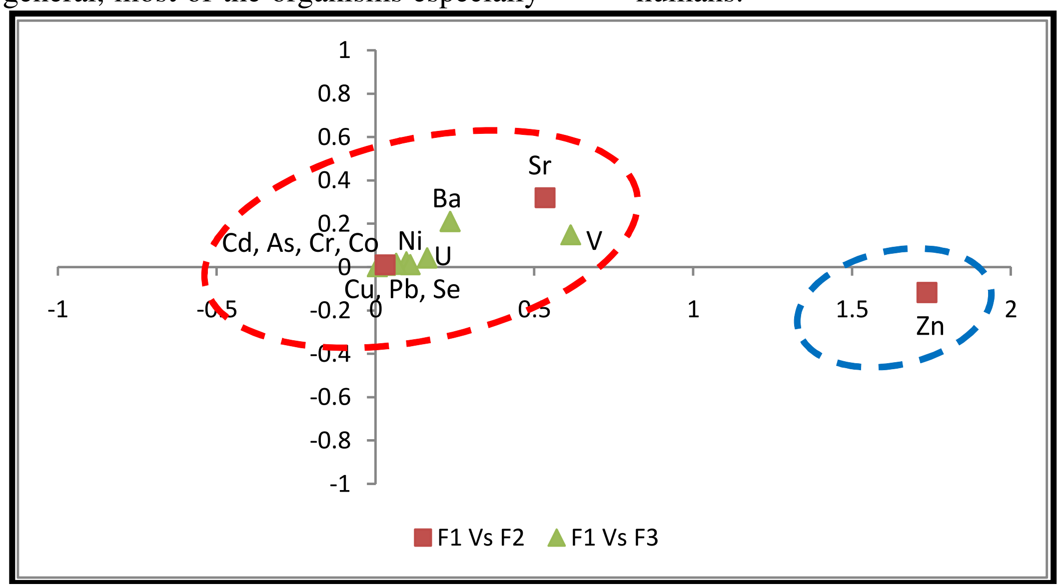

Fig. 5: Metals association in the geochemical environment of the study area.

Table 3: Microbial Loads of the Wastewater Samples

Locations	Site Code	Mean Viable Count	Mean Coliform Load
1	Cassava Industry	4.8×10^4	2.4×10^2
2	School	10.8×10^5	6.4×10^4
3	Hospital	10.2×10^9	6.9×10^5
4	Mechanic Site	2.0×10^5	8.8×10^4
5	Fish farm	20.4×10^5	12.4×10^4
6	Mosque	8.8×10^4	10.6×10^1
7	Dam	12.4×10^2	6.8×10^2

Table 4: Distribution of bacteria in the wastewater samples

Location	Site Code	Organisms
1	Cassava Industry	*Pseudomonas aeruginosa,* Escherichia *coli, Enterobacter* sp. *Bacillus cereus, Proteus vulgaris,*
2	School	*Escherichia coli, Enterobacter* sp. *Citrobacter, Proteus mirabilis, Shigella* spp
3	Hospital	*Pseudomonas aeruginosa,* Escherichia *coli, Enterobacter* sp. *Bacillus cereus, Proteus vulgaris, Shigella* sp. *Klebsiella* sp.
4	Mechanic Site	*Enterobacter* sp. *Pseudomonas aeruginosa*
5	Dam	*Escherichia coli, Enterobacter* sp.
6	Mosque	*Proteus, Shigel*la spp, *Escherichia coli*
7	Fish Farm	*Pseudomonas aeruginosa, Escherichia coli, Salmonella* sp. *Proteus vulgaris, Aeromonas* sp.

