Journal of Scientific Research and Reports

Volume 30, Issue 9, Page 335-357, 2024; Article no.JSRR.122347
ISSN: 2320-0227

Comparative Analysis of Locally Sourced Adsorbents for Iponda and Idominasi, Abandoned Gold Mine Wastewater Bioremediation in Osun State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i92358

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122347

Original Research Article

Received: 24/06/2024
Accepted: 27/08/2024
Published: 31/08/2024

ABSTRACT

This study investigates and compares the effects of Neem leaf (NL) and coconut husk (CCH) adsorbents in reducing the levels of heavy metal concentration and elemental content in wastewater from two specific abandoned gold mining sites, namely Iponda (Iponda wastewater- IPWW)

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Cite as: *Dada, Ebenezer Olujimi, Promise Ayanfe Ajibade, Emmanuel Ayoade Adedeji, Saheed Ayobami Akanji, Odunayo Deborah Akinwumi, Akeem Olatunde Arinkoola, and Taofeek Olalekan Salawudeen. 2024. "Comparative Analysis of Locally Sourced Adsorbents for Iponda and Idominasi, Abandoned Gold Mine Wastewater Bioremediation in Osun State, Nigeria". Journal of Scientific Research and Reports 30 (9):335-57. https://doi.org/10.9734/jsrr/2024/v30i92358.*

(longitude 4°43'18''E, Latitude 7°43'57''N) and Idominasi (Idominasi wastewater -IDWW) (longitude 4°42'0''E, Latitude 7°40'59''N).
Preparation of locally sourced adsorbents, bioremediation process through adsorption and physico-chemical analysis of the treated wastewater samples were carried out. Adsorbents were prepared from washed, air-dried neem leaves, grinded to 40 microns size to facilitate penetration of the adsorbate. In addition, washed and airdried CCH was carbonized in an electric muffle furnace at between 300 ^{0}C and 350 ^{0}C over a period of 30 minutes, and then granulated and sieved with a mesh size of 40 µm to ensure uniform size. Measured dosages of adsorbent (0.5 g, 0.75 g, and 1 g) were added to a 50 ml volume of wastewater and the mixture was agitated at different speeds ranging from 30 rpm to 120 rpm. The treated wastewater samples were then subjected to various physico-chemical analytical tests to determine the effect of the adsorbents on the reduction of the heavy metal concentration and elemental content of the wasted water samples. The results of this study demonstrate that both NL and CCH adsorbents have a significant impact on the wastewater from the two abandoned gold mining sites, IPWW and IDWW. This impact is reflected in the reduction of heavy metal and other element concentrations in the wastewater. Furthermore, it can be concluded that the bioremediation process is more effective when utilizing NL compared to carbonized CCH. Locally sourced cheap non-edible biomass materials hitherto considered as wastes have proved to be highly effective and efficient when used as adsorbents in the treatment of wastewater from abandoned gold mining sites. This is evident from the results obtained from this study.

Keywords: Adsorption; bioremediation; gold mining; pollution; wastewater.

1. INTRODUCTION

The process of industrialization and natural resource extraction has resulted in extensive environmental pollution and contamination, with vast quantities of hazardous waste being discharged into global pollution hotspots [1]. Gold mining, as a prominent industrial activity, has the potential to cause significant and lasting environmental pollution [2,3] The various techniques used in gold extraction can have detrimental effects on the environment, and one of the primary environmental concerns associated with gold mining is the production of large volumes of wastewater [4,5]. This wastewater contains not only the chemicals utilized in the extraction process but also heavy metals and other harmful elements derived from the ore itself. When mining operations are abandoned or poorly managed, the discharge sites for this wastewater may be left untreated, resulting in exposure to significant environmental problems [6,7] This exposure encompasses emissions into essential natural resources like air, water, and soil, extending even to the most remote and secluded regions [5]. Mining as one of the human activities with well-known negative implications for the environment involves the extraction of natural mineral resources, whether in solid or liquid form, from deposits or quarries using specialized equipment and techniques [5,8,9].

While gold mining holds the promise of generating positive economic advantages, it also introduces risks to human health, plant life, and the environment through the release of waste materials into the immediate vicinity [10,11] Consequently, many gold mining sites become non-viable once mining operations are completed. A specific concern tied to these sites is the presence of heavy metals in the wastewater generated during the mining process. This wastewater holds the potential to transport harmful and toxic substances into nearby water systems. Heavy metal pollutants such as copper (Cu), arsenic (As), iron (Fe), zinc (Zn), and lead (Pb) have been found in considerable quantities in such environments [8].

A range of methods, including precipitation, filtration, ion exchange, reverse osmosis, evaporation, membrane technology, carbon adsorption, electro-winning, pre-concentration, wastewater coagulation, chelation, redox, and electrochemical techniques, constitute the spectrum of established approaches used to eliminate heavy metals from water sources [12-14]. Among these, adsorption emerges as one of the most potent means to cleanse contaminated water. Heavy metals have a very negative influence on ecosystems and human health. Abnormal high levels of metals, such as lead (Pb) and arsenic (As), released into the environment have the characteristic to disturb the biotic system and can ultimately cause human beings to suffer from serious neurological damage and cardiovascular diseases. Further, these metals bio-accumulate in the food chain and further deteriorate the problem, wherein long-term risk is linked with the existence of the metals, posed to the wildlife population, and possibly the human population [15].

It therefore, becomes necessary to search for approaches and methods that are effective in the reduction of the release of these metals into the environment. This has, in turn, helped the development of biotechnological approaches that are being explored productively to solve the same challenges. Biotechnology, which uses biological agents such as microbes and plants, has metal-adsorbing abilities through remediation techniques and forms sustainable avenues of contrast with the conventional approaches involving chemical and physical [16,17].

This application is based on the principles of green chemistry aimed at reducing environmental footprints in every effort of remediation. This not only helps in the detoxification of contaminated sites but also assists in biodiversity protection, salvaging these natural habitats from dangerous anthropogenic pollution [18,19]. Concerning this, it is therefore important to note that some organisms can bind and immobilize heavy metals, and researchers could make use of this natural ability in reducing, by immobilization, mobility and bioavailability to the environment of such contaminants [20]. The green remediation measures would promote community participation and advocacy for environmental protection; it supports localism in the sense that it would develop local solutions to local issues and, in turn, reinforce the sustainability and resilience of localities against environmental risks. Integration of such local traditional knowledge into the restoration and preservation of their environment, natural resource management, and capacity building will be used for increased learning while ensuring community participation [21]. Thus, through biotechnological means, the investigation and realization of heavy metal removal from wastewater will represent both a means for pollution control as well as one of the measures on the path to greater environmental stewardship and sustainable development. The urgency of amelioration in contamination issues, posed by heavy metals, has led to an exploration of different techniques for the remediation, in which biotechnology comes to be a pivot. Its capability to provide efficient, cost-effective, and ecologically sound alternatives to traditional methods makes it a very important tool to aid in the world's efforts against pollution.

In recent times, employing biotechnology to neutralize toxic substances has garnered significant research attention for diminishing the concentration of heavy metals in wastewater. The concept of environmental pollution has gained substantial focus due to technological advancements, turning it into a prominent topic within the realm of controlling metal pollutants due to their environmental impact [22]. In many instances, the most widely adopted method remains the sorption technique due to its cost-effectiveness, availability, and practicality in waste management. Sorption, as defined by Wang and Chen [23], refers to the process of removing metal or metalloid species, compounds, and particulates from a solution using biological materials. The utilization of locally available agricultural plant materials enhances the attractiveness of sorption as the preferred method for research purposes [22].

Therefore, this study employs a biotechnological treatment approach that incorporates locally accessible substances and utilizes a sorption technique to diminish the levels of heavy metals and various contaminants within wastewater originating from deserted gold mining sites in the Iponda and Idominasi regions of Osun State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The gold mining sites selected for this study are located in Iponda and Idominasi in Osun State. The two areas are located within geographical coordinates along Ilesha road, Osun State, Nigeria, with longitude $4^{o}43^{1}8^{11}$E, Latitude $7^{o}43^{1}57^{11}$N and longitude $4^{o}42^{1}0^{11}$ E, latitude $7^{o}40^{1}59^{11}$ N, respectively.

2.2 Sample Collection

Wastewater samples were collected from Iponda wastewater (IPWW) and Idominasi wastewater (IDWW) from the gold mining sites into two (2) separate clean 25 L plastic containers with air tight covers that had been previously rinsed with the wastewaters prior to collection. Each wastewater sample collected was left undisturbed for 24 h at room temperature (25

°C). The Neem Leaf (NL) were sourced from a local farm situated alongside Adunni in Ogbomoso, Oyo state. Leaves were carefully cleansed with distilled water and air dried at room temperature until constant weight was obtained. The dried leaves were kept for subsequent usage. Coconut Husk (CCH) were procured from local farmers in Ogbomoso, Oyo State.

2.3 Preparation of NL Adsorbent

Neem leaves (Fig. 1) were processed using mortar and pestle to grind them into a finely ground powder in other to increase the surface area. The powdered NL were sieved to particle size of 40 microns to facilitate penetration of the adsorbate (NL) into the effluent [24].

Fig. 1. Neem leaf (NL)

2.4 Preparation of CCH as Adsorbent

Coconut Husk (CCH) was removed from the coconut fruits and thoroughly cleaned to remove any external impurities. Subsequently, the sample was air-dried at room temperature for a period of 21 days and then weighed until constant weight was obtained. The dried and weighed husks samples were wrapped in double layers of aluminium foil and then placed into the crucible. The crucible, containing the prepared CCH was then put in an electric muffle furnace. Carbonization was carried out within a temperature range of 300°C to 350°C over a period of 30 minutes. After cooling, the oven-dried char underwent a granulation process and was subsequently sieved to achieve a mesh size of 40 µm. The final product was then stored for further use.

