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Muritala Adeniyi Olusola
Federal University of Medicine and Medical Sciences
Olufemi Stephen Odulaja
Olabisi Onabanjo University
Tawakalt Adeola Olusola
Ajayi Crowther University
Emmanuel Damilare Olatunji
Federal University of Agriculture
Taofeeq Folawiwo Adeleye
Olabisi Onabanjo University
Emmanuel Olurotimi Ogunbiyi
Bowen University
Saliu Alao Amolegbe
Federal University of Agriculture
Caroline Avosuahi Akinremi
caakinremi@funaab.edu.ng

Federal University of Agriculture

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Enhanced Cd(II) ion Chemosensing by a Curcumin Extract -Silver nanoparticle Nanocomposite: Synthesis, Optimization and Characterization

Muritala Adeniyi Olusola[a], Olufemi Stephen Odulaja[b], Tawakalt Adeola Olusola [c], Emmanuel Damilare Olatunji[d], Taofeeq Folawiwo Adeleye[b], Emmanuel Olurotimi Ogunbiyi[e], Saliu Alao Amolegbe[d], Caroline Avosuahi Akinremi[d]

[a] Department of Chemistry, Faculty of Sciences, Federal University of Medicine and Medical Sciences, PMB 2009, Abeokuta, Ogun State, Nigeria.
Federal University of Medicine and Medical Sciences, Abeokuta

[b] Department of Chemical Sciences, Olabisi Onabanjo University, PMB 2002, Ago-Iwoye, Nigeria

[c] Department of Chemical Sciences, Ajayi Crowther University, PMB 1066, Oyo Town, Oyo State. Nigeria

[d] Department of Applied Chemistry, College of Physical Sciences, Federal University of Agriculture, PMB 2240, Abeokuta, Ogun State, Nigeria.
[e] Department of Industrial Chemistry, Bowen University, PMB 284, Iwo, Osun State, Nigeria.

*Corresponding Author: caakinremi@funaab.edu.ng (C. A. Akinremi)

Highlights

- Curcumin extract was used as a green platform to fabricate AgNP nanocomposite.
- Curcumin's Cd(II)-sensing response was considerably improved by AgNP incorporation.
- The detection of Cd(II) demonstrated a low detection limit.
- Cd(II) recognition and signal transduction were improved by synergistic curcumin–AgNP interactions as nanocomposite.
- Selective detection of Cd(II) in water was made possible by the nanocomposite.

Abstract

The detection of Cadmium (Cd^{2+}), a toxic heavy metal of global concern commonly absorbed and accumulated by plants and animals in water are expensive with high technology. This study focused on preparing chemosensor for Cd^{2+} that will be user and eco-friendly using readily available raw materials. The synthesis of chemosensor for Cd^{2+} in water using silver nanoparticles functionalized curcumin (AgNps) solution was developed. The developed chemosensor ($Ag^{0}Cur$) was monitored and characterized using Ultraviolet-Visible spectroscopy (Uv-Vis), Fourier Transform Infra-Red spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray spectroscopy (EDX). The chemosensor interacted spontaneously when in contact with the Cd^{2+} ion in water, the Cd^{2+} solution transformed to orange while those of Pb^{2+} and Hg^{2+} to yellow. The FTIR results revealed the interaction of the AgNps solution with curcumin in acetonitrile. Change was observed in the intensities of the absorption peaks of the nanocomposite compared with the peaks observed in curcumin. The Uv-Vis analysis further confirmed the interaction between the nanoparticle solution and the curcumin extract. The absorption observed around 239 nm and 420 nm in the curcumin extract shifted to lower wavelength of absorption around 235 nm and 357 nm when AgNps interacted with curcumin solution. The chemosensor SEM micrograph showed nano-fibre shapes which was found to be sensitive and selective on Cd^{2+} in water to a detection limit of 0.0013 ppm compared with Hg^{2+} and Pb^{2+}, however, its sensitivity and selectivity was pH dependent in basic media. The chemosensor also tested positive on industrial effluent from foundries.

Keywords: Curcumin, silver nanoparticles, nanocomposite, heavy metals and chemosensor

1.0 INTRODUCTION

The adverse effect of heavy metals has been a serious concern to chemists, biochemists and environmental scientists to mention few. The heavy metals such as cadmium (Cd), mercury (Hg), lead (Pb) are highly poisonous and they occur naturally in traces in the environment. Cadmium (Cd) is one of the heavy metals that occurs naturally in the environment, it is a highly toxic metal [1]. Cd is one of the most important heavy metals with vital threats over food chain [1,2]. It is also a known fact that heavy metals contaminate the soil through the use of phosphorus fertilizers, Cd-containing sludge and manures, wastewater, electric power stations, metal industries urban traffic and cement industries [3]. The consumption of plants grown in Cd-containing soils allow it get into the food chain which consequently creates serious threat to human and animal health. Uncontaminated soils have cadmium concentrations of generally below 0.5 mg kg^{-1}, while the value in contaminated soils may be as high as 3.0 mg kg^{-1} depending on soil parent material [2]. The integrity of numerous ecological cycles can be jeopardized by heavy metal ions from manufacturing sources, which can also have a detrimental effect on human health thru the food chain and drinking water. Increased concentrations of well-known toxic metals like lead, mercury, arsenic, and selenium are often found in aqueous wastes [4].

