Removal of Contaminant in Electroplating Waste Water and Its Toxic Effect Using Biosynthesized Silver Nanoparticles

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Abstract

The emergence of industries in developing countries is a rising challenge where the generation of undesirable liquid wastes containing pollutants are discharged into water bodies without adequate treatment. This research investigated the removal of contaminant in electroplating wastewater and its toxic effect using biosynthesized silver nanoparticles. Fresh leaves of *Piliostigma thonningii* were used to synthesize silver nanoparticles (Ag NPs). Dynamic light scattering (DLS), transmission electron microscope (TEM) and fourier transform infrared (FTIR) were used to characterize the produced Ag NPs. The electroplating wastewater was treated using green synthesized silver nanoparticle and subjected to physicochemical analysis using standard methods. The sub-chronic toxicity studies on the blood and liver tissues were carried out. At various conditions of concentration, temperature, pH and time, TEM showed the biosynthesized SNPs (1, 2, 3, and 4) to exhibit different particle size at 50 nm spherical shapes. FTIR revealed the presence of functional groups; -OH, -C = C, -C = O, -C-H and -NO. At different conditions, the SNPs demonstrated at the ability to remove pollutants in the electroplating wastewater with SNP4 displaying a higher affinity. In the toxicity evaluation of SNPs treated wastewater in rats, the heamatological parameters showed no significant influence on some parameters compared to the control group. However, the histopathological examination revealed toxic effects on the liver sections. It can be concluded that the biosynthesized Ag NPs contained functional groups that acts as stabilizing and reducing agent during the synthesis of Ag NPs had the ability to remove contaminant from electroplating wastewater.

1.0 Introduction

Water is one of the most essential resources for the existence of life on earth. To maintain a good and healthy living, hygienic source of water is required by humans and animals for drinking, cooking and other purposes. In countries experiencing population growth and extended drought, there are difficulties accessing clean water as the available sources are diminished (Jameel et al., 2011). The emergence of industries in developing countries is a rising challenge where the generation of industrial liquid wastes containing pollutants of intolerable levels such as heavy metal ions and organic molecules are discharged into water bodies without adequate treatment, environmental monitoring and control causing global concerns. These effluents often maybe consumed and utilization by unsuspecting people leading to serious health complications which may sometimes progress to loss of lives in both human and animals (Bankole et al., 2019; Li et al., 2017).

Electroplating industries are significantly engaged in the growth of technologies which consume and releases large volumes of wastewater. (Upadhyay Contamination of water bodies by electroplating, manufacturing and petrochemical activities are considered as global threats due to the increasing population and demand by people and aquatic organisms for water (Bankole et al., 2017). Electroplating is a harmful cause of ecological pollution resulting in the concentrations of heavy metals found in the largely formed wastewaters. It comprises of deposition of ornamental and shielding layers of metals and/or non-metallic surfaces which are dependent on the kind of technological processes involved (Belova, et al., 2020).

The over-exposure to manganese ions, chlorobenzene and dichlorobenzene produced from steel plants effluents and discharge from industrial chemical factories have been reported to have neurological effects, while the accumulation of nickel ions in the body causes decreased body weight, heart, kidney or liver damage and dermatitis (Ściskalska, *et al.*, 2014). Other health hazards associated with the consumption of polluted water includes impairment of cardiovascular system and reproductive problems caused by Atrazine in runoff from herbicides used on row crops (Pathak & Dikshit, 2011). Lead poisoning and its seepages into natural deposits has been reported to cause a delay in the physical and mental development of infants and children. It has also been attributed to the death of over 500 children in Zamfara state of Nigeria (Lo et al, 2012; Galadima & Garba, 2012). Copper ions are also reported to caused gastrointestinal disturbances, abdominal pains, nausea and vomiting (Pizarro et al., 2001).

Therefore, with the field of Nanotechnology that offers application of materials such as metals, metal oxides and polymers at nano size with higher surface area ratio can be employed in various field (Khan et al., 2019). There are some properties that make nanoparticles attractive as sorbents which includes; their larger surface area compared to bulk particles and their potential to sorb and bind with different types of surfaces and contaminants in wastewater, some of which may be toxic to living tissues (Šileikaitė et al., 2006). Among all the nanoparticles, silver nanoparticles (Ag NPs or nanosilver) are at the pull of research because of their novel physical, compound and organic characteristics contrasted with their large scaled counterparts (Sharma *et al.*, 2009). Ag-NPs display wide range of bactericidal and fungicidal activities that has made them prominent in different scope such as plastics, cleansers, glues, nourishment etc. (Garcıa-Barrasa *et al.*, 2011; Fabrega et al., 2011; Dallas et al., 2011).