Fig. 2. Coconut husk (CCH)

2.5 Adsorption Experiments

The experiment was carried out using wastewater collected from two disused gold mining sites, namely Iponda and Idominasi. A measured dosages of adsorbent (0.5 g, 0.75 g, and 1 g) were added to a 50 ml volume of wastewater and mixture was agitated using an electric stirrer, which operated at varying speeds (30 rpm, 60 rpm, 90 rpm and 120 rpm), depending on the specific test. A constant contact time of 30 min was adopted for the adsorption experiment. The use of a constant contact time was based on the result of a previous study where the effect of contact time on adsorption process had been found to be of direct proportionality [25]. Thus, the effect of contact time was not considered in this study.

2.6 Physical and Chemical Characterization

The wastewater samples were analysed for temperature, pH, total alkalinity, total hardness, calcium hardness, biological oxygen demand (BOD), chemical oxygen demand (COD), chloride, bicarbonate, conductivity, turbidity and confirmatory test according to the standard procedures [26,27]. The colour, odour, pH, temperature, dissolved oxygen (DO), turbidity, and electrical conductivity (EC) of the wastewater were determined at the point of collection. The pH was measured with the use of a portable digital analysis meter (HQ40d, HACH, USA). EC was measured with the use of a portable HACH conductivity metre. Temperature and DO were measured using DO metre (HI9143, HANNA, Italy) (DO-200, Lvibond, Germany). Turbidity was measured using a Turbicheck Turbidity meter

(The Tintometer Limited, Lovibond House, Amesbury, UK)

2.6.1 pH test

A precise 10 mL aliquot of the sample was measured and transferred into a conical flask. To assess its acidity, 10 drops of bromothymol blue was introduced, and the flask was carefully inverted to ensure thorough mixing. Subsequently, the resulting solution was transferred into a cuvette and positioned on the left-hand side of the Lovibond comparator. On the right-hand side, another cuvette containing a water sample was placed. To determine the acidity level, the colour of the solution was compared to the colour standards displayed on the Lovibond disc. The disc was rotated until a matching colour was achieved. Upon completion of the experiment, it was observed that the value indicated on the Lovibond disc was in concordance with the acidity level [28].

2.6.2 Total alkalinity test

The burette was rinsed with 0.02N sulfuric acid to eliminate any potential impurities and mounted on a stand and loaded with 0.02N sulfuric acid, with the addition of sodium thiosulfate (NaS_2O_3). To prepare the water sample, 50 mL of the sample was measured using a graduated cylinder and poured into a conical flask. Three drops of phenolphthalein indicator were introduced into the flask's contents. The presence of alkalinity, specifically hydroxyl ions, within the water sample caused the solution to turn pink. The disappearance of the pink colour signified the complete neutralization and removal of all hydroxyl ions from the water sample by the acid. To ensure result accuracy, the titration process was replicated thrice until consistent values were obtained [29].

2.6.3 Total hardness test

The burette was first loaded with a standard solution of Ethylenediaminetetraacetic acid (EDTA) until it reached the zero mark. Following this, 50 mL of the wastewater sample was cautiously transferred to a flask. To this flask, 2 mL of ammonia buffer was added, and 1 gram of Ericrome Black T (EBT) was introduced as an indicator [30,31]. Ericrome Black T (EBT) served the purpose of detecting the presence of ions in the water sample. EBT forms a pink complex when it binds with free metal ions in the water, facilitating the visual detection. However, during the titration process, EDTA exhibits a stronger affinity for metal ions than EBT. Consequently, when the standard EDTA solution is titrated against the water sample with EBT indicator, the solution's colour shifts from an initial wine-red to blue at the endpoint [32]. This colour transformation signifies the successful chelation of metal ions in the water sample by EDTA. Throughout the experiment, careful records were maintained of the initial and final burette readings to determine the volume of EDTA solution consumed during titration. The procedure was repeated multiple times to ensure the acquisition of consistent and congruent results, guaranteeing accuracy and reliability. Finally, the titre value obtained from the titration was multiplied by 20 to ascertain the concentration or quantity of the target metal ions present in the water sample [33]. This methodology allows for the evaluation of the water's metal ion content and aids in assessing its quality and potential environmental impact.

2.6.4 Calcium hardness test

After a meticulous cleaning process, the burette was filled with an EDTA solution. Following this, a clean conical flask was completely filled with a 50 mL water sample. To this water sample, 2 mL of sodium hydroxide (NaOH) was added [31]. In addition, an appropriate quantity of Murexide, a widely used complexometric indicator in analytical chemistry for titrations involving various metal ions such as calcium, copper, nickel, cobalt, thorium, and rare-earth metals, was introduced into the flask. The titration process was initiated by gradually adding the EDTA solution from the burette into the flask containing the water sample and the indicator. During titration, a conspicuous colour shift took place, transitioning from pink to purple. This colour transformation was the result of the complex formation between Murexide and the metal ions present in the water sample. The volume of EDTA solution consumed at the point of the colour change was documented as the "titre" value. To ensure precision and reliability, the experiment was repeated multiple times to secure consistent outcomes [34]. This complexometric titration, employing Murexide as the indicator and EDTA as the titrant, facilitated the quantitative determination of metal ions in the water sample. By using the titre value and the concentration of the EDTA solution, the experiment aimed to evaluate the concentration of metal ions, particularly calcium ions, within the water sample. This information is vital for assessing water quality and its potential environmental impact.

2.6.5 Chloride ion test

A precise 100 mL portion of the wastewater was measured and gently poured into a pristine conical flask. For the purpose of an indicator, 2 mL of potassium chromate was introduced. This substance is recognized as a yellow crystalline solid with no discernible odour but a rather unpleasant bitter taste. The ensuing titration was executed with the use of silver nitrate. Throughout the titration procedure, a noticeable colour alteration was observed, shifting from a vibrant green to a murky brown tint. To guarantee precision, the process was replicated multiple times until a consistent value was achieved, and subsequently, the average of the results was computed [7].

2.6.6 Bicarbonate test

A 100 mL portion of the wastewater was accurately measured and gently transferred into a clean conical flask. To serve as an indicator, 2 mL of potassium chromate, a yellow crystalline solid with no detectable odour but a somewhat disagreeable bitter taste, was added. The titration that followed was carried out using silver nitrate. During the titration process, a distinct change in colour was observed, transitioning from a vivid green to a murky brown hue. The procedure was repeated several times to ensure accuracy until a consistent value was obtained, and then the average of the results was calculated [6].

2.6.7 Conductivity test

A small volume of the water sample was gently dispensed into a compact beaker, and the conductivity meter's electrode was cautiously submerged into the sample. The conductivity meter was then turned on, and the recorded conductivity value was noted. Following this, the mode button on the conductivity meter was pressed to switch to the Total Dissolved Solids (TDS) testing mode, and the associated TDS value was likewise recorded [8].

2.6.8 Turbidity test

The Spectrophotometer is an invaluable tool that offers colour measurement capabilities to assess both the aesthetic appeal and the level of purity in water. One of the techniques it employs involves quantifying turbidity by examining light penetration. This is accomplished by passing light through the water sample and gauging the amount of light that scatters and disperses before returning to the sensor, thereby enabling the calculation of turbidity. In a liquid with high turbidity, light is prominently scattered, whereas in a liquid with low turbidity, light dispersion is minimal. A light is passed through the sample and reflected light is measured as turbidity in the Nephelometric Turbidity Unit (NTU).To conduct this measurement, a small portion of the water sample was poured into a beaker, and the electrode of the turbidity meter was meticulously immersed into the sample. Subsequently, the spectrophotometer was activated to initiate the measurement process, and the corresponding turbidity value was recorded for further analysis and assessment of water quality [8].

2.6.9 Confirmatory test

To verify the presence of coliform bacteria in a water sample that displayed positive growth in the presumptive test following incubation, a series of dilutions for the wastewater sample was prepared using sterile dilution water. All agar used in this procedure adhered to the manufacturer's guidelines. Subsequently, each dilution was introduced onto a selective medium, such as the membrane filtration method. The plates containing the inoculated samples were then incubated at 35°C for a period ranging from 24 to 48 hours. After the incubation interval, a careful count of the colonies on the membrane filters was conducted. To determine the quantity of coliform bacteria in the wastewater sample, the following formula was employed: Number of coliform bacteria = (number of colonies on the membrane filter) x (reciprocal of the sample volume filtered). This method enabled the quantitative assessment of coliform bacteria in the water sample, providing crucial insights into its safety and potential contamination levels [6].

2.6.10 Bacteriological examination

The broth was meticulously prepared following the manufacturer's guidelines. Subsequently, 50 mL of the prepared double-strength broth was gently transferred into a universal bottle, with a Durham tube securely attached to it. Additionally, 10 mL of the double-strength broth was distributed into five McCartney bottles, and each McCartney bottle was equipped with a Durham tube to collect gas. These McCartney bottles were diligently labelled for clear identification. To convert the remaining double-strength broth into single-strength, an equivalent volume of double-strength broth was mixed with an equal volume of distilled water. This dilution process transformed the broth into single-strength. From this single-strength broth, 1.5 mL was dispensed for subsequent use or testing [6].

2.6.11 Biochemical Oxygen Demand (BOD)

The officially sanctioned procedure for Biochemical Oxygen Demand (BOD) sampling and analysis entails quantifying the reduction in dissolved oxygen (D.O.) caused by organic matter decomposition. Effective process control necessitates access to real-time data for prompt adjustments and the optimization of treatment procedures. Hence, although the BOD test offers valuable information about the general organic content and potential water body impacts, supplementary rapid and continuous monitoring techniques are frequently employed to enable efficient process control in wastewater treatment plants and similar applications [7,8].