In order to ensure that the concentrations of heavy metals are not high enough to pose a threat to human health, the detection of these ions is crucial to environmental science [5]. Sensor has been described as a chemical indicator that produces a chemical response in the presence of an analyte in form of colour changes or electronic transitions. It is commonly defined to be a chemical indicator in an instrument that

produces a signal indicative of the presence of an analyte [6]. The special qualities of nanoparticles have drawn a lot of interest in nanosized metal, their potential applications have been implored in magnetics, optics, catalysts and biomedicine. Inorganic and organic pollutants, metal ions inorganic, and toxins have all been studied in the past decade using nanoparticles as functional probes [7]. Nanoparticles typically measuring 1 to 100 nm in size exhibit distinctive characteristics that are not found in bulk-size materials. This is primarily due to the significant physical confinement of electrons or holes within the nanoparticles [7]. Noble metal nanoparticles, such as silver, are used in colorimetric sensing applications. These applications depend on a quantitative coupling between metal nanoparticles, which causes a dramatic change in photonic properties thru aggregation mechanisms, resulting in color changes [8]. Silver nanoparticles show promise as naked eye-distinguishable readout sensors because of their extremely high extinction coefficients and the ability to alter their plasmonic band depending on size and distance [9]. Curcumin(1,7-bis-(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione) a natural component of the rhizome of turmeric (*Curcuma longa*) [10], has recently attracts the attention of researchers due to its unique ability to work through so many pathways with its astonishing antioxidant, anti-inflammatory, chemopreventive, antiangeogenic, antiviral and antibacterial properties [11]. A naturally occurring organic ligand with intrinsic fluorescence and electrocatalytic properties is curcumin (diferuloylmethane). It can provide sensitive signals like fluorescence, luminescence, ultraviolet absorption shifts, and electrochemical data because of keto-enol tautomerism [12]. Curcumin-colored cellophane test strips have been used in literature to detect pH and carbon (IV) oxide gas [13]. The goal of this research project is to use silver nanoparticles to increase curcumin's activity in order to detect the presence of cadmium ions in water

because sample preparation is expensive and requires a certain procedure in standard instrumentation usage.

2.0 MATERIALS AND METHODS

2.1 Sample collection

Turmeric rhizome was obtained from Osiele market in Abeokuta, Ogun State and identified at FRIN, Ibadan, Oyo State. It was blended and airdried into particle size of 2 mm sealed in a polythene bag for further usage.

2.2 Materials

All aqueous solutions were prepared from analytical grade chemicals using distilled water. Sodium borohydride was purchased from Sigma Aldrich, U.S.A and used without further purification. Other reagents used are silver nitrate ($AgNO_3$), Sodium hydroxide (NaOH), Ethanol, Soluble starch, Lead chloride, Cadmium sulphate etc. which was obtained from the Chemistry Department, Federal University of Agriculture, and Abeokuta. Uv-vis spectrophotometer used was CE2000 series Uv-vis spectrophotometer of the Central Research Laboratory of The Polytechnic of Ibadan and T29 Uv-vis spectrophotometer of the Chemistry Department, Federal University of Agriculture, Abeokuta, Ogun State. The Atomic Absorption Spectroscopy (AAS) and SEM-EDX (Q930R ES series) operating at an accelerated voltage of 15 kV was used at the Chemistry Department and Mechanical Engineering Department, Covenant University in Ogun State. FTIR was used at the University of Ibadan, Central Laboratory, Oyo State.

2.3 Extraction of Curcumin from Turmeric (*Curcuma longa*)

Turmeric rhizomes sample (Fig. 1a) was weighed out (100.0 g). This was peeled, then grounded in a mortar and air dried at room temperature for 8 days. The dried turmeric was then further ground to obtain the powder. The procedure adopted by Kim et al.

[14], was then used for the extraction of curcumin from the turmeric powder with slight modification. 8 g of turmeric powder was dissolved in 125 mL of acetonitrile which was then refluxed at 80 º C for 25 minutes. After the extraction the solid residues was filtered out using sintered glass and the cleared solution was used as prepared. Further purification of the extracts was avoided to achieve efficient sensitization.

2.5 Synthesis of silver nanoparticle

The method of Kamal, et al. [15] was adopted for the synthesis of silver nanoparticles with little modification (Fig. 1b). Silver nitrate salt (0.034 g) was dissolved into 200 mL of distilled water, 100 mL of the solution was transferred into a beaker in a water bath. After 10 minutes, 2 mL of 1% sodium hydroxide solution was added drop wisely to the hot silver nitrate solution and the solution changed to brownish colour, which later become clearer with brown particles underneath.