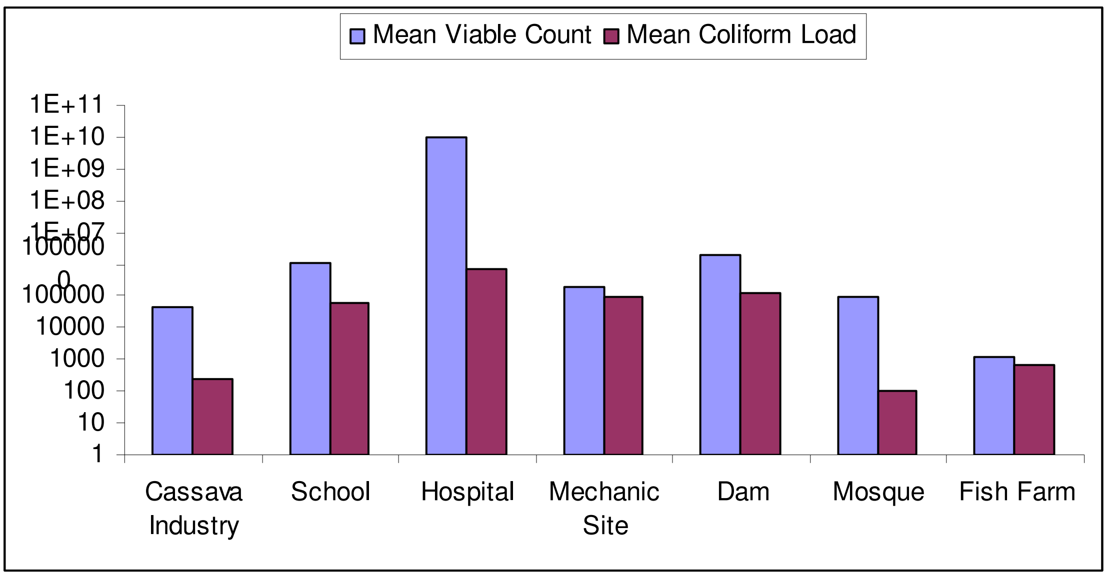

Fig. 6: Mean heterotrophic and coliform counts of sampled wastewaters

However, it became clearer in recent years that they are opportunistic pathogens and can cause severe illness such as respiratory and urinary tract infections in humans, with hospital-acquired infections caused by this organism (*Mastromarino* et al; 2013). The highest number of isolates and genera isolated were from the hospital wastewater. This may be as a result of the peculiar infectious nature of this type of wastewater. Effluents arising from these sources has been described as hazardous, infectious and consisting of infectious bacteria from patients, drugs, reagents, human tissues and the likes (*Mastromarino,* 2013). It is therefore expected to undergo special treatment before they can be discharge in designated places. In this study it was observed that these wastewaters were disposed on the ground /municipal drains. This can amount to grave health hazards when such find its way into surface water and groundwater majorly used as drinking water sources via infiltration and runoff.

Results of viable bacteria and coliform counts were very high in this study especially from wastewaters arising from hospital, fish farm and the school environment Tables 3 and 4. The high coliform counts signify presence of faecal pathogens in wastewater and this is of grave concern to public health. This is because these wastewaters flow right within the metropolis and the probability of direct and indirect contamination via physical contact and groundwater contamination is high. Other studies have reported high microbial loads in wastewaters arising from both municipal and hospitals necessitating special treatments (Dumontet *et al*., 2001, Gerardi and Zimmerman, 2005, Wang *et al*., 2014). Only the dam wastewater was seen to have very low microbial load. This may be due to the toxic nature of the wastewater. Industrial wastewater has been equally reported to have lower microbial loads compared to municipal wastewaters (Wang *et al*., 2014).

Conclusion

Comparison of trace metals concentration with the standard revealed a highly polluted wastewater from cassava market/industry for all the metals**.** Fe, Mn, As, U and V are extremely high signifying low quality wastewater from Cassava market/industry. However, wastewater toxic effects may be hazardous to the environment and to the receiving water bodies, causing undesirable poisonous effects on the aquatic biota as well as human health when such infiltrates into groundwater. The Isolates observed belong to nine genera that can cause public health apprehension such as: *Pseudomonas, Serratia, Bacillus, Escherichia, Enterobacter, Citrobacter, Salmonella, Klebsiella, Proteus* and *Aeromonas.* The most frequently and consistent isolate-genera include *Enterobacter and Escherichia coli;* that are primarily considered as indicators of faecal pollution capable of affecting human health through contamination of surrounding groundwater sources were conspicuously found in the wastewaters of Oyo province. The isolation of these pathogenic organisms found in this study can be of grave consequence to public health.