2.6.12 Chemical Oxygen Demand (COD)

The most prevalent technique for assessing Chemical Oxygen Demand (COD) is colorimetric analysis. In this process, COD is initially oxidized using acid, and indicator compounds like hexavalent dichromate are employed. Nonetheless, specific compounds may introduce interference in colorimetric analysis, necessitating titration as an alternative approach to accurately determine COD levels. The COD test holds paramount importance for gauging the extent of contamination in water, particularly post-wastewater treatment [27,35]. Elevated COD readings signify a notable presence of organic pollution in the water sample. High COD levels indicate a substantial quantity of organic compounds that rely on oxygen for decomposition, potentially depleting dissolved oxygen in aquatic environments and posing risks to aquatic life. Hence, it is imperative to monitor and regulate COD levels in water to evaluate the efficacy of wastewater treatment processes and safeguard water bodies and the environment. The reduction of COD levels through effective treatment methods contributes to mitigating the impact of organic pollution, promoting the overall health and sustainability of water resources.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Characterization

The results of the raw wastewater Iponda wastewater (IPWW) and Idominasi wastewater (IDWW) of abandon gold mining sites has been discussed elsewhere [8]. Physicochemical characterization for treated wastewater samples from IPWW and IDWW are shown in Tables 1 and 2 for NL adsorption, and Tables 3 and 4 for CCH adsorption. These tables encompass various crucial parameters, including pH, total hardness, calcium hardness, chloride ion levels, bicarbonate content, conductivity, turbidity, confirmatory testing for coliform bacteria, bacteriological examination, biochemical oxygen demand, and chemical oxygen demand. Comparing these results to the untreated wastewater analyses conducted by Dada et al. [8] for IPWW and IDWW, it becomes evident that NL and CCH adsorbents have significantly improved the quality of wastewater in both locations. Notably, NL has a more pronounced positive impact on the IPWW and IDWW when compared to CCH. The results showed a substantial reduction in the concentrations of various parameters with NL adsorption, relative to CCH. Further analysis of NL adsorption reveals that its effectiveness increases as the mass of the adsorbent increases for both IPWW and IDWW. In contrast, the effectiveness of CCH adsorption diminishes with an increase in the adsorbent's mass. However, when comparing these results to the World Health Organization (WHO) standards, it's apparent that only the pH values fall within the standard limits. Other parameters show significant deviations from the WHO standards, indicating the need for further treatment or remediation to meet these health and environmental guidelines. Tables 5, 6, 7, and 8 also contained the results of the bacteriological examination of the wastewater from Iponda and Idominasi following treatment with NL and CCH adsorbents.

3.1.1 pH and temperature

pH is a measure of acidity or alkalinity and is one of the stable parameters that specify a relative amount of free hydrogen and hydroxyl ions in the water [14]. It is a simple parameter but extremely important, since most of the chemical reactions in aquatic environment are controlled by changes in pH [36]. Aquatic organisms are sensitive to pH change, also biological treatment requires pH control monitoring. The pH of Iponda gold mining site wastewater (IPWW) before treatment was 7.6 as earlier discussed somewhere else [8] which was within the WHO standard and after the water has been treated as shown in Table 1 was 7.2 with 1.0 g dose of NL as adsorbent. In both cases pH values were above Neutral which was within the range of permissible limits 6.0-

9.5,6.0-9.0 and 6.5-8.5 [37] specified by WHO, [17] has similarly reported an alkaline pH for gold mining wastewater after treatment, using cocopeat as adsorbent. A pH of below 6.5 may be corrosive to plumbing fixtures and reticulation and the general guideline value is within 6.5 and 8.5 to all mine water discharges. Also, the results of physicochemical characterization of water samples reveal that wastewaters of the Idominasi gold mining (IDWW) zone are slightly acidic to neutral (6.8). The pH values of the different samples express a slight acidity but still remain close to one another. This slight acidity is attributed to the presence of sulfides [8], in particular the pyrite accompanying the gold, the hydrolysis of which acidifies the environment. Such pH ranges systematically induce an increase in the rate of absorption of trace elements in surface sediments. The results pH showed after treatment was found to be 6.8.

Temperature is one of the most important ecological features that controls behavioural characteristics of organisms, solubility, gases and some salt in the water. The temperature of wastewater is important primarily because it affects the aquatic and biological life in receiving water bodies. Change in temperature affects the wastewater in a number of ways, firstly as the temperature was at room temperature (25.1 ^{o}C), this temperature is extremely low [38]. The extremely low temperature adversely affects the sedimentation. Secondly, the solubility of gases in wastewater decreases with increases in temperature and increases with decrease in temperature. Lower temperature tends to increase the dissolved oxygen solubility which is detrimental to the living organisms in the water. The temperature of IPWW initially was 25.6^{o}C and when it was treated was 25.1^{o}C (Table 1). The values are comparable to the standard permissible limit provided by WHO and FEPA. The temperature results for IPWW in Table 1 showed that it favours mesophilic microbial growth and organic matter biodegradation (moderate-temperature-loving bacteria) found in water, soil and in higher organisms. These microorganisms are the most common type of microbes studied. Their optimum growth temperature ranges between 25°C and 40°C. However, when the temperature falls below 20^{o}C, it can be seen that the rate of microbial activity and biodegradation is found to be slower.

3.1.2 Turbidity and electrical conductivity

Turbidity is a measure of fine suspended matter in the water. This was found to be relatively high for IPWW (before treatment) and after treatment as shown in Table 1. The suspended matter scatters light and gives a “cloudy” appearance. Turbidity of a wastewater depends on the strength of the wastewater, the stronger the concentration of the wastewater the higher is the turbidity [40] The turbidity concentration values obtained for IPWW was found to be relatively lower than the values reported by Edjere et al. [41] and range of 40-120 NTU obtained by Saalidong et al. [42]. Hence turbidity is an indirect measurement of suspended matter. Increased turbidity in surface water may become objectionable since it limits light penetration and increases heat absorption. Particles causing turbidity can also be a medium of absorption and transport for bacteria. Turbidity is generally measured by a light scattering nephelometer. In coal mine water for example, light is absorbed by coal particles rather than reflected. Turbidity measurement for mine effluents may be useful for receiving water impact studies.

Electrical conductivity (EC) is probably one of the simplest and most important properties for controlling the quality of water. It reflects the degree of overall mineralization and provides us with information on the salinity rate [43]. EC is a measure of the sample's ability to conduct current [44]. This is attributed to dissolved organic and inorganic ions in the wastewater [45]. Inorganic ions have the most significant influence on the water conductivity. High values of EC shows that inorganic ions are much more present in the wastewater. It shows that high EC in the wastewater is an indication of high total dissolved solid (TDS) concentration. Therefore, EC is directly proportional to the total filtration concentration. The EC values for IPWW before and after as discussed earlier was 256.7 µS/cm and when treated with neem leaves was also found to be 256.7 µS/cm. This results was lower than the WHO values 500-1000 µS/cm. Electrical Conductivity (EC) is the numerical expression of the ability of aqueous solution to carry an electric current. High level of mineralization is a typical characteristic of many coal mining discharges. In most cases, a direct relationship between Electrical Conductivity and TDS can be established. This makes determination of TDS easier as EC can be measured readily with an instrument. As seen in the Table 1, the electrical conductivity for mine water can be substantially high due to the presence of dissolved salts.

Table 1. Physicochemical analysis results for treated wastewater samples from Iponda for Neem leaf adsorption

Parameter	IPWW (Untreated Watewater)	0.5 g adsorbent (Treated Wastewater) (mean value)	0.75 g adsorbent (Treated Wastewater)(mean value)	1 g adsorbent (Treated Wastewater) (mean value)	WHO	SON
PH	6.8	6.8	7.2	7.2	6.0-9.5	6.5-8.5
Turbidity (NTU)	27.5	39.25	44.15	49.85	1	5
Dissolved Oxygen (mg/L)	1.2	1.26	1.26	1.26	6.5-8	
Temperature ^oC	25.1	25.5	26.05	25.8	25	Ambient
Total Alkalinity (mg/L)	494	164	152	130	0-200	
Total Hardness (mg/L)	168	84	72	58	600	
Calcium Hardness (mg/L)	98	30	20	10	0-60	150
Calcium Ions (mg/L)	39.2	12	8	4	0-100	
Magnesium Hardness (mg/L)	70	54	52	48	0-60	
Magnesium Ions (mg/L)	17.5	13.5	13	12	12	20
Chloride Ions (mg/L)	22.5	20.25	18.55	17.15	0-250	250
Iron (mg/L)	0.65	0.0005	0	0	0.3	0.3
Silica (mg/L)	1.1	0.045	0	0	1	
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	2.58	0.002	0	0	50	50
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0.016	0	0	0	1	0.2
Copper (mg/L)	3.1	0.0005	0	0	1.3	1
Manganese (mg/L)	0.009	0	0	0	0.05	0.2
Aluminum (mg/L)	0	0	0	0	0.05	0.2
Fluoride (mg/L)	0	0	0	0	0.7	1.5
Sulphide (mg/L)	0.17	0	0	0	250	0.05
Chromium (mg/L)	0.55	0.001	0	0	0.1	0.05
Conductivity (µS/cm)	1002	256.7	256.7	256.7	500-1000	1000
Sulphate (mg/L)	68	9	9	9	100	100
Potassium (mg/L)	3.9	0	0	0	0-5	
Phosphate (mg/L)	13.4	2.425	2.0705	1.848	0-1000	
Zinc (mg/L)	0.82	0.165	0.0545	0	0-5	3
Carbonate (mg/L)	168	84	72	58	60	
Bicarbnate (mg/L)	841.8	280.6	280.6	280.6	245	
Flocculation (PPM)	600	105	125	145	558	
COD (mg/L)	1020	37.5	31.2	24	250	
BOD (mg/L)	0.2	0.4	0.4	0.4	0-1	
Total Filtrable Solids (mg/L)	287.8	94.5	183	271.5	338	
Total non-Filtrable Solids (mg/L)	0.47	0.0635	0.1555	0.188	4-20000	