The cost and toxicity associated with the chemical method has encouraged the use of biological method for silver nanoparticle synthesis (Ahmad et al., 2003). Previously, *Piliostigma thonningii* leave have been use to synthesised silver nanoparticle and applied to the purification of simulated waste water (Shittu *et al.*, 2017). Therefore, this study is aim at investigating the ability of the synthesised silver nanoparticle for removing contaminant in electroplating waste water and the toxicological effect on experimental rats.

2.0 Materials And Methods

2.1 MATERIALS

2.1.1 PLANT SAMPLE

Fresh leaves of *Piliostigma thonningii* were collected from military Barracks Minna Niger State, Nigeria.

2.1.2 WASTE WATER

Waste water was obtained from Electroplating section of scientific equipment development institute (SEDI) Minna, Niger state, Nigeria.

2.1.3 EXPERIMENTAL ANIMAL

Experimental animals were obtained from the Department of Biochemistry, Federal University of technology, Minna

2.2 METHODS

2.2.1 Plant sample preparation

Fresh leaves of *Piliostigma thonningii* were collected from the plant was identified at in the Department of Plant Biology, Federal University of Technology Minna, Nigeria. The voucher number is FUT/PLB/FAB/001. The leaves were washed with distilled water, and air dried at room temperature to prevent the destruction of thermo labile constituent of the plant by direct sun rays. The leaves were then milled into coarse powder. Twenty-five (25 g) of the powdered leaves of *P. thonningii* was weighed and transferred into a 1000 ml conical flask containing 500 ml distilled water. It was mixed properly and then boiled for 25 minutes. The filtrate was used for further studies (Shittu *et al*., 2017).

2.2.2 Biosynthesis and characterization of silver nanoparticles

Silver nanoparticle was produced as previous reported by Shittu *et al*., (2017). Aqueous extract of *P. thonningi* (5 ml) was added to 95 ml of aqueous solution of 1.25 mM Ag NO_3 and heated with stirrer at 65°C for 60 min. To improve the biosynthesis of Ag NPs, the following factors were considered; silver nitrate ($AgNO_3$) and leaf extract concentrations, temperature, pH and time (Table 1). The formed brown coloured nanoparticles were collected and characterized using UV-1800 Shimadzu spectrophotometer with peak range of 200-700nm. and Zetasizer 3000 (Malvern Instruments, UK) was used to determine the diameter or distribution of the Ag NPs by dynamic light scattering (DLS). Transmission Electron Microscope (TEM) was carried out to assess the shape and size of the silver nanoparticles (Ag NPs). While, the functional group of reducing agent was assessed by fourier transform infrared spectroscopy (FTIR).

Table 1
Experimental design for biosynthesis of Ag NPs

Factors	Conc. Of $AgNO_3$ (mM)	Conc. of leaf extract (ml)	Temperature (°C)	pH	Time (min)
SNP1	1.00	7.5	75	6.5	60
SNP2	1.00	7.5	65	7.0	60
SNP3	1.13	9.22	70	7.5	55
SNP4	1.00	7.5	65	6.5	50

2.2.3 CHARACTERIZATION OF THE WASTERWATER

The electroplating wastewater was subjected to characterization immediately after collection. Total dissolved solid (TDS), electrical conductivity (a multi-parameter analyser C3010), dissolved oxygen (DO) (DO_2 Meter), pH (a multi-parameter analyser C3010), alkalinity, the total amount of nitrate, nitrite, sulfate, phosphate, ammonium, chloride, cyanide, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were determined using American Public Health Association (APHA) method (Gupta et al., 2012). All these analyses were carried out at Regional Water Quality laboratory, Federal Ministry of Water Resources, Minna.

2.2.4 ELECTROPLATING WASTE WATER

The waste water was diluted 10ml to 1 litre of distilled water to make 1:100 dilution factor. One gram of the functionalized silver nanoparticles and PEG was added to 15ml of the diluted waste water and shake at 200 rpm for 60 minutes and then filtered with filter paper.

2.2.5 DETERMINATION OF LD_{50}

The lethal dose ($LD_{50)}$ of the silver nanoparticles was determined by oral administration to experimental rats per Locks method (Lorke, 1983)

2.2.6 DETERMINATION OF SUB CHRONIC TOXICITY

Twenty-eight rats weighing between (165 ± 25.37) g were divided into 7 groups. Each consist of four (4) rats per group.

Group 1: served as the normal control group and received distilled water

Group 2: served as the vehicle control group and received polyethylene glycol in distilled water.

Group 3: served as silver nanoparticle group received oral 300mg/kg body weight of nanoparticle treated water based on the LD_{50} for 28 days.

2.2.7 Blood and Liver collection

On the 29th day, rats were fasted overnight and anesthetized by ether and sacrificed. Blood was collected in EDTA tubes for haematological evaluation. The liver was preserved in 70% formalin for histopathology study.