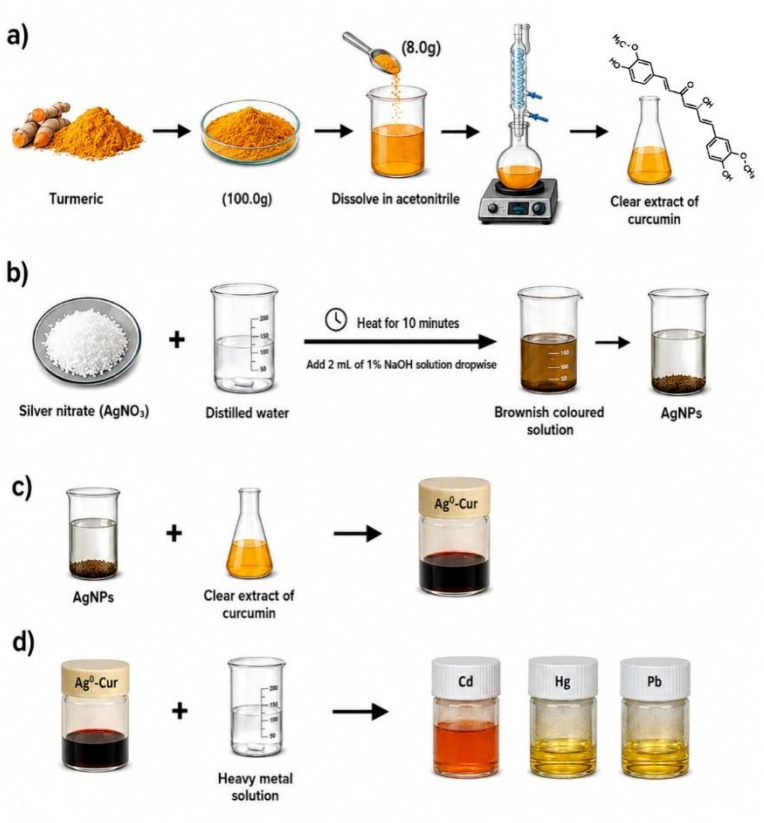


Fig. 1 Schematic synthesis of zerovalent silver curcumin nanocomposite

2.6 Study of the Interaction of Nanometals with Curcumin extract in Acetonitrile

To 20.0 mL of metal nanoparticles solution in 100 mL standard flask, 1.0 mL of the curcumin extract in acetonitrile solution was added to the metal nanoparticles solution which was then shaken vigorously. A cuvette was filled with the mixture and the Uv-Vis spectrum was obtained using Uv-Visible spectrophotometer (T29 Uv-Vis), in order to determine the concentration that will give the maximum absorption band. The solution filled in the cuvette was not discarded which was transferred back into the mixture in the standard flask. 1.0 mL of the curcumin extract was added to the mixture again and the process was repeated till 20 mL of curcumin solution was used [16].

2.7 Synthesis of zerovalent nanocomposite sensor

2.7.1 Synthesis of zerovalent silver-curcumin nanocomposite sensor

Zerovalent silver-curcumin nanocomposite was prepared (Fig. 1c) by measuring 7 mL of silver nanoparticles solution into a clean beaker, in which 20 mL of the curcumin extract in acetonitrile was measured and added to the silver nanoparticles solution. The solution gave a reddish- brown colour upon the addition of curcumin extract.

2.8 Preparation of standard solutions of cadmium, lead and Mercury

2.8.1 Preparation of standard solution of cadmium

Accurately weighed 1.854 g of cadmium sulphate was dissolved into 20 mL of distilled water in a beaker, which was then transferred into 1000 mL standard flask and make up with distilled water to the mark to give 1000 ppm of cadmium solution. Different concentration of 0.1,1,5 and 100 ppm was then prepared from the stock.

2.8.2 Preparation of standard solution of mercury

Exactly 0.135 g of mercuric chloride was weighed and dissolved in 10 mL of diluted nitric acid (1:10) and distilled water was added to make exactly 100 mL and 100 ppm mercuric solution.

2.8.3 Preparation of standard solution of lead

Exactly 1.598 g of lead nitrate was weighed and dissolved in 10 mL of diluted nitric acid (1:10) and distilled water was added to make exactly 1000 mL of 100 ppm.

2.9 Application of the Chemosensor Ag^0Cur

2.9.1 Batch experiment

Batch experiment was carried out on different concentrations of Cadmium, prepared from a stock solution; which include a blank (0 ppm), 0.1 ppm, 1 ppm, 5 ppm, 100 ppm of Cadmium. From the standard solution were measured 5 mL into a separate test tubes and 0.1 mL of each of the sensors was added to each and monitored using the Uv-Vis spectrophotometer.

2.9.2 Analysis of Water Sample

Water effluent was collected from steel mining industry at Odogunyan road, Ikorodu, Lagos, Nigeria. 100 mL of the water sample was filtered twice using Whatman filter paper. The presence and amount of cadmium in the water filtered was predetermined using AAS, without the digestion of the water sample.

2.9.3 Selectivity Studies

5 mL of each of the 100 ppm of cadmium, mercury and lead solutions prepared was measured into different test tubes, in which 0.1 mL of zerovalent silver-curcumin nanocomposite was added to each of the solutions separately (Fig. 1d). The solution in each of the test tubes changed spontaneously upon the addition of the sensor, in which the colour of the solution containing cadmium changed from colourless to orange and the solutions spiked with mercury and lead changed from colourless to yellow colour after added separately to the heavy metals spiked solution. Uv-Vis spectrophotometer (CE 2000) was then used to monitor the electronic transition.

2.9.4 Application of chemosensor on water effluent from steel mining industry

100 mL of water effluent from steel mining industry was filtered twice using whatman filter paper. 5 mL of the filtrate was measured into a clean test tube and 0.1 mL of zerovalent silver-curcumin nanocomposite was added to the water solution in the test tube, the water changed immediately upon the addition of the nanocomposites to orange colour from colourless solution which was the same as when it was added to standard solution of cadmium. The Uv-Vis spectrophotometer (CE 2000) was then used to monitor the interaction.

2.10 Characterization of the products

2.10.1 Uv-Vis Spectrophotometer

The Uv-Vis spectrophotometer (CE 2000) was used to monitor the electronic transition of the curcumin extract in acetonitrile, zerovalent silver-curcumin nanocomposite in which the cuvette was filled with the solutions separately and the Uv-Vis spectrum was obtained.

2.10.2 Fourier Transform Infra-Red Spectrometer

The prepared zerovalent silver-curcumin nanocomposite solution was air dried for 7 days and a little amount of each of the dried nanocomposites were mixed with KBr which was then load into the FTIR spectrometer using KBr disc and the FT-IR spectrum was obtained with Shimadzu FT-IR in the 4000 – 350 cm^{-1} region.