SON: Standard Organization of Nigeria Drinking water standard [39]

Table 2. physicochemical analysis results for treated wastewater samples from IDWW for Neem leaf adsorption

Parameter	IDWW (Untreated Watewater)	0.5 g adsorbent (Treated Waste water) (mean)	0.75 g adsorbent (Treated Waste water (mean)	1 g adsorbent (Treated Waste water (mean)	WHO	SON
PH	6.8	6.8	6.8	6.8	6.5-8.5	6.5-8.5
Turbidity (NTU)	200	41.25	45.25	50.1	1	5
Dissolved Oxygen (mg/L)	1.2	1.28	1.28	1.28	6.5-8	
Temperature ºC	25.1	25.4	25.55	25.8	25	Ambient
Total Alkalinity (mg/L)	494	383	357	340	0-200	
Total Hardness (mg/L)	168	124	120	112	600	
Calcium Hardness (mg/L)	98	71	63	55	0-60	150
Calcium Ions (mg/L)	39.2	28.4	25.2	22	0-100	
Mangnesium Hardness (mg/L)	70	53	57	57	0-60	
Magnesium Ions (mg/L)	17.5	13.25	14.25	14.25	12	20
Chloride Ions (mg/L)	146	140.5	140.15	137.5	0-250	250
Iron (mg/L)	0.65	0.575	0.41	0.28	0.3	0.3
Silica (mg/L)	1.1	1	0.826	0.73	1	
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	2.58	0.94	0.8895	0.759	50	50
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0.016	0	0	0	1	0.2
Copper (mg/L)	3.1	2.645	2.01	1.5	1.3	1
Manganese (mg/L)	0.009	0	0	0	0.05	0.2
Aluminum (mg/L)	0	0	0	0	0.05	0.2
Fluoride (mg/L)	0	1.13	1.13	1.13	0.7	1.5
Sulphide (mg/L)	0.17	0	0	0	250	0.05
Chromium (mg/L)	0.55	0.5355	0.473	0.3825	0.1	0.05
Conductivity (µS/cm)	1002	1002	1002	1002	500-1000	1000
Sulphate (mg/L)	68	68	68	68	100	100
Potassium (mg/L)	3.9	0	0	0	0-5	
Phosphate (mg/L)	13.4	12.3	11.335	10.88	0-1000	
Zinc (mg/L)	0.82	0.2	0	0	0-5	3
Carbonate (mg/L)	168	124	120	112	60	
Bicarbonate (mg/L)	841.8	841.8	873	928.95	245	
Flocculation (PPM)	600	122.5	138.5	150	558	
COD (mg/L)	1020	985.355	914.65	856.1	250	
BOD (mg/L)	0.2	0.2	0.2	0.2	0-1	
Total Filtrable Solids (mg/L)	287.8	290.2	320.25	373.4	338	
Total non-Filtrable Solids (mg/L)	0.47	0.155	0.265	0.4	4-20000	

Table 3. Physicochemical analysis results for treated wastewater samples from IPWW for coconut husk adsorption.

Parameter	Raw Analysis	0.5 g adsorbent (Treated Waste water) (mean)	0.75 g adsorbent (Treated Waste water) (mean)	1 g (mean)adsorbent (Treated Waste water)	WHO Standard
PH	6.8	7.6	7.8	8.1	6.5-8
Turbidity (NTU)	200	66.75	77.5	87	1
Dissolved Oxygen (mg/l)	1.2	0.735	0.81	0.87	6.5-8
Temperature ^oC	25.1	25.4	25.4	25.65	25
Total Alkalinity (mg/L)	494	228	244	270	0-200
Total Hardness (mg/L)	168	95	119	142	120
Calcium Hardness (mg/L)	98	72	93	114	0-60
Calcium Ions (mg/L)	39.2	28.8	37.2	45.6	0-100
Mangnesium Hardness (mg/L)	70	23	26	28	0-60
Magnesium Ions (mg/L)	17.5	0	0	0	12
Chloride Ions (mg/L)	146	26.75	32.25	39	0-250
Iron (mg/L)	0.65	0.3385	0.42	0.4645	0.3
Silica (mg/L)	1.1	0.367	0.4075	0.443	1
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	2.58	0.052	0.077	0.1025	10
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0.016	0.0055	0.015	0.0255	1
Copper (mg/L)	3.1	0.018	0.0345	0.054	1.3
Manganese (mg/L)	0.009	0	0	0	0.05
Aluminum (mg/L)	0	0.0075	0.0165	0.027	0.05
Fluoride (mg/L)	0	0	0	0	0.7
Sulphide (mg/L)	0.17	0	0	0	250
Chromium (mg/L)	0.55	0.078	0.097	0.11	0.1
Conductivity (mg/L)	1002	270.75	288.55	305.4	500-1000
Sulphate (mg/L)	68	2	0	0	100
Potassium (mg/L)	3.9	4.095	4.845	5.37	0-5
Phosphate (mg/L)	13.4	3.747	3.8285	3.94	0-1000
Zinc (mg/L)	0.82	0.335	0.53	0.7	0-5
Carbonate (mg/L)	168	95	119	142	60
Bicarbnate (mg/L)	841.8	299.7	299.7	299.7	245
Flocculation (PPM)	600	190	210	227.5	558
COD (mg/L)	1020	59	80	105.5	250
BOD (mg/L)	0.2	0.4	0.4	0.4	0-1
Total Filtrable Solids (mg/L)	287.8	121.025	142.76	164	338
Total non-Filtrable Solids (mg/L)	0.47	0.065	0.2	0.405	4-20000

Table 4. physicochemical analysis results for treated wastewater samples from IDWW for coconut husk adsorption

Parameter	Raw Analysis (Untreated Wastewater)	0.5 g adsorbent (Treated Waste water) (mean)	0.75 g adsorbent (Treated Waste water) (mean)	1 g adsorbent (Treated Waste water) (mean)	W.H.O Standard
PH	6.8	7.2	7.4	7.6	6.5-8
Turbidity (FTU)	200	88.35	103	108.9	1
Dissolved Oxygen (mg/l)	1.2	0.59	0.6	0.65	6.5-8
Temperature ºC	25.1	25.3	25.5	25.7	25
Total Alkalinity (mg/L)	494	240	250	264	0-200
Total Hardness (mg/L)	168	108	125	138	120
Calcium Hardness (mg/L)	98	61	77	100	0-60
Calcium Ions (mg/L)	39.2	24.4	30.8	40	0-100
Magnesium Hardness (mg/L)	70	47	48	38	0-60
Magnesium Ions (mg/L)	17.5	11.75	12	9.25	12
Chloride Ions (mg/L)	146	161.4	172.2	180	0-250
Iron (mg/L)	0.65	0.715	0.85	1	0.3
Silica (mg/L)	1.1	1.6275	1.822	1.9405	1
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	2.58	1.0105	1.0425	1.0725	10
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0.016	0.0095	0.0175	0.0355	1
Copper (mg/L)	3.1	3.255	3.3855	3.4795	1.3
Manganese (mg/L)	0.009	0.001	0.001	0.003	0.05
Aluminum (mg/L)	0	0	0	0	0.05
Fluoride (mg/L)	0	1.16	1.16	1.16	0.7
Sulphide (mg/L)	0.17	0.595	0.705	0.845	250
Chromium (mg/L)	0.55	0.9815	1.0115	1.029	0.1
Conductivity (mg/L)	1002	1013.5	1033.5	1053	500-1000
Sulphate (mg/L)	68	41	34	27.5	100
Potassium (mg/L)	3.9	2.815	2.925	3.045	0-5
Phosphate (mg/L)	13.4	13.6	13.78	13.94	0-1000
Zinc (mg/L)	0.82	0.915	1.006	1.0175	0-5
Carbonate (mg/L)	168	108	125	138	60
Bicarbonate (mg/L)	841.8	858.6	858.6	858.6	245
Flocculation (PPM)	600	260	305	330	558
COD (mg/L)	1020	1075	1158.5	1192.5	250
BOD (mg/L)	0.2	0.2	0.2	0.2	0-1
Total Filtrable Solids (mg/L)	287.8	374.75	420.4	473.2	338
Total non-Filtrable Solids (mg/L)	0.47	0.185	0.3	0.445	4-20000

Table 5. Bacteriological examination of the wastewater from iponda after treatment with neem leaf adsorbent

Sample No	Description of Samples			pH	Calories Per CC Growing on Nutrient Agar At 37 °C in 24 h	Presumptive Results of Coliform Organisms at 48 Hours of Incubation At 37 °C			Most probably Numbers of Bacteria Coliform per 100ml of water sample.
	Adsorbent	Mass of Adsorbent (g)	Speed (rpm)			50ml	10ml	1ml	
1	Neem	0.5	30, 60 and 90	6.8	Cluster	1	5	5	180 and above
2	Neem	0.5	120	6.8	Cluster	1	5	4	180 and above
3	Neem	0.75	30, 60 and 90	7.2	Cluster	1	5	4	180 and above
4	Neem	0.75	120	7.2	Cluster	1	5	5	180 and above
5	Neem	1	30, 60 and 90	7.2	Cluster	1	5	5	180 and above
6	Neem	1	120	7.2	Cluster	1	5	5	180 and above