Concerted efforts must be made by Government and private sectors to treat wastewaters to make it less toxic by varying treatment and recycling to remove the toxic constituents such as (As, Pb, Se and other metals) as well as microorganisms before discharging them to the receiving surface water. The populace should frequently advocate to Government to stringently control, regulate and treat marine or bilge waters from domestic, industries and commercial centres before liberating them into surface water through various injection channels. Adequate sewage control and construction of wastewater management facilities should be encouraged and supported.

References

Abida, K. and Haq, N.B. (2013). Adsorptive Removal of Uranium from Wastewater: *A Review: Journal of the Chemical Society of Pakistan,* 35(3): 1041-1052.

Adekola, F.A., Eletta, O.A. and Atanda, S.A. (2002). Determination of the level of some heavy metals in urban run-off water in Lagos, Nigeria, *Journal of Applied Science and Environmental Management,* 6(2):

23-26.
DOI: 10.4314/jasem.v6i2.17171

Agorbode, L. and Navia. R. (2009). Heavy metals retention capacity of a non-conventional Sorbent developed from a mixture of industrial and agricultural wastes. *Journal of Hazard and Materials,* 167(1-3):536-544. DOI:10.1016/ j.jhazmat.2009.01.027Aj

Ajibade, O.M., Tomori, O.O. and Abidoye, R. (2009). Comparative and correlative parameters for geochemical and biochemical oxygen demand of effluents in Ota industrial estate Southwestern Nigeria. *Water Resources*, 19(1): 41-55.

Alhello, A. and Al-Saad H.T. (2020). Heavy Metals Indicies in Shatt Al-Arab River, Basrah Province, Iraq. I: *Sediments Pollution Resources,* February Suppl. Issue: 39: (14-19).

Ali, E.H. and Hashem, M. (2007). Removal efficiency of the heavy metals Zn (II), Pb(II) and Cd(II) by *Saprolegnia delica* and *Trichoderma viride* at different pH values and temperature degrees. *Microbiology,* 35(3): 135-144.

American Public Health Association 1998 Standard Methods for the Examination of Water and Wastewater, Springfield, New York, NY, USA, 19th edition.

Ansari, M.I. and Malik, A. (2007). Biosorption of nickel and cadmium by metal resistant bacterial isolates from agricultural soil irrigated with industrial wastewater. *Bioresource Technology* 98(16): 3149-3153.

Ayers R.S. and Westcot, D.W. (1985). Water Quality for Agriculture. FAO Irrigation and Drainage 29: 8-96.

Bhattacharya, A.K. Mandal, S.K. and Das S.K. (2006). Adsorption of Zn (II) from aqueous solutions by using different adsorbents. *Chemical Engineering Journal,* (123): 43–51.

Brooks, S.M. (1986). Pulmonary reactions to miscellaneous mineral dusts, man-made mineral fibres, and miscellaneous pneumoconioses. In: Merchant JA, editor. Occupational respiratory diseases. Cincinnati (OH): United States Department of Health and Human Services, Appalachian Laboratory for Occupational Safety and Health; (DHHS (NIOSH) Publication No. (86–102): 401–458

Corti-Monzón, G., Nisenbaum, M., Villegas-Plazas, M., Junca, H. and Murialdo, S. (2020). Enrichment and characterization of a bilge microbial consortium with oil in water-emulsions breaking ability for oily wastewater treatment. *Biodegradation,* (31): 57–72.

Church, J., Lundin, J.G., Diaz, D., Mercado, D., Willner, M.R., Lee, W.H. and Paynter, D.M. (2019). Identification and characterization of bilgewater emulsions. *Science of the Total Environment,* 691(1): 981–995.