2.10.3 Scanning Electron Microscopy with EDX

The zerovalent silver-curcumin nanocomposite was exposed to air for 8 days in order for the solvent in each of them to evaporate. SEM micrograph was obtained using Q930R ES series, Scanning Electron Microscopy.

3.0 RESULTS AND DISCUSSION

3.1 Physical screening of the Products

Preliminary study of the interaction of curcumin with the nanoparticle solution was carried out and the Uv-Vis spectrophotometer was used to determine the concentration of the nanoparticle solution in curcumin with maximum absorbance and it was revealed that 1:3 of the silver nanoparticles solution to curcumin gives the maximum absorbance. On the addition of the nanocomposite to the cadmium ion in aqueous solution in order to determine the detection limit of the chemosensor and also to verified the selectivity on some selected heavy metals such as lead and mercury. It was observed (Fig. 2) that the solution of cadmium transformed to orange while those of mercury and lead transformed to yellow instantaneously and this can be as a result of the strong chalcophile affinities and mobility of cadmium to oxygen in carbonate compared to lead and mercury.

3.2 Spectral Properties of the Products

3.2.1 Uv-Vis Spectral Result

The curcumin extract showed an intense absorption band (Fig. 3) at around 239 nm and 420 nm which can be associated with $n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$ transition with absorbance of 0.2 which was similar to the previous studies [14]. The electron excitation from $n \rightarrow \pi^*$ was as a result of the presence of C=O stretch and the $\pi \rightarrow \pi^*$ transition, resulted from the conjugated di-enes which is responsible for this band in the visible region. The zerovalent silver-curcumin nanocomposite showed wavelength of absorptions around 235 nm and 357 nm in which each has absorbance of 0.4. The Uv-Vis spectra revealed that there is an interaction between the metal nanoparticles solution and the curcumin extract in acetonitrile, this leads to shift in the wavelength of absorption to

higher energy with increase in absorbance of each of the zerovalent metal-curcumin nanocomposite. This was as a result of the optical and electronic properties of the nanoparticles solutions that functionalised the curcumin. The spectra in (Fig. 4), shows the interaction of zerovalent silver-curcumin nanocomposite in cadmium ion aqueous solution upon the addition of the silver- based nanocomposite at pH of 11.5. It was observed that there was no too much distinct shift in the wavelength of absorption upon the addition of the silver- based nanocomposite but there was increase in the absorbance of the cadmium ion containing solution as the concentration of the cadmium ion in aqueous solution increases. It was also observed that the absorbance decreased drastically when the nanocomposite was added to the distilled water (DW) that was not spiked with cadmium ion solution. The observations can be as a result of ligand to metal charge transfer, due to the interaction of the cadmium ion with the oxygen atoms in the curcumin and this can result to a shift in absorption band. The curcumin act as a ligand in which the cadmium ion coordinated between the curcumin in the zerovalent metal-curcumin nanocomposites which induced the aggregation of the zerovalent metal-curcumin nanocomposite. The Uv-Vis spectra (Fig. 5) revealed the studies of the interaction of the zerovalent silver-curcumin nanocomposite with cadmium, mercury and lead ion in aqueous solution at 100 ppm. It was observed that only the cadmium ion in aqueous solution gives absorption band around 350 nm upon the addition of the zerovalent silver-curcumin nanocomposite which was not observed in mercury and lead ion containing solutions. This shows that the synthesized zerovalent metal-curcumin nanocomposite is highly selective on cadmium ion compared to mercury and lead ions which resulted to a shift in the plasmonic absorption peak and this was not observed in lead and mercury ions due to the

aggregation of the metal nanocomposites by the cadmium ion as a result of its ionic radius [17].

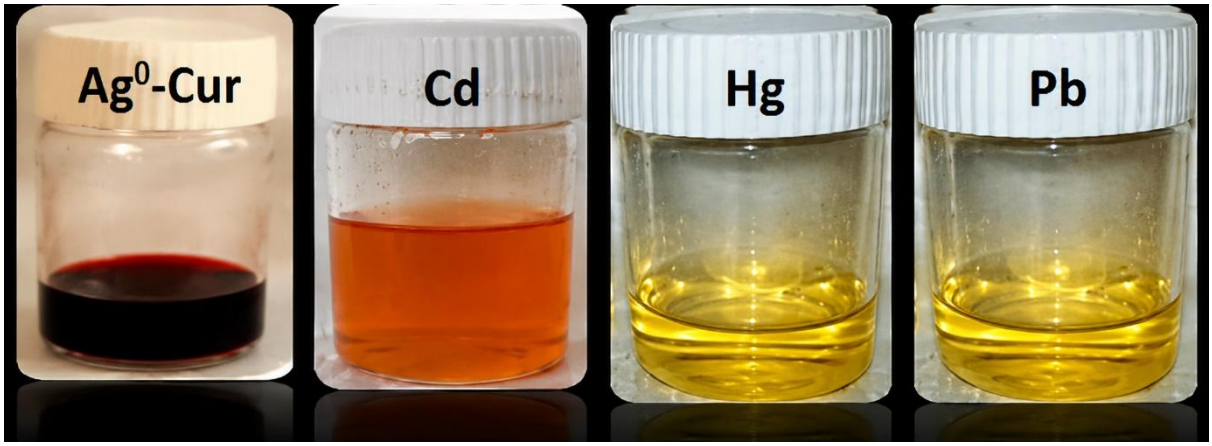


Fig. 2 Physical Screening of zerovalent silver-curcumin nanocomposite (Ag^0 Cur)