Table 6. Bacteriological Examination of the wastewater from IDWW after treatment with neem leaf adsorbent

Sample No	Description of Samples			pH	Calories Per CC Growing on Nutrient Agar At 37 °C in 24 h	Presumptive Results of Coliform Organisms at 48 Hours of Incubation At 37 °C			Most probably Numbers of Bacteria Coliform per 100ml of water sample.
	Adsorbent	Mass of Adsorbent (g)	Speed (rpm)			50ml	10ml	1ml	
1	Neem	0.5	30, 60 and 90	6.8	Cluster	1	5	5	180 and above
2	Neem	0.5	120	6.8	Cluster	1	5	5	180 and above
3	Neem	0.75	30, 60 and 90	6.8	Cluster	1	5	5	180 and above
4	Neem	0.75	120	6.8	Cluster	1	5	5	180 and above
5	Neem	1	30, 60 and 90	6.8	Cluster	1	5	5	180 and above
6	Neem	1	120	6.8	Cluster	1	5	5	180 and above

Table 7. Bacteriological examination of the wastewater from IPWW after treatment with coconut husk adsorbent

Sample No	Description of Samples			pH	Calories Per CC Growing on Nutrient Agar At 37℃ in 24 hours	Presumptive Results of Coliform Organisms at 48 Hours of Incubation At 37℃			Most probably Numbers of Bacteria Coliform per 100ml of water sample.
	Adsorbent	Mass of Adsorbent (g)	RPM			50ml	10ml	1ml	
1	Coconut Husk	0.5	30, 60 and 90	7.6	Cluster	1	5	5	180 and above
2	Coconut Husk	0.5	120	7.6	Cluster	1	5	4	180 and above
3	Coconut Husk	0.75	30,60 and 90	7.8	Cluster	1	5	4	180 and above
4	Coconut Husk	0.75	120	7.8	Cluster	1	5	5	180 and above
5	Coconut Husk	1	30, 60 and 90	8.1	Cluster	1	5	5	180 and above
6	Coconut Husk	1	120	8.1	Cluster	1	5	5	180 and above

Table 8. Bacteriological Examination of the wastewater from Idominasi after treatment with coconut husk adsorbent

Sample No	Description of Samples			pH	Calories Per CC Growing on Nutrient Agar At 37 °C in 24 h	Presumptive Results of Coliform Organisms at 48 Hours of Incubation At 37 °C			Most probably Numbers of Bacteria Coliform per 100ml of water sample.
	Adsorbent	Mass of Adsorbent (g)	Speed (rpm)			50ml	10ml	1ml	
1	Coconut Husk	0.5	30, 60 and 90	7.2	Cluster	1	5	5	180 and above
2	Coconut Husk	0.5	120	7.2	Cluster	1	5	5	180 and above
3	Coconut Husk	0.75	30, 60 and 90	7.4	Cluster	1	5	5	180 and above
4	Coconut Husk	0.75	120	7.4	Cluster	1	5	5	180 and above
5	Coconut Husk	1	30, 60 and 90	7.6	Cluster	1	5	5	180 and above
6	Coconut Husk	1	120	7.6	Cluster	1	5	5	180 and above

3.1.3 Alkalinity, chlorides, sulphates, nitrate nitrogen, total hardness and biological oxygen demand (BOD)

Alkalinity is the measure of negative ions that react to neutralize hydrogen ions, indicating water's capacity to counteract acids [46]. The primary components are bicarbonate (HCO^{3-}), carbonate (CO_3^{2-}), and hydroxide ions. The initial total alkalinity for untreated IPWW was 494 mg/L, which decreased to 130 mg/L after treatment. This aligns with the World Health Organization [47] guideline range of 0-200 mg/L. Water with exceedingly high alkalinity can be corrosive and unsuitable for various applications. However, in mine waters, excessive alkalinity can prevent pH reduction resulting from biochemical reactions of sulphur compounds with water. The result shows the effectiveness of neem leaves as adsorbent for treatment of wastewater. Chloride is naturally present in water in small quantities depending on the geological formations with which the water has been in contact. Nevertheless, chlorides have been reported to adversely affect metals associated with water handling systems [48]. From the Table 1, the initial chloride was found to be 22.5 mg/L and it was found to be 17 mg/L after treatment. At higher concentration, it may also accelerate corrosion rates in the pipe systems. Water with excess chloride concentration is unsuitable for irrigation or domestic supplies [49].

Sulphates are naturally present in water, often originating from mineral deposits like gypsum. However, the biological oxidation of pyrites leads to dissolved sulphates, potentially increasing their concentration, even when using fresh water as a carrier medium. Elevated sulphate levels can induce a laxative effect and impart an unpleasant taste to the water consumed [50]. The results shows the effectiveness of neem leaves as a good adsorbent in the sense that the sulphates value reduced from 68 to 9 mg/L after treatment, this value is lower than the WHO standard (100 mg/L).

Nitrates are end point of the aerobic decomposition of organic nitrogenous matter. The value of nitrates in IPWW and IDWW before was 2.58 mg/L. The results after treatment were found to be 0.00 mg/L and 0.759 mg/L which were below the maximum permissible limit of 50 mg/L by WHO. Excessive presence of nitrate in conjunction with phosphate and potassium causes algal blooms which can result in the death of aquatic organisms [24].

Total hardness is the property of water which prevents lather formation with soap and it also increases the boiling points of water. Hardness of water mainly depends upon the amount of magnesium and calcium salts dissolved [51]. The value of total hardness of untreated wastewater samples from a previous work was found to be 88 and 168 mg/L, for both IPWW and IDWW respectively [8], these values upon treatment were found to have reduced considerably with as the amount of adsorbents were increased respectively for the samples from the two sites. The values recorded are below the maximum permissible limit [16] as shown in Tables 1 and 2.

3.2 Heavy Metals found in the Treated Wastewater

After conducting each test, the experiment's final results were compared to the analysis provided by [24] for wastewater from the abandoned gold mining sites in IPWW and IDWW. It was observed that neem leaf had a more positive impact on the absorption and bioremediation of Iponda and IDWW, resulting in a reduction in the concentration of heavy metals in the wastewater compared to the use of coconut husk. This improvement was achieved without any filtration.

Additionally, it was noted that the efficiency of heavy metal adsorption increased when 1 gram of neem leaf was added to the wastewater at both sites, following mixing at a speed of 120 rpm. This suggests that as the mass of the adsorbent and the contact time increased, the adsorption efficiency improved. However, excessive adsorbent, beyond 1 gram, had no significant effect on the wastewater and could lead to the formation of a slurry.

On the other hand, for CCH, lower amounts of coconut char proved to be more effective in the adsorption process, particularly when applied at a lower mixing speed. These results are summarized in Tables 9 and 10 and depicted in Figs. 3 and 4 (showing the concentrations of heavy metals in IPWW and IDWW after treatment with neem leaf adsorbent) and in Tables 11 and 12, along with Figs. 5 and 6 (illustrating the concentrations of heavy metals in IPWW and IDWW following treatment with coconut husk adsorbent.

Table 9. The concentration of heavy metals in IPWW following treatment with neem leaf adsorbent

Heavy Metals	0.5 G		0.75 G		1 G	
	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm
Calcium Ions (mg/L)	12.8	11.2	8.8	7.2	4.8	3.2
Magnesium Ions (mg/L)	13.5	13.5	13	13	12.5	11.5
Iron (mg/L)	0.001	0	0	0	0	0
Silica (mg/L)	0.09	0	0	0	0	0
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	0.004	0	0	0	0	0
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0.001	0	0	0	0	0
Copper (mg/L)	0.002	0	0	0	0	0
Manganese (mg/L)	0.19	0.14	0.099	0.01	0	0
Aluminum (mg/L)	86	82	74	70	62	54
Sulphide (mg/L)	12.8	11.2	8.8	7.2	4.8	3.2
Chromium (mg/L)	13.5	13.5	13	13	12.5	11.5
Potassium (mg/L)	0.001	0	0	0	0	0
Zinc (mg/L)	0.09	0	0	0	0	0
Carbonate (mg/L)	0.004	0	0	0	0	0

Table 10. The concentration of heavy metals in IDWW following treatment with neem leaf adsorbent

Heavy Metals	0.5 G		0.75 G		1 G	
	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm
Calcium Ions (mg/L)	28.8	28	25.6	24.8	22.4	21.6
Magnesium Ions (mg/L)	13	13.5	14	14.5	14	14.5
Iron (mg/L)	0.61	0.54	0.47	0.35	0.31	0.25
Silica (mg/L)	1	1	0.841	0.811	0.759	0.701
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	0.94	0.94	0.916	0.863	0.802	0.716
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0	0	0	0	0	0
Copper (mg/L)	2.93	2.36	2.17	1.85	1.62	1.38
Manganese (mg/L)	0	0	0	0	0	0
Aluminum (mg/L)	0	0	0	0	0	0
Sulphide (mg/L)	0	0	0	0	0	0
Chromium (mg/L)	0.55	0.521	0.485	0.461	0.411	0.354
Potassium (mg/L)	0	0	0	0	0	0
Zinc (mg/L)	0.4	0	0	0	0	0
Carbonate (mg/L)	124	124	120	120	112	112