2.2.8 Histological examination

The tissue sections for histological examination were prepared by standard embedding and H-E staining protocol under light microscope. The photomicrographs were captured at 100× using the software Presto Image Folio package.

2.3 Statistical Analysis

Values are represented as mean ± standard error of mean. The data were statistically analysed using one-way analysis of variance (ANOVA) and (Mahajan, 1997). Data from the histopathological test were compared with their respective controls and differences at p 0.05 were considered significant.

3.0 Results And Discussion

3.1 Biosynthesis and characterization of silver nanoparticles

In this study, the successful biosynthesis of Ag NPs using *P. thonningii* leaf extract was confirmed by the development of brown colour. The observed colour change proposes that the interactions of silver ions with *P. thonningii* leaf extract led to its reduction and formation of Ag NPs (Kambale et al., 2020). This explains the origin of the surface plasmon resonance absorption in the particles which was confirmed by UV-Vis absorption spectroscopy as previously reported by Shittu *et al*., (2017). Some of the phytochemicals confirmed in *P. thonningii* leaf extract are flavonoids, phenols and terpenoids, which have been considered as likely bio-reducing and stabilizing agents for the synthesis of Ag NPs (Afreen et al., 2020; Shittu *et al*., 2017).

3.2 Particle size of silver nanoparticles synthesized from aqueous leaf extract of *Piliostigma thonnigi*

The biosynthesized silver nanoparticles size for various condition is shown in Fig. 1. The conditions give different particle size range of 59.64 to 114.20 dnm. Whereas the most intense particle size is 114.20 dnm. Concentrations of metal salts, reaction time, solution temperature and reducing agent have been reported to influences the size of particle synthesized (Šileikaitė et al., 2006).

3.3 Transmission Electron Microscopy (TEM)

In this study, the shape and size of the biosynthesized Ag NPs were analysed using TEM (Fig. 2). The micrographs displayed at 50 nm magnification suggests that all SNPs were spherical shaped. SNP1, SNP2 and SNP3 were smaller sized and showed properties of aggregation with the exception of SNP 4 which were of various sizes and loosely bound. The properties of nanoparticles depend on size, shapes, their interaction with stabilizers, surrounding media and preparation methods (Khodashenas and Gborbani 2019; Haruta, 2004).

3.4 Functional group composition of Biosynthesized Silver Nanoparticle

The FT-IR spectra for SNP1, SNP2, SNP3 and SNP4 are shown in Fig. 3. They indicate the presences of different functional groups in *P. thonningii* leaf extract that acted as stabilizing and reducing agent during the synthesis of Ag NPs (Fig. 5). The FTIR spectra identified the major strong peaks at range 2882 to 2893 and 3457 to 3493cm^{-1}; the minor peaks at range 1468 to 1480 and 1653 to1662 cm^{-1}. The peak at range 3457 to 3493cm^{-1}corresponds to -O-H stretch which can be assigned to H-bonded -O-H stretch and hydroxyl groups. These peaks maybe attributed to presences of polyphenolic groups. In addition, the peaks at range 1468 to 1480 and 1653 to 1662 cm^{-1} indicates the existence of -C = C or -C = O stretching vibration (alkenes) and -NO asymmetric stretch (nitro compounds). While the peak at 2882 to 2893 cm^{-1} maybe attributed to the C-H alkane functional group. The FTIR results verified the participation of the plant phytochemicals (polyphenols, alkene, carboxyl) on the surface of the AgNPs through the -OH, C-H, C-O functional groups (Ali et al., 2018).

3.5 WATER ANALYSIS

3.5.1 Untreated and Treated wastewater Profile

Table 2 shows the result of some water analysis parameter which serve as indicators of water quality for industrial electroplated water before and after treatment with PEG and biosynthesized silver nanoparticle (SNPs). PEG and biosynthesized SNPs have the highest percentage removal of heavy metals in electroplating waste water. There was significant reduction in the total dissolved solid (TDS) concentration of the silver nanoparticle treated waste water, ranging from pH of 0.83 to 5.98, dissolved oxygen of 4.0 to 4.60, total alkalinity of 100 to 1000 as compared to before treatment.