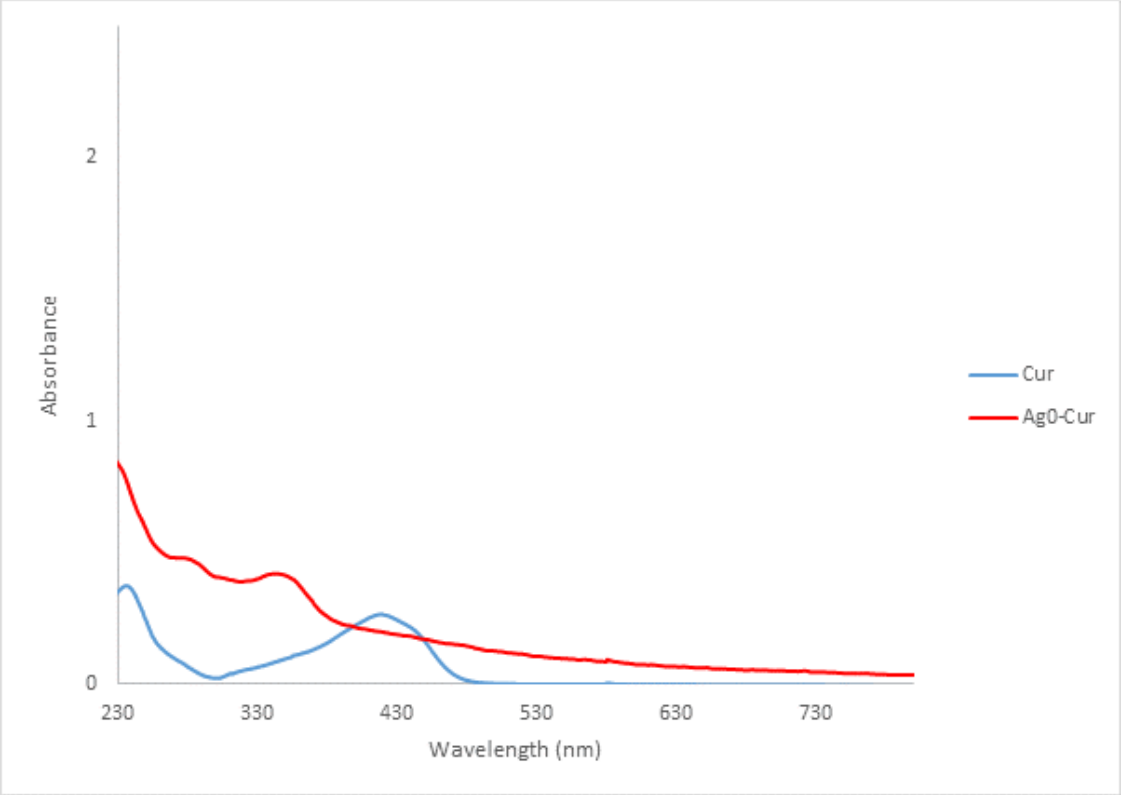


Fig. 3 Uv-Vis spectra of curcumin, Ag^0-Cur

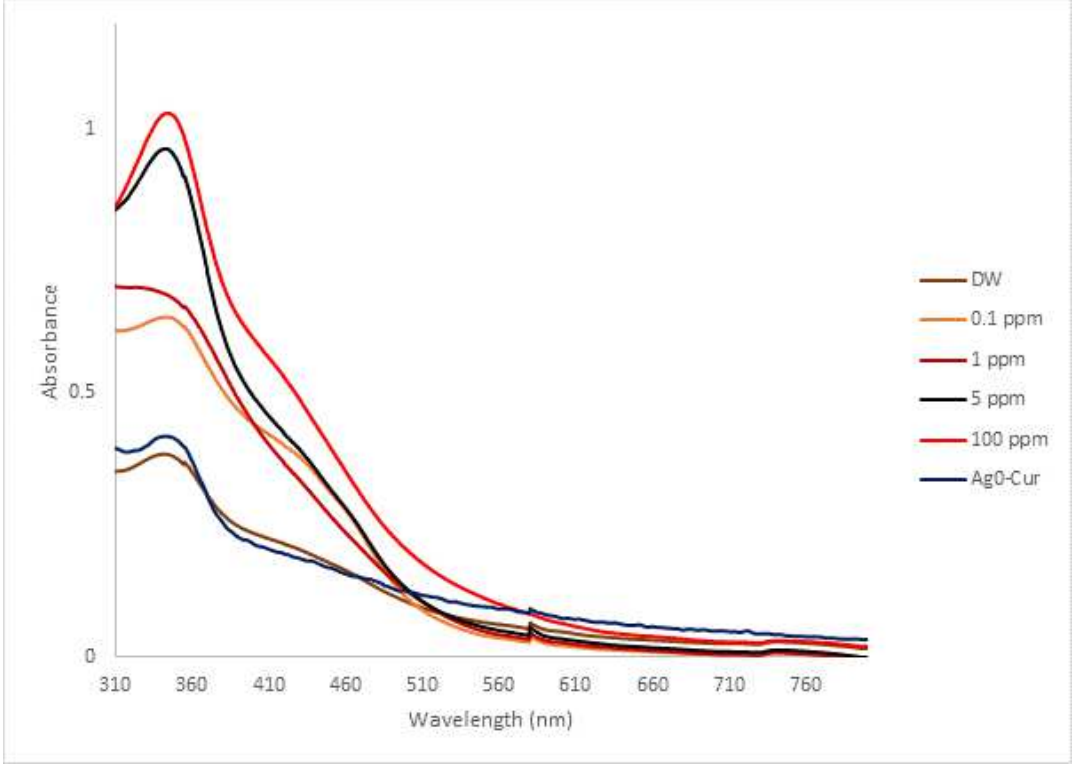


Fig. 4 Zerovalent silver-curcumin at varying concentration of cadmium ion in aqueous solution

The spectra (Fig. 6), revealed the Uv-Vis spectra of the effect of pH on zerovalent silver-curcumin nanocomposite. The zerovalent silver-curcumin nanocomposite was effective only at the basic medium. It was also revealed from the spectra that as the pH increases the absorbance also increases, but the absorbance increased most at the pH of 12 and 14. This shows that the zerovalent metal-curcumin nanocomposites gives optimal detection for cadmium ion in aqueous solution at higher pH, this can be as a result of the deprotonation of the curcumin on zerovalent metal-curcumin nanocomposites.