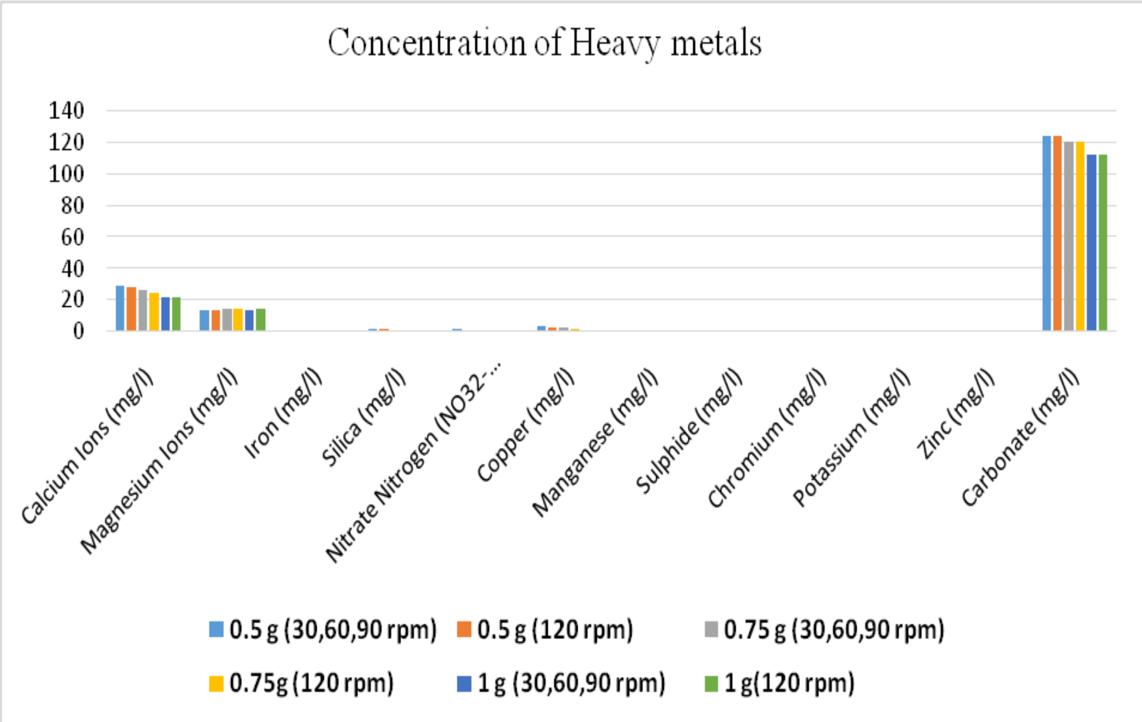

Fig. 3. The concentration of heavy metals in IPWW following treatment with neem leaf adsorbent

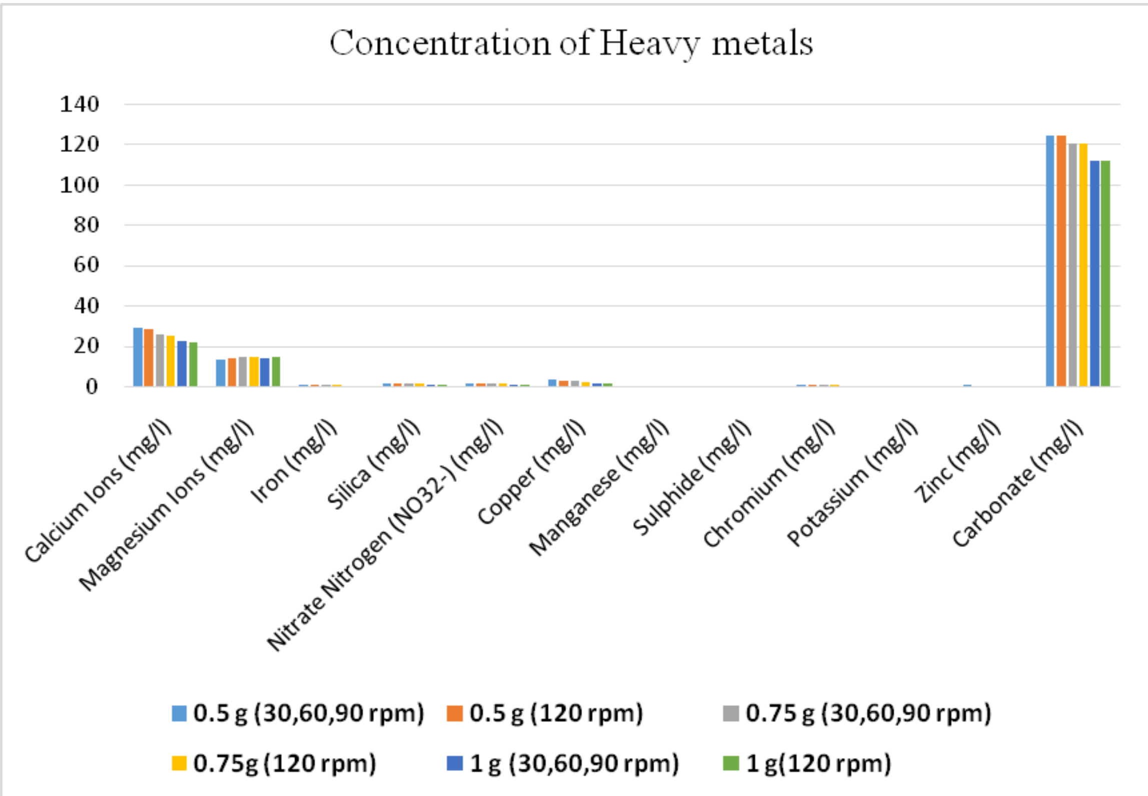

Fig. 4. The concentration of heavy metals in Idominasi wastewater following treatment with neem leaf adsorbent

Table 11. The concentration of heavy metals in Iponda wastewater following treatment with coconut husk adsorbent

Heavy metals	0.5g		0.75g		1 g	
	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm
Calcium Ions (mg/L)	27.2	30.4	35.2	39.2	44	47.2
Magnesium Ions (mg/L)	6	5.5	6	7	7	7
Iron (mg/L)	0.31	0.367	0.402	0.438	0.456	0.473
Silica (mg/L)	0.35	0.384	0.399	0.416	0.431	0.455
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	0.041	0.063	0.071	0.083	0.095	0.11
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0.003	0.008	0.013	0.017	0.022	0.029
Copper (mg/L)	0.014	0.022	0.031	0.038	0.047	0.061
Manganese (mg/L)	0	0	0	0	0	0
Aluminum (mg/L)	0.006	0.009	0.014	0.019	0.023	0.031
Sulphide (mg/L)	0	0	0	0	0	0
Chromium (mg/L)	0.072	0.084	0.093	0.101	0.107	0.113
Potassium (mg/L)	3.96	4.23	4.59	5.1	5.28	5.46
Zinc (mg/L)	0.29	0.38	0.47	0.59	0.66	0.74
Carbonate (mg/L)	92	98	112	126	138	146

Table 12. The concentration of heavy metals in Idominasi wastewater following treatment with coconut husk adsorbent

Heavy metals	0.5 g		0.75 g		1 g	
	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm	30,60,90 rpm	120 rpm
Calcium Ions (mg/L)	23.2	25.6	28	33.6	38.4	41.6
Magnesium Ions (mg/L)	12	11.5	13	11	9.5	9
Iron (mg/L)	0.68	0.75	0.81	0.89	0.94	1.06
Silica (mg/L)	1.531	1.724	1.779	1.865	1.91	1.971
Nitrate Nitrogen (NO_3^{2-}) (mg/L)	1	1.021	1.035	1.05	1.066	1.079
Nitrite Nitrogen (NO_2^{2-}) (mg/L)	0.008	0.011	0.015	0.02	0.031	0.04
Copper (mg/L)	3.21	3.3	3.36	3.411	3.459	3.5
Manganese (mg/L)	0.001	0.001	0.001	0.001	0.003	0.003
Aluminum (mg/L)	0	0	0	0	0	0
Sulphide (mg/L)	0.57	0.62	0.68	0.73	0.81	0.88
Chromium (mg/L)	0.96	1.003	1.007	1.016	1.025	1.033
Potassium (mg/L)	2.8	2.83	2.9	2.95	3.01	3.08
Zinc (mg/L)	0.88	0.95	1.003	1.009	1.014	1.021
Carbonate (mg/L)	106	110	122	128	134	142

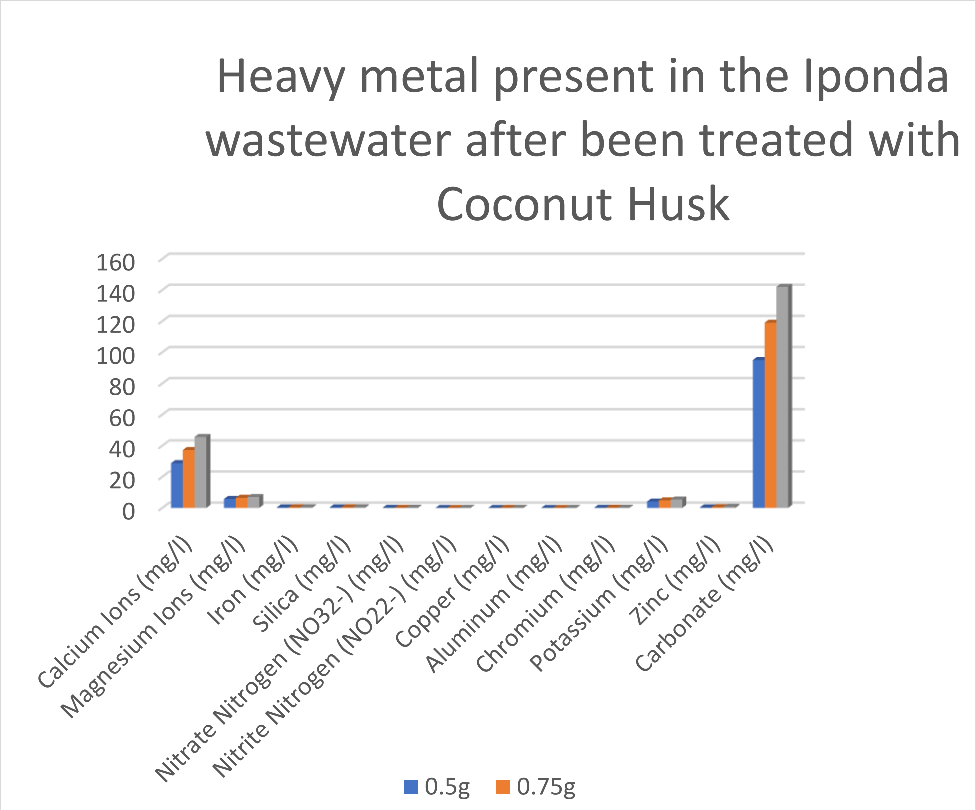

Fig. 5. The concentration of heavy metals in Iponda wastewater following treatment with coconut husk adsorbent