The cleanliness of water and the quality of the purification systems are directly associated to the TDS. TDS are the entire quantity of salts, minerals, charged ions and/or metals dissolved in a given volume of water (Jameel et al., 2011). The initial concentration for TDS in the wastewater was 191 500 nevertheless, when Ag NPs were added, the efficiency of removing pollutants was observed to drop with SNP4 having a significantly 95.91% reduction. The conductivity of water is dependent on its TDS, that is the concentration of dissolved ions in the water as the purer the water the weaker its conductivity (Jameel et al., 2011). This result explains the corelation between the TDS and conductivity result for SNP4. High concentrations of chloride were observed in the untreated wastewater. When chlorine is introduced into the water, the quantity of electrolytes in the water upsurges, which in turn elevates the conductivity of the water which can be harmful to plants and aquatic life (Bankole et al., 2017).

pH is a chemical constituent of wastewater which has a direct influence on toxicity and solubility of compounds, survival of marine organisms and also affecting the treatability of water. During the wastewater treatment with Ag NPs, the pH increased from 0.83 to 5.98. The pH changes observed in the treated wastewater may be due to their exposure to Ag NPs (Madela, 2018). Variations of pH can stimulate aggregation of particles by altering their surface charge properties and under acidic conditions, accumulation and sedimentation do not occur (Li et al., 2013).

Dissolved oxygen is the amount of oxygen present in water with low levels being an indicator of pollution. It is one of the significant factors in determining water quality, contamination control, treatment process and the key life sustaining component for aquatic organisms. The quantity of dissolved oxygen in the SNPs treated water improved compared to the untreated water. The Ag NPs may have enhanced the process of oxidation in the waste water by providing oxygen (Rubel et al., 2019).

Biochemical oxygen demand is the volume of oxygen essential for the biodegradation of organic matter in the presence of oxygen. The high Biochemical oxygen demand is as a result of high level of organic contamination of water which reduced after treatment with Ag SNPs due to the adsorption of organic matter on the surfaces of Ag NPs. The loosely bound nature of SNP4, increased its available surface area and capacity to adsorb organic matter compared to the aggregated SNPs 1, 2 and 3 which may have reduced the surface area given that the particles will be interacting with each other leading to a decreased adsorption efficiency. Ag NPs have been reported to possess adsorbent properties for which decreased size produces increased surface area in relation to its shape. (Qi et al., 2021; Uma *et al.,* 2018).

Chemical oxygen demand is the quantity of the organic matter susceptible to oxidation by strong chemical oxidant into carbon dioxide and water. This parameter may help to determine the impact of organic pollution in water and estimate the effectiveness of the treatment process. Liquid wastes comprise of different oxidizable chemical waste materials which can reduce chemical oxygen demand in the water (Rubel et al., 2019; Saleh, 2015).

Nitrogen is significant in the generation and control of water contamination. Nitrogen in the process of conversion of ammonia to nitrite and nitrite to nitrate leads to oxygen and alkalinity consumption (Sperling, 2007). The content of ammonia before treatment was 1500 and it reduced to a range of 4-10mg/L. high concentrations of ammonia is poisonous to fishes.

Nitrate and nitrite in the wastewater were 89,100 and 5.7 mg/L and decreased to 990 and 1.60 respectively after treatment with SNP3 having the least nitrite concentration. The presence of nitrate in the wastewater samples is due to its usage as a corrosion inhibitor in industrial process water (Bankole et al., 2017).

Furthermore, phosphorus is present in the form of phosphate and pH dependent in polluted waters. They exist either bound to soluble organic matters or to particulate organic materials in wastewater and essential for the growth of microbes and a high concentration in water bodies can lead to eutrophication (Sperling, 2007). phosphate was significantly reduced in all SNPs treated water compared to the untreated wastewater.

Industrial electroplating involves process which produces effluents with high levels of heavy metals, cyanides (5–20) % and sulphate complexes (Naveen et al., 2011). The cyanide content in the waste water was reduced after treatment from 180 mg/L to 8.00mg/L which still falls below the required limit.

The concentration of sulfate was reduced from 18,000 in the untreated effluent to a range of 730–1,030 mg/L in the SNPs treated groups. However, these values were still over the WHO permissive limit of 250mg/L (WHO, 2003).

Table 2: Wastewater and treated electroplating wastewater using green synthesized silver nanoparticle

Parameter	Wastewater Before treatment	PEG	SNP1	SNP2	SNP3	SNP4
TDS (mg/L)	191,500	16,744	11,736	9,376	8,520	7,825.6
Conductivity (µS/cm)	286,000	25,000	17,520	14,000	12,720	11,680
Dissolved Oxygen (mg/L)	4.0	4.18	4.27	4.40	4.45	4.60
pH	0.83	3.39	4.97	5.46	5.67	5.98
Chloride (mg/L)	5,500	1,079.2	818.4	1,227.2	780.8	1,004.0
Sulphate (mg/L)	18,000	1,900	1,030	900	790	730
Total Alkalinity (mg/L)	100	1,050	1,000	1,000	1,000	480
Nitrate (mg/L)	89,100	2,180	1,730	1,470	1,200	990
Nitrite (mg/L)	5.7	2.96	2.72	3.20	1.60	1.84
Ammonium (mg/L)	1500	40	10	7	5	4
Cyanide (mg/L)	180	18.0	14.0	11.0	9.50	8.00
Phosphate (mg/L)	278	83.9	59.1	50.3	48.1	40.4
Calcium (mg/L)		528	1,232	1,372.8	1,056	950.4
Biochemical Oxygen Demand (mg/L)	4.0	19.6	18.5	18.9	14.4	1.00
Chemical Oxygen Demand (mg/L)	109,400	12,260	11,600	11,870	9,010	120
Total Bacteria Count (cfu/1mL)	0	0	0	0	0	0