Fonds, A.W., Van Den Eshof, A.J. and Smit, E. (1987). Integrated criteria document barium. Bilthoven, National Institute of Public Health and Environmental Protection (RIVM Report No. 218108004).

Gerardi M.H. and Zimmerman, M.C. (2005). Wastewater Pathogens Wiley-Interscience publication pp 170.

Gopinath, A., Nair, S.M., Kumar, N.C. and Jayalakshmi, K.V. (2010). A baseline study of trace metals in a coral reef sedimentary environment, Lakshadweep Archipelago. *Environmental Earth, Sciences*, 59(6): 1245-1266.

Hart, B.T. (1982). Uptake of trace metals by sediments and suspended particulates: a review. *Hydrobiologia,* 91(1): 299-313.

Islam, M.S., Uddin, M.K., Tareq, S.M., Shammi, M., Kamal, A.I., Sugano, T., Kurasaki, M., Saito, T., Tanaka, S. and Kuramitz, H.. (2015). Alteration of Water Pollution Level with the Seasonal Changes in Mean Daily Discharge in Three Main Rivers around Dhaka City, Bangladesh, *Environments,* 2*(*3): 280-294.

Khanitchaidecha, W., Nakamura, T., Sumino, T. and Kazama, F. (2010). Performance of intermittent aeration reactor on NH4-N removal from groundwater resources. *Water Science and Technology*. 61(12): 3061-3069.

Kravchenko, J., Darrah, T.H., Miller, R.K., Lyerly, H.K. and Vengosh, A. (2014). A review of the health impacts of barium from natural and anthropogenic exposure. *Environ Geochem Health,* (36): 797-814.

Kribek, B., Majey, V., Knesl, I., Nyambe, I., Mihaljevic, M., Ettler, V. and Sracek, O. (2014). Concentrations of arsenic, copper, cobalt, lead and zinc in cassava (*Manihot esculenta* Crantz) growing on uncontaminated and contaminated soils of the Zambian Copperbelt. *Journal of African Earth Sciences,* 99((1): 713-723.

Lesmana, S.O., Febriana, N., Setaredjo, N., Sunarso, J. and Ismadji, S. (2009). Studies on potential applications of biomass for the separation of heavy metals from water and wastewater. *BiochemEng Journal,* 44(1): 19–41.

Mahdavi, H., Liu, Y. and Ulrich, A.C. (2013). Partitioning and bioaccumulation of metals from oil sands process affected water in indigenous *Parachlorella kessleri*. *Chemosphere*. 90(6): 1893-1899.

Pérez, A. Ortuno, S.J. Aguilar, M.I. Meseguer, V. Saez, J. and Llorens, M. (2009). Use of chemical modification to determine the binding of Cd (II), Zn (II) and Cr(III) ions by orange waste. *Biochemical Engineering Journal*, 53(1): 2-6. DOI - 10.1016/j.bej.2008.12.010

Mastromarino, P., Vitali, B. and Mosca, L. (2013). Bacterial vaginosis: a review on clinical trials with probiotics. *New Microbiologica,* 36(3): 229–238.

Milik, J., Pasela, R., Lachowicz, M. and Chalamoński, M. (2017). The concentration of trace elements in sewage sludge from wastewater treatment plant in Gniewino. *Journal of Ecological Engineering*, 18(5): 118-124.

Mishra, P.C. and Patel, R.K. (2009). Removal of lead and zinc ions from by low-cost adsorbents. *Journal Hazard Materials*, 168(1): 319-325.

Mukhopadhyay, U., Govindasamy, L., Ravikumar, K., Velmurugan, D. and Ray, D. (1998). Synthesis and structural characterization of a triply bridged copper (II)–zinc (II) Schiff base complex with N, O coordination. *Inorganic ChemCommun.,* 1(4): 152-154.