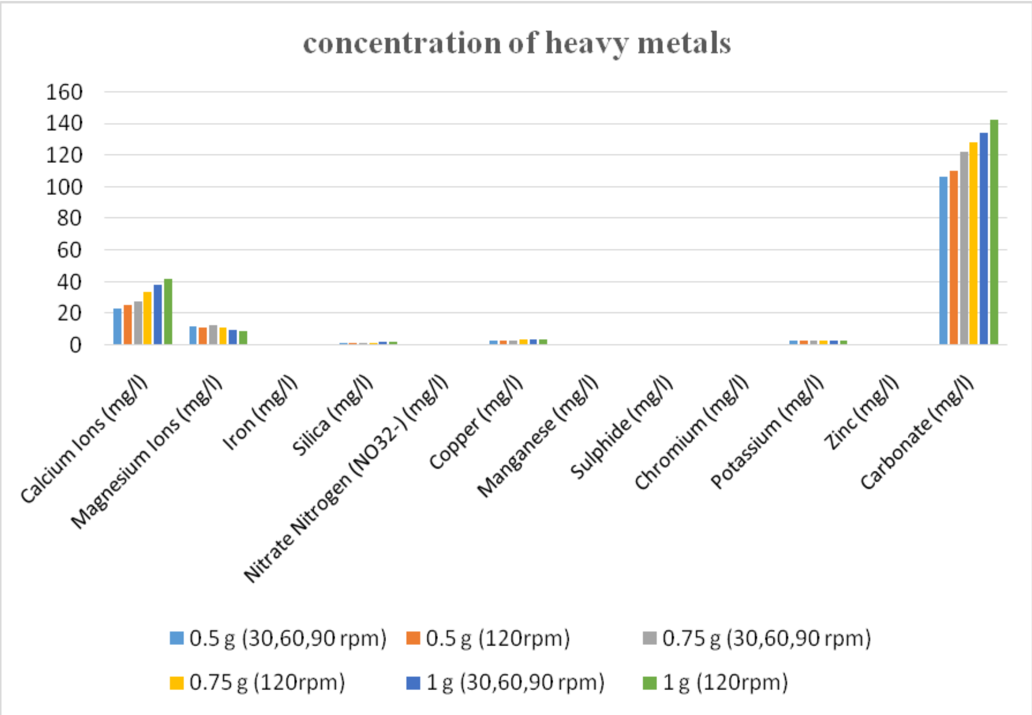

Fig. 6. The concentration of heavy metals in Idominasi wastewater following treatment with coconut husk adsorbent

4. CONCLUSION

The Mining industry plays a major role in the development of the economy of many nations. However, there are some adverse effects attributable to this highly developmental process, especially contamination of the surrounding through the wastewater released to the environment aftermath the mining operations. This study is very relevant and useful within the scientific community, because it has shown how wastewater from abandoned gold mines may be rejuvenated in a way to minimize exposure to hazards in the environment. In addition, this study has shown that adsorbents could be efficiently developed locally and thus making this process to be sustainable. Finally, this study had demonstrated the use of locally available materials and a sorption process to reduce the concentrations of heavy metals and other pollutants in wastewater from abandoned gold mining sites.

This research focused on examining the impact of neem leaf and coconut husk adsorbents on wastewater from two abandoned gold mining sites in southwest Nigeria. The findings demonstrated that both neem leaf and coconut husk adsorbents positively contribute to the bioremediation of Iponda and Idominasi wastewaters. The bioremediation process, involving the neutralization of heavy metals, proves to be highly efficient and effective in wastewater treatment, as evidenced by the results obtained. It is worth noting that the effectiveness of coconut husk as a heavy metal adsorbent may vary based on several factors, including initial heavy metal concentrations, contact time, agitation speed (rpm), and the dosage of coconut husk. Comparatively, the bioremediation process is more effective when employing neem leaf in contrast to carbonized coconut husk. This bioremediation process is applicable to abandoned mining sites, making it valuable for purposes like fish farming or as a water source in the form of a dam for irrigation during the dry season. Additionally, it serves the function of preventing wild animals from inhabiting the area. Further investigations and optimization of the adsorption process are essential to determine the optimal conditions for removing heavy metals using coconut husk.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ajibade F, Ajibade F, Adelodun B, Adelodun B, Lasisi K, Lasisi K, Fadare O, Ajibade T, Ajibade T, Nwogw, N, Sulaymon I, Ugya, A, Ugya A, Wang H, Wang A. Environmental pollution and their socioeconomic impacts., 2021; 321-354.
Available at:https://doi.org/10.1016/b978-0-12-821199-1.00025-0.
2. Zhao G, Li X, Zhu J, Zhao X, Zhang J, Zhai J. Pollution assessment of potentially toxic elements (PTEs) in Soils around the Yanzhuang Gold Mine Tailings Pond, Pinggu County, Beijing, China. International Journal of Environmental Research and Public Health. 2021;18. Available::https://doi.org/10.3390/ijerph18147240.
3. Capparelli M, Cabrera M, Rico A, Lucas-Solis O, Alvear-SD, Vasco S, Galarza E, Shiguango L, Pinos-Vélez V, Pérez-González A, Espinosa R, Moulatlet G. An Integrative Approach to Assess the Environmental Impacts of Gold Mining Contamination in the Amazon. Toxics. 2021;9.
Available::https://doi.org/10.3390/toxics9070149.
4. Lin L, Yang H, Xu, X. Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review. Frontiers in Environmental Science; 2022.
DOI: 10.3389/fenvs.2022.880246
5. Funeka M, Alseno KM, Hlanganani T, Zenixole RT. Mining wastewater treatment technologies and resource recovery techniques: A review. International Journal of Advances in Engineering Management. 2023;5(5):1193-1203.
DOI:10.35629/55252-050511931203.
6. Zahoor A, Mao G, Jia X, Xiao X, Chen JL. Global research progress on mining wastewater treatment: a bibliometric analysis. Environmental Science Advances. 2022;1:92
DOI: 10.1039/d2va00002d

7. Mac´ıas-Quiroga IF, Henao-Aguirre PA., Mar´ın-Fl´orez A, Arredondo-L´opez, SM, Sanabria-Gonz´alez NR. Bibliometric analysis of advanced oxidation processes (AOPs) in wastewater treatment: global and Ibero-American research trends, Environ. Sci. Pollut. Res. 2021;28(19):23791–23811.
8. Dada EO, Ojo DO, Ismail T, AdiamoTI, Akanji SA, Alade AO.Qualitative and Quantitative Analysis of Heavy Metal Contamination in Wastewater from Abandoned Gold Mining Sites in Iponda and Idominasi Areas of Osun State. Science Focus “In Press”; 2024.
9. Ezenwa YO, Osita CO, Hope I. Environmental Aspects of Solid Mineral Resources Development in Nigeria: An Overview. International Journal of Advanced Academic Research. 2020;82-94.
10. Thomas G, Sheridan C, Holm PE. A critical review of phytoremediation for acid mine drainage-impacted environments. Sci. Total Environ. 2022;811.
DOI: 10.1016/J.SCITOTENV.2021.152230.
11. Yaraghi N, Ronkanen AK, Torabi Haghighi A, Aminikhah M, Kujala K, Kløve B. Impacts of gold mine effluent on water quality in a pristine sub-Arctic river. J. Hydrol. 2020;589
DOI: 10.1016/J.JHYDROL.2020.125170
12. Ali H, Khan E, Ilahi I. Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. J. Chem. 2019;1–14.
Available:https://doi.org/10.1155/2019/6730305
13. Samaei S.M., Gato-Trinidad S., Altaee A. Performance evaluation of reverse osmosis process in the post-treatment of mining wastewaters: case study of costerfield mining operations, Victoria, Australia. J. Water Process Eng. 2020;34.
DOI: 10.1016/J.JWPE.2019.101116.
14. Meseldzija S, Petrovic J, Onjia A., Volkov-Husovic T, Nesic A, Vukelic N. Utilization of agro-industrial waste for removal of copper ions from aqueous solutions and mining-wastewater. J. Ind. Eng. Chem. 2019;75:246–252.
DOI: 10.1016/J.JIEC.2019.03.031
15. Briffa J, Sinagra E, Blundell R. Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon. 2020;6(9).
Available:https://doi.org/10.1016/j.heliyon.2020.e04691.
16. Kapahi M, Sachdeva S. Bioremediation options for heavy metal pollution. Journal of Health and Pollution, 2019;9.
Available at :https://doi.org/10.5696/2156-9614-9.24.191203.
17. Zhang W, Zhang H, Xu R, Qin H, Liu H, Zhao K Heavy metal bioremediation using microbially induced carbonate precipitation: Key factors and enhancement strategies. Frontiers in Microbiology. 2023;14.
Available:https://doi.org/10.3389/fmicb.2023.1116970.
18. Chen T., Kim, H., Pan, S., Tseng, P., Lin, Y, Chiang, P. Implementation of green chemistry principles in circular economy system towards sustainable development goals: Challenges and perspectives.. The Science of the total environment. 2020;716L136998.
Available:https://doi.org/10.1016/j.scitotenv.2020.136998.
19. Wale T, Suryavanshi S, Wavare V, Phalke P, Sharmale M. Review on green chemistry. Journal of Drug Delivery and Therapeutics; 2023.
Available:https://doi.org/10.22270/jddt.v13i7.5919.
20. Han H, Wu X, Yao L, Chen Z. Heavy metal-immobilizing bacteria combined with calcium polypeptides reduced the uptake of Cd in wheat and shifted the rhizosphere bacterial communities.. Environmental pollution. 2020;267:115432.
Available:https://doi.org/10.1016/j.envpol.2020.115432.
21. Barclay N, Klotz L. Role of community participation for green stormwater infrastructure development. J. Environ Mgt. 2019;251:109620.
Available:https://doi.org/10.1016/J.JENVMAN.2019.109620.
22. Dada EO, Adeniran PO, Dauda MO, Afolabi TJ, Alade AO. Application of Agricultural Waste for the Adsorption of Pharmaceutical Pollutants In Wastewater: A Review. LAUTECH Journal of Civil and Environmental Studies. 2021;6(1)
DOI:https://laujoces.org/article_download/vol_6_1_2021/Paper%203.pdf.
23. Wang J, Chen C. Biosorbents for heavy metals removal and their future. Biotechnology Advances. 2009;27(2):195-226.