TDS= Total dissolved solid

3.6 Haematological Studies

The haematological profile displays valuable information on cellular elements, extent of damage to the blood and their therapeutics response to treatments (Gara et al., 2021; Etim et al., 2014). Table 3 shows the haematological parameters of administration of treated water with PEG and biosynthesized Ag NPs. The Ag NPs treated water had no observable influence on Hb, PCV, MCHC, RBC, neutrophils and lymphocytes compared to the control group. This outcome suggests that the factors (concentration of $AgNO_3$, concentration of leaf extract, temperature, pH and time) considered during the synthesis of the silver nanoparticles (SNP1, SNP2, SNP3 and SNP4) used in treating the water (Ag NPs treated water) may have not repressed the synthesis of blood cells and as well not increased or suppressed the immune response of treated animals (Gara et al., 2021).

RBCs accounts for majority of the blood cells and any intrusion leads to either an increase or decrease of packed cell volume. Hb and PCV are involved in the transport of nutrients and oxygen to tissues to enhance the release of energy for the body (Isaac *et al.*, 2013). Granulocytes are cells in the innate immune system that helps to fight microbial infections, respiratory complications, allergies and have the ability to generate antibodies by phagocytosis (Shittu et al., 2021; Okunlola et al., 2015).

MCV, MCH, MCHC are valuable parameters used in diagnosing different types off anaemia and monitoring toxicity that may affect blood or alter the health status of an animal (Etim *et al.*, 2018). The MCH result obtained suggests that the SNP1 and SNP2 treated water may have slightly transformed the oxygen carrying capacity of haemoglobin in the red blood cells to the tissues (Manisha *et al.*,2013).

Blood platelets are known to play a major role in blood clotting. The factors involved in the synthesis of SNP4 may have influenced its high platelet concentration proposing that in an event of injury to the animals, the process of blood clotting may be shortened and excessive blood loss avoided (Etim et al., 2014).

Table 3
Haematological Profile of Oral Administration of silver Nanoparticle Treated Water after 28days

GRP	Hb(g/dL)	PCV(%)	MCV(Fi)	MCH(pg)	MCHC(g/dl)	R BC×(10)%	PLC×(10)%	TWBC	Neutrophils (N)	Lymp(L)	Eos(E)
C	10.26± 0.55^{a}	31.3 ± 1.45^{ab}	52.3± 0.33^{bc}	17.0 0± 0.00^{b}	32.3 ± 0.33^{abc}	6.30± 0.11^{ab}	147.0± 15.58^{a}	5.00 ± 0.63^{cd}	9.50± 4.33^{ab}	65.67± 9.82^{ab}	24.33± 5.48^{abc}
SNP1	9.30± 3.05^{a}	29.6± 9.52^{ab}	49.3± 0.33^{bc}	15.0± 0.00^{a}	31.0± 0.57^{ab}	6.26± 1.81^{ab}	321.0 ± 135.7^{abc}	2.20 ± 0.64^{a}	8.40± 2.94^{a}	65.33± 8.37^{ab}	25.66± 5.48^{abc}
SNP2	7.70± 0.40^{a}	25.0 ± 0.00^{a}	51.0 ± 0.57^{abc}	16.00 ± 0.57^{a}	30.6± 1.45^{ab}	4.90 ± 0.05^{a}	284.0 ± 82.92^{ab}	5.73± 0.37^{cd}	10.53± 4.64^{ab}	73.66± 6.64^{b}	15.66 ± 2.02^{a}
SNP3	9.13± 1.36 a	27.3± 3.75ab	48.33 ± 0.88a	16.66± 0.33b	33.3± 0.33bc	5.73± 0.78ab	206.0± 69.85a	4.63 ± 0.60abc	13.00 ± 5.77ab	56.67± 8.56ab	28.33± 2.60bc
SNP4	11.63± 1.84 a	34.0± 5.77ab	49.0± 0.00ab	16.6± 0.33b	34.3± 0.33c	6.86± 1.18ab	505.0± 2.08c	7.30± 1.27d	12.33± 3.76ab	69.33± 4.09b	17.33± 0.33a
PEG	13.00± 0.75a	42.66± 2.60b	54.0± 2.88c	16.66± 0.88b	30.33± 0.33a	8.10± 0.00b	473.6 ± 26.84bc	5.86± 0.69cd	3.33 ± 0.33a	78.66± 2.33b	17.66 ± 2.02ab

Each value are of three determinations ± SEM Values are significantly different in comparison with control ($p < 0.05$).