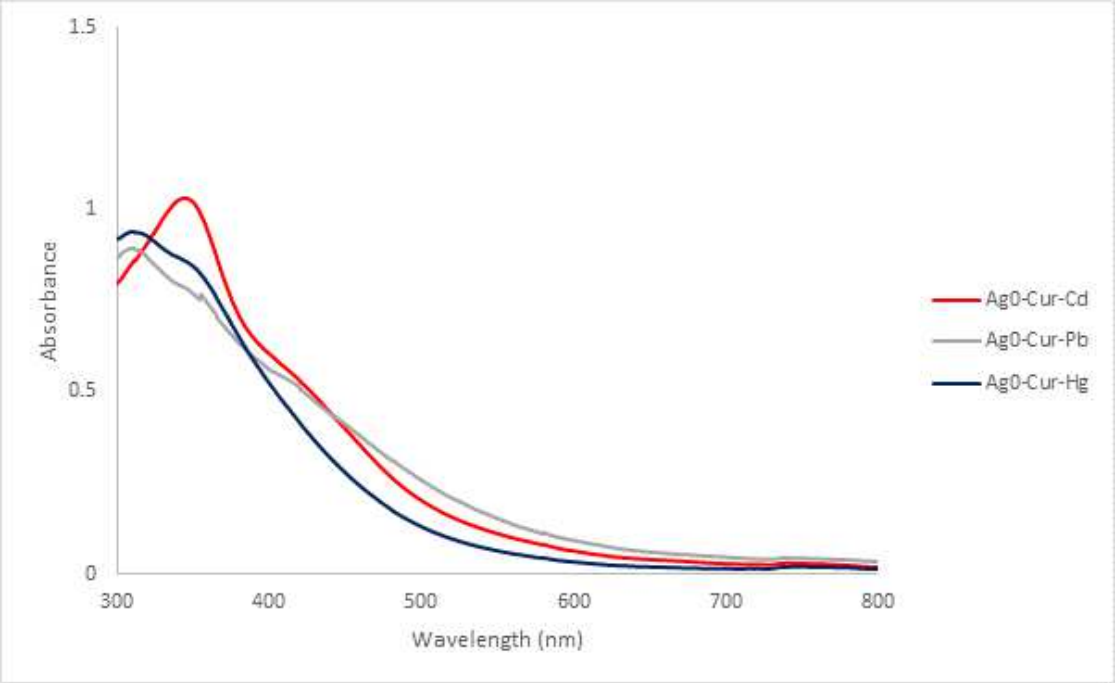


Fig. 5 Zerovalent silver-curcumin on 100 ppm of cadmium, mercury and lead ion in aqueous solution