Available:https://doi.org/10.1016/j.biotechadv.2008.11.002

24. Costa W, Bento A, Araújo J, Menezes J, Costa J, Cunha F, Coutinho H, Filho F, Teixeira R. Removal of copper(II) ions and lead(II) from aqueous solutions using seeds of Azadirachta indica A. Juss as bioadsorvent. Environmental research, 2020;183:109213. Available:https://doi.org/10.1016/j.envres.2020.109213.

25. Dada EO, Ojo IA, Alade AO, Afolabi TJ, Amuda OS, Jameel AT. Biosorption of Bromophenol Blue from Aqueous Solution Using Flamboyant (Delonix regia) Pod. Chemical Science International Journal. 2020;29(5):32-50. Available:http://www.journalcsij.com/index.php/CSIJ

26. APHA. Standard Methods for the Examination of Water and Wastewater. 21st Edition, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC; 2005.

27. Kolb, M., Bahadir, M., & Teichgräber, B. Determination of chemical oxygen demand (COD) using an alternative wet chemical method free of mercury and dichromate.. Water Research. 2017;122:645-654 . Available:https://doi.org/10.1016/j.watres.2017.06.034.

28. Dewangan S, Toppo D, Kujur, A. Investigating the Impact of pH Levels on Water Quality: An Experimental Approach. International Journal for Research in Applied Science and Engineering Technology; 2023 Available:https://doi.org/10.22214/ijraset.2023.55733.

29. Jadeja A, Hirpara D, Vekaria L, Sakarvadia H. Assessment of Irrigation Water Quality. Soil Fertility and Nutrient Management; 2021 Available:https://doi.org/10.1201/9781003200239-13.

30. Chen B, Zhao H, Chen S, Long F, Huang B, Yang B, Pan, X. A magnetically recyclable chitosan composite adsorbent functionalized with EDTA for simultaneous capture of anionic dye and heavy metals in complex wastewater. Chemical Engineering Journal; 2019. Available:https://doi.org/10.1016/J.CEJ.2018.08.222.

31. Canlı O, Güzel B, Çetintürk K. Determination of Ethylene-diaminetetraacetic Acid (EDTA) levels in surface waters by high performance liquid chromatography (HPLC)-Ultraviolet/Visible (UV/VIS) detector. 2022 Available:https://doi.org/10.51435/turkjac.1124687.

32. Chatla, A., Almanassra, I., Kochkodan, V., Laoui, T., Alawadhi, H, Atieh, M. Efficient Removal of Eriochrome Black T (EBT) Dye and Chromium (Cr) by Hydrotalcite-Derived Mg-Ca-Al Mixed Metal Oxide Composite. Catalysts; 2022. Available:https://doi.org/10.3390/catal12101247.

33. Lalremsanga H. Estimation of total hardness of water samples by EDTA method; 2021.

34. Eugene RW, Baird RB, Eaton AD. Standard methods for the examination of water and wastewater. Calcium, EDTA Titrimetric method; 2012. Available:www.standardmethods.org

35. Wu D, Hu Y, Liu Y. A. Review of detection techniques for chemical oxygen demand in wastewater. American Journal of Biochemistry and Biotechnology. 2022. Available:https://doi.org/10.3844/ajbbsp.2022.23.32.

36. Pinheiro J, Windsor F, Wilson R, Tyler C. Global variation in freshwater physico-chemistry and its influence on chemical toxicity in aquatic wildlife. Biological Reviews. 2021;96. Available:https://doi.org/10.1111/brv.12711

37. WHO. Guidelines for Drinking- Water Quality. Geneva, fourth edition; 2017. Available:http://www.who.int/water_sanitation_health/publications/drinking-water-qualityguidelines-4- including-1stadde.

38. Luo Y, Yao J, Wang X, Zheng M, Guo D, Chen, Y. Efficient municipal wastewater treatment by oxidation ditch process at low temperature: Bacterial community structure in activated sludge.. The Science of the Total Environment. 2019; 703:135031. Available:https://doi.org/10.1016/j.scitotenv.2019.135031.

39. Nigerian Industrial StandarD NIS-554-2015 Nigerian Standard for Drinking Water Quality 17-20 Available:https://africacheck.org/sites/default/files/Nigerian-Standard-for-Drinking-Water-Quality-NIS-554-2015.pdf accessed on 24/08/2024

40. Afreen N, Mohammad Y, Abdul Q, Yassine E, Viola V, Khan, Sana B. M, Hesam K, Satbir S, Chander P, Yang H, Hussameldin I, Sayed M. Wastewater treatment: A short assessment on available techniques. Alenxandra Engineering Journal, 2023;76:505-516. Available:doi.org/10.1016/j.aej.2023.06.05
41. Edjere O , Adesami B . A Preliminary Study of the Leaching Effect of Phthalate Plasticizers in Sachet (Pure) Water Quality at Ambient Temperature. FUPRE Journal of Scientific and Industrial Research. 2023;2578-1129
42. Saalidong BM, Aram SA, Otu S, Lartey PO. Examining the dynamics of the relationship between water pH and other water quality parameters in ground and surface water systems. PLoSONE 2022; 1-17.
Available:https://doi.org/10.1371/journal.pone.0262117.
43. Mambou NL, Mache JR, Ayiwouo NM, Takougang KS, Abende SRY, Roukaiyatou SO. Physicochemical characterization of mining waste from the betare-oya gold area (East Cameroon) and an Adsorption Test by Sabga Smectite (North-West Cameroon) 2020
DOI: 10.1155/2020/6293819
44. Aniyikaiye TE, Oluseyi T, Odiyo JO, Edokpayi JN. Physico-chemical analysis of wastewater discharge from selected paint industries in Lagos, Nigeria. International Journal of Environmental Research and Public Health. 2019;16 (7):1235.
DOI: 10.1155/2020/6293819
45. Agoro MA, Okoh OO, Adefisoye MA, Okoh AI. Physicochemical properties of wastewater in three typical South African sewage works. Pol. J. Environ. Stud. 2018;27(2):491-499.
DOI: https://doi.org/10.15244/pjoes/74156
46. He W, Zheng S, Chen X, Lu D, Zeng Z. Alkaline aging significantly affects mn(Ii) adsorption capacity of polypropylene microplastics in water environments: Critical Roles of Natural Organic Matter and Colloidal Particles; 2022.
Available:http://dx.doi.org/10.2139/ssrn.4064405
47. World Health Organization. Guidelines for drinking-water quality [electronic resource]: Incorporating 1st and 2nd Addenda, Volume 1: Recommendations, 3rd edn. World Health Organization, Geneva, Switzerland; 2008.
48. Oyekunle D, Cai J, Gendy E, Chen Z. Impact of chloride ions on activated persulfates based advanced oxidation process (AOPs): A mini review. Chemosphere, 2021;280:130949.
Available:https://doi.org/10.1016/j.chemosphere.2021.130949.
49. Lu J, Ma M, Li D, Xu S. Experimental study on chloride ion removal in high-salt wastewater system. IOP Conference Series: Earth and Environmental Science. 2020;495.
Available:https://doi.org/10.1088/1755-1315/495/1/012065.
50. Cheng L, Jiang C, Li C, Zheng L. Tracing Sulfate Source and Transformation in the Groundwater of the Linhuan Coal Mining Area, Huaibei Coalfield, China. International Journal of Environmental Research and Public Health. 2022;19.
Available:https://doi.org/10.3390/ijerph192114434
51. Samaniego J, Tanchuling M. Treatment of small scale gold mining wastewater using pilot-scale sedimentation and Cocopeat filter bed system. Global Journal of Environmental Science and Management. 2019;5:461-470.
Available:https://doi.org/10.22034/GJESM.2019.04.06.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/122347