3.7 Histopathological Studies

The control group sections of the liver stained by H & E is show in Fig. 4A were given distilled water as compared to nanoparticle treated water (SNP1–4) (Fig. 4B - E). The architecture of the liver was preserved with congested blood vessels in control group. This is similar to report by Shittu et al., 2021 who reported intact hepatocytes after treatment with silver nanoparticles. while Ag NPs treated water (SNP1–4) (Fig. 4B - E) shows thickened hepatic, thrombosed central vein and mild inflammation around the blood vessels. While PEG treated water showed thrombosed and recanalized blood vessels and focal areas of necrosis Fig. 4F.

The Ag NPs in the circulating blood can dissolve silver ions constantly leading to its leak from the vessels inducing the immune cells in the peripheral tissues causing inflammatory reactions (Guo et al., 2015). Ag NPs have been reported to accumulate in organs with abundant vascular networks and exposure to Ag NPs can intensify thrombotic risks (Guo et al., 2015). Bian et al., (2019) reported that Ag NPs induced thrombosis at ≥ 10 mg/kg by promoting procoagulant activation of RBCs. Studies have shown that recanalization is part of the physiological process in the veins of thrombus remodelling. Possibly, the presence of thrombus releases inflammatory mediators which together with the process of recanalization may damages venous valves (Brandão et al., 2014).

Congestion in the liver is the accumulation of blood vessels resulting from either increased hepatic venous pressure or decreased hepatic blood flow (Gara et al., 2021). Ag NPs can induce necrotic cell death as a result of its deposition in the liver leading to alterations seen as necrosis (Rezaei et al., 2018).

4.0 Conclusion

From the study, it was observed that under various conditions of concentration, temperature, pH and time, TEM showed the biosynthesized SNPs (1, 2, 3, and 4) to exhibit different particle size of around 50 nm with spherical shapes. FTIR revealed the presence of functional groups; -OH, -C = C, -C = O, -C-H and -NO. At different conditions, the SNPs demonstrated at the ability to remove pollutants in the electroplating wastewater with SNP4 displaying a higher affinity. In the toxicity evaluation of SNPs treated wastewater in rats, the heamatological parameters showed no significant influence on Hb, PCV, MCHC, RBC, neutrophils and lymphocytes. However, the histopathological examination revealed toxic effects on the liver sections.

Declarations

Competing Interest

The Authors have no competing interests.

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Figures

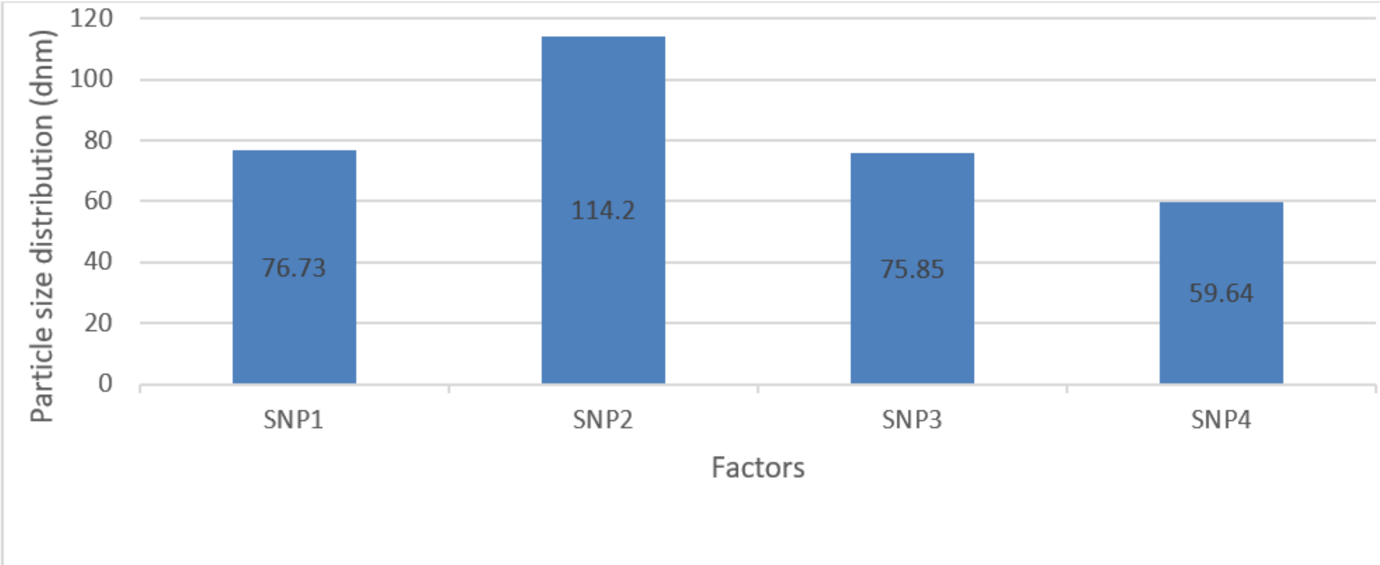

Figure 1

Particle size diameter of the biosynthesized silver nanoparticle.