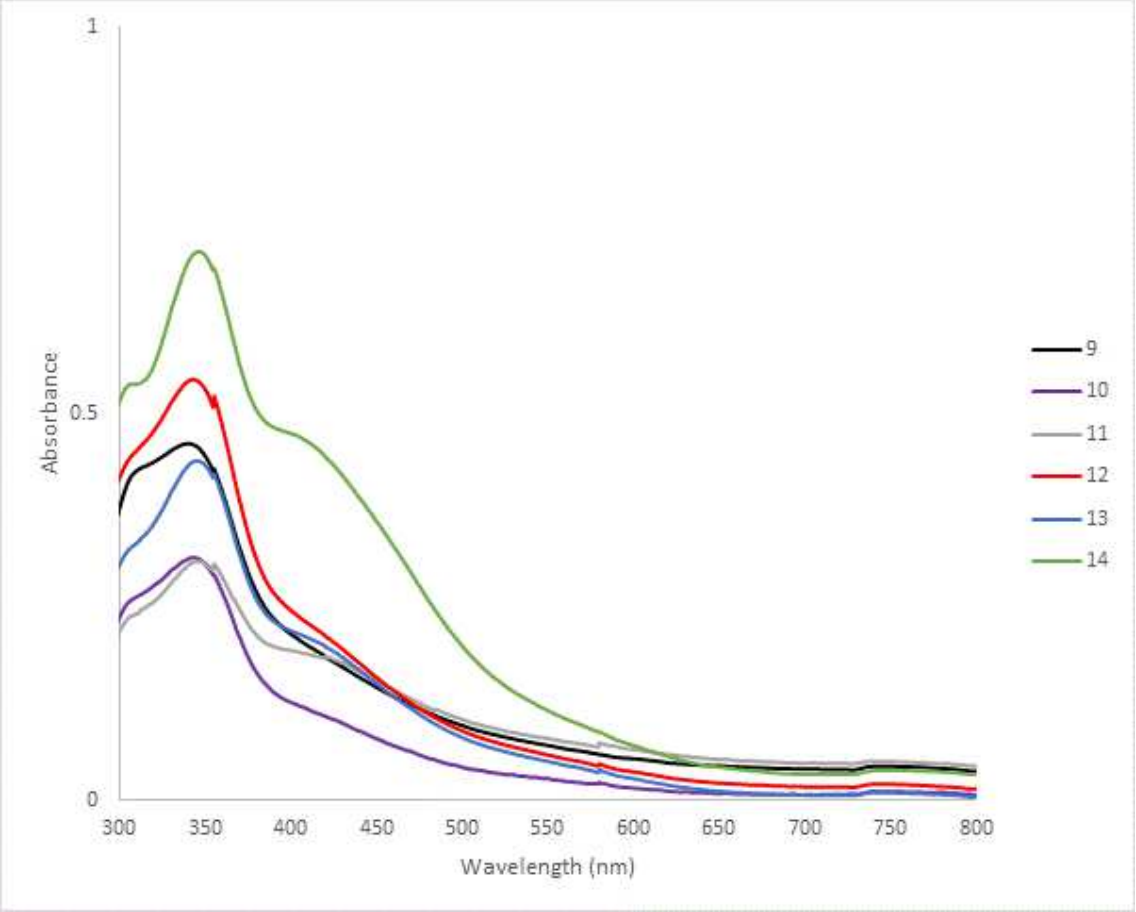


Fig. 6 Zerovalent silver-curcumin nanocomposite with 0.1 ppm of cadmium ion in aqueous solution at pH range of 9 -14

3.2.2 Fourier Transform Infra-Red Spectrometer Result

The spectrum of curcumin in the present study (Fig. 7) was in line with the earlier report by Priyadarsini [18]. The curcumin in acetonitrile shows broad band at 3543 cm^{-1} which was assigned to the vibrations of the free hydroxyl-group of phenol (Ar-OH). The bands at 746 and 918 cm^{-1} were attributed to the bending vibrations of the C-H bond of alkene groups ($RCH=CH_2$). An intense band at 1634 cm^{-1} assigned to the vibration of the carbonyl bond (C=O) which was not accompanied by a small shoulder and this was attributed to the enol form of curcumin. The bands at 1378 and 1039 cm^{-1} corresponding to the vibrational mode of C−O elongation of the alcohol and phenol groups confirmed the extraction of curcumin from turmeric. The band at 1438 cm^{-1} is attributed to the C=C of alkene, in which all the peaks observed conforms to the literature report [18,19] of curcumin.

The FTIR spectra of curcumin and its zerovalent silver-curcumin nanocomposite was shown in the (Fig. 8), the bands around 1634 and 1438 cm^{-1} corresponds to the stretching vibrations of C=O and C=C of curcumin, in which there is no shift in the C=O stretch of the zerovalent silver-curcumin nanocomposite which shown absorption around 1634 cm^{-1} and a blue shift in the absorption band of C=C stretch of the zerovalent silver-curcumin nanocomposite which shifted to 1450 cm^{-1}. The absorption band of the curcumin around 1378 and 1039 cm^{-1} was attributed to the vibrational mode of C-O shifted to 1361 and 1065 cm^{-1} in the zerovalent silver-curcumin nanocomposite. The FTIR spectra (Fig. 9) shown the spectra of the zerovalent silver-curcumin nanocomposite compared to the zerovalent silver -curcumin nanocomposite in cadmium solution. The absorption band of C=O stretch and the symmetric vibrational mode of C-O for the zerovalent silver-curcumin nanocomposite shifted to 1641 and 1108 cm^{-1} which shows that there is a coordination between the cadmium

and the oxygen i.e. Ligand to Ligand Charge Transfer (LLCT) which could be as a result of electron density from the oxygen lone pair of electrons [20]. The asymmetric vibrational mode of the C-O for zerovalent silver-curcumin nanocomposite disappeared completely during the interaction of the sensor with the cadmium ion in aqueous solution in which this confirmed that the sensor detects the presence of cadmium in water through aggregation.