Nobi, E.P., Dillipan, E., Thangaradj, T., Sivakumahr, K. and Kanman, L. (2010). Geochemical and geo-statistical assessment of heavy metal concentration in the sediments of different coastal ecosystems of Andaman Islands, India. *Estuarine, Coastal and Shelf Science*, 87(2): 253-264. https://doi.org/10.1016/j.ecss.2009.12.019

Oguntoyinbo, J.S. (1978). Climate; In Oguntoyinbo, J.S. Areola, O.O. and Filani, M.A. Geography of Nigerian Development, Hienemann Ibadan, 45-70. Final Report, February 2002.

Olatunji, A.S. and Ajayi, F. (2016). Potentially Toxic Contamination of Cultivated Wetlands in Lagos, Nigeria. *Journal of Health and Pollution,* 6(10): 95-102.

Pejic, B., Vukcevic, M., Kostic, M. and Skundric, P. (2008). Biosorption of heavy metal ions from aqueous solutions by short hemp fibers: effect of chemical composition. *Journal Hazard Materials*, 164(1): 146-153.

Rezic, I. (2013). Cellulosic fibres-biosorptive materials and indicators of heavy metals pollution. *Microchem, J.,* 107(1): 63-69.

Schroeder, H.A. and Kramer, L.A. (1974). Cardiovascular mortality, municipal water, and corrosion. *Archives of Environmental Health*, 28(6): 303-311.

Sengil, I.A. and Ozacar, M. (2008). Competitive biosorption of Pb^{2+}, Cu^{2+}, and Zn^{2+} ions from aqueous solutions onto valonia tannin resin. *Journal of Hazardous Materials,* 166(2-3): 188-1494.

Singh, A.K., Hasnain, S.I. and Banerjee, D.K. (2003). Grain Size and Geochemical Portioning of Heavy Metals in Sediments of the Damodar River- A Tributary of the Lower Ganga, India. *Environmental Geology,* 39(1): 90-98.

Srivastava, V.C., Mall, I.D. and Mishra, I.M. (2007). Adsorption thermodynamics and isostericheat of adsorption of toxic metals into bagasse fly ash (BFA) and rice ash husk (RHA). *ChemEng Journal,* 132(1): 267-278.

Tarasenko, N.Y., Pronin, O.A. and Silayev, A.A. (1977). Barium compounds as industrial poisons (an experimental study). *Journal of Hygiene, Epidemiology, Microbiology, and Immunology*, 21: 361-373.

Ucun, H., Aksakal, O. and Yildiz, E. (2009). Copper (II) and Zinc (II) Biosorption on *Pinus sylvestris* L. *Journal of Hazard Materials*, 161(1): 1040-1045.

USEPA, (1985a). Health advisory-barium. Washington, DC, US Environmental Protection Agency, Office of Drinking Water.

USEPA, (1985b). Drinking water criteria document for barium. Washington, DC, US Protection Environmental Agency, Office of Drinking Water.

Vallejuelo, S.F. (2010). Risk assessment of trace elements in sediments: The case of the estuary of the Nerbioi–Ibaizabal River (Basque Country). *Journal of Hazardous Materials,* 181(1-3): 565-573, 2010.

Vilar, V.J.P., Botelho, C.M.S. and Boaventura R.A.R. (2007). Chromium and zinc uptake by algae Gelidium and agar extraction algal waste: kinetics and equilibrium. *J. Hazard Mater*,149(3): 643-649.

Vijayaraghavan, K. Teo, T.T. Balasubramanian, R. and Joshi, U.M. (2008). Application of Sargassum biomass to remove heavy metal ions from synthetic multi-metal solutions and urban storm water runoff. *Journal of Hazard Mater,* 164(2-3): 1019-1023.

Wang, J. and Chen, C. (2009). Biosorbents for heavy metals removal and their future *Biotechnology Advances,* 27(2): 195-226.

Wongsasuluk, P. Chotpantarat, S. Siriwong, W. and Robson, M. (2014). Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. *Environ. Geochem. Health,* 36(1): 169-182.

Wu, W., Yang, F. and Yang, L. (2012). Biological denitrification with a novel biodegradable polymer as carbon source and biofilm carrier. *Bioresource Technology*, 118(1): 136 - 140.