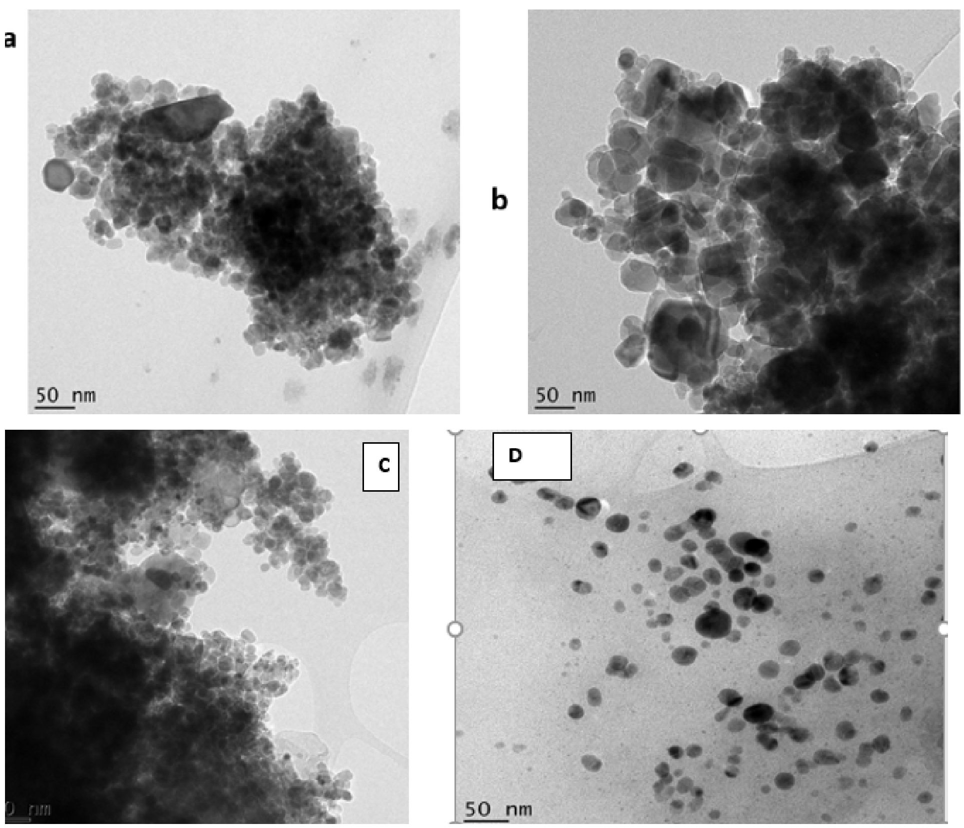

Figure 2

TEM of bio-synthesized silver nanoparticle A (SNP1); B (SNP2) C (SNP3); D (SNP4)

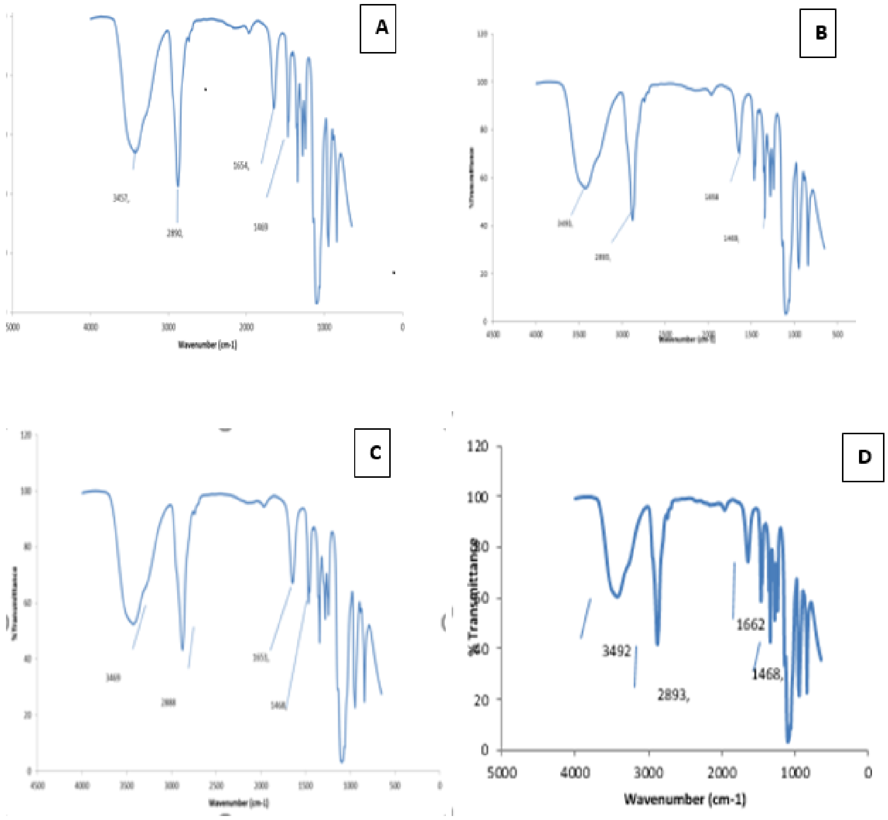

Figure 3

FT-IR spectral of biosynthesized Silver Nanoparticle A (SNP1); B (SNP2) C (SNP3); D (SNP4)

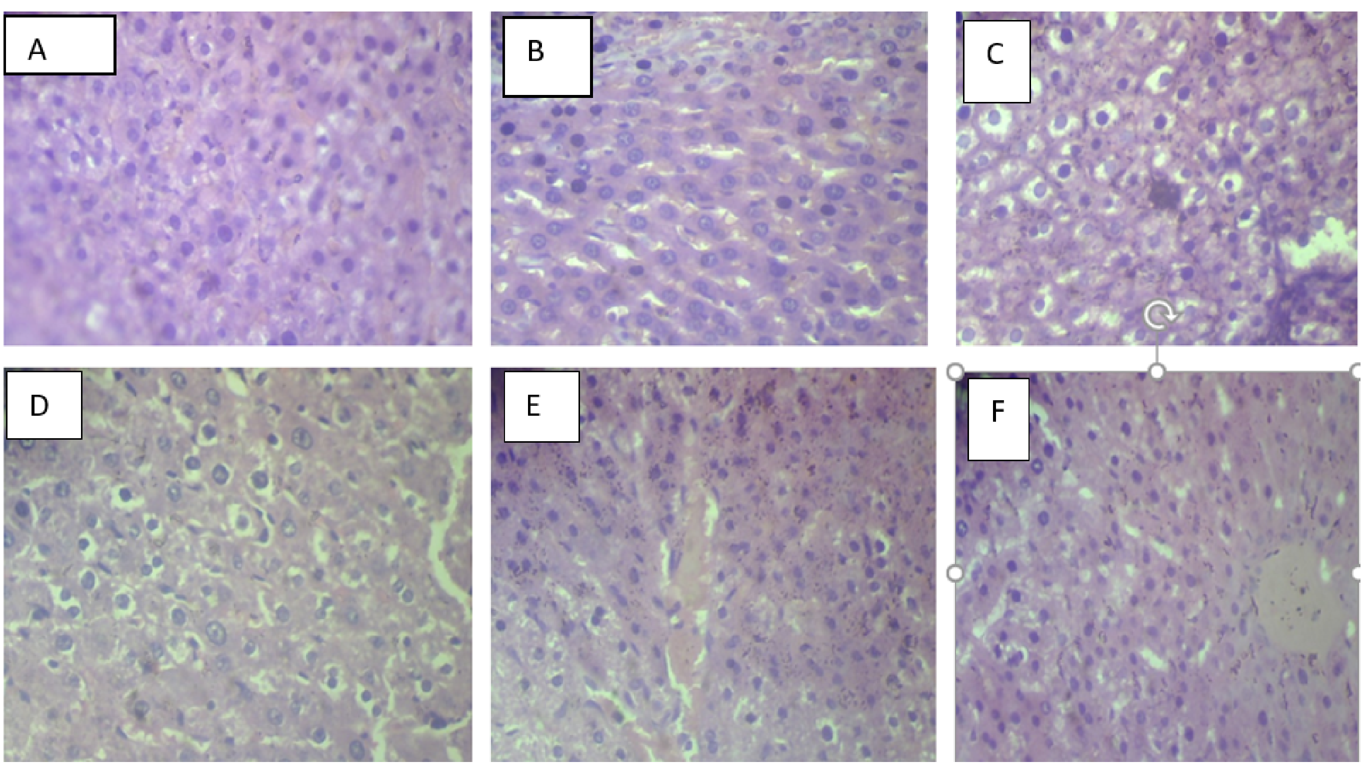

Figure 4

Effect of Ag NPs and PEG treated water on histopathological sections of liver in rats. Hematoxylin and eosin stain at x100 magnification.

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Figure 5

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