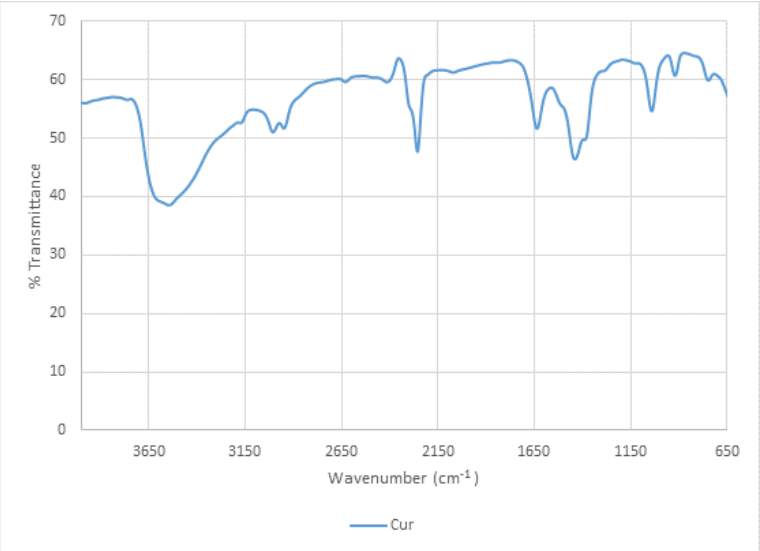


Fig. 7 FTIR spectra of curcumin extract in acetonitrile

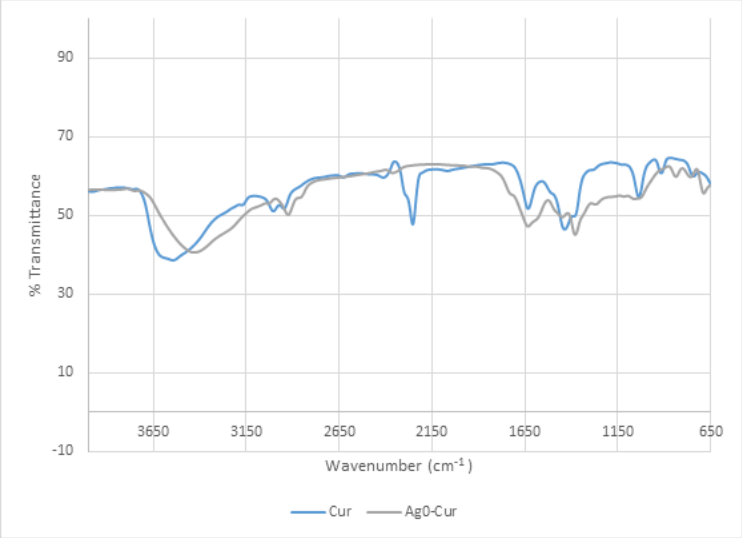


Fig. 8 FTIR spectra of curcumin and zerovalent silver-curcumin nanocomposite

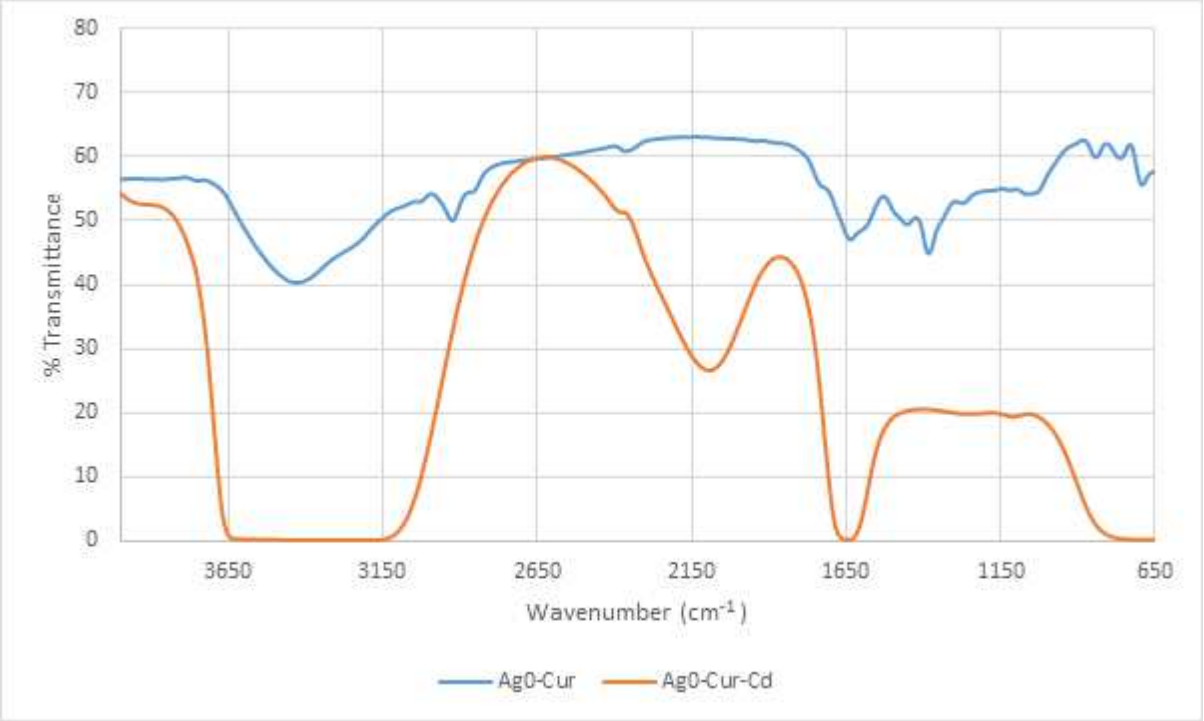


Fig. 9 FTIR spectra of zerovalent silver-curcumin and zerovalent silver-curcumin in cadmium ion solution

3.2.3 Results on Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray Analysis (EDX)

The SEM micrographs and EDX of the synthesized zerovalent silver-curcumin nanocomposite was shown (Fig. 10). The SEM image (Fig. 10a), revealed the morphology of the zerovalent silver-curcumin nanocomposite which forms a nano fibres shape and this can be due to the presence of the curcumin compared to the literature morphology of silver nanoparticles reported by Halder et al. [21]. The EDX spectrum (Fig. 10b), shows the EDX spectrum spot profile of zerovalent silver-curcumin nanocomposite which shows a strong and two weak peaks of silver including strong peaks for oxygen and carbon which could be as a result of the curcumin extract used. The peaks spotted 3 keV confirmed the presence of silver [22], nitrogen and carbon were also spotted, in which the sodium peak at 2 keV could be as a result of the reducing agent used during the synthesis of the nanoparticles solution and the presence of nitrogen peaks was as a result of the acetonitrile used for the extraction

of the curcumin from the turmeric rhizomes. The percentage composition of each element present in the zerovalent silver-curcumin nanocomposite was shown (Fig. 11), which revealed the composition of the elemental component as silver (0.2 %), nitrogen (1.9 %), carbon (19.9 %), sodium (29.3 %) and oxygen (48.7 %). The result shows that silver element has the lowest weight percentage due to the chemical reduction while oxygen has the highest weight percentage which could be as a result of the presence of oxygen in the ligand and stabiliser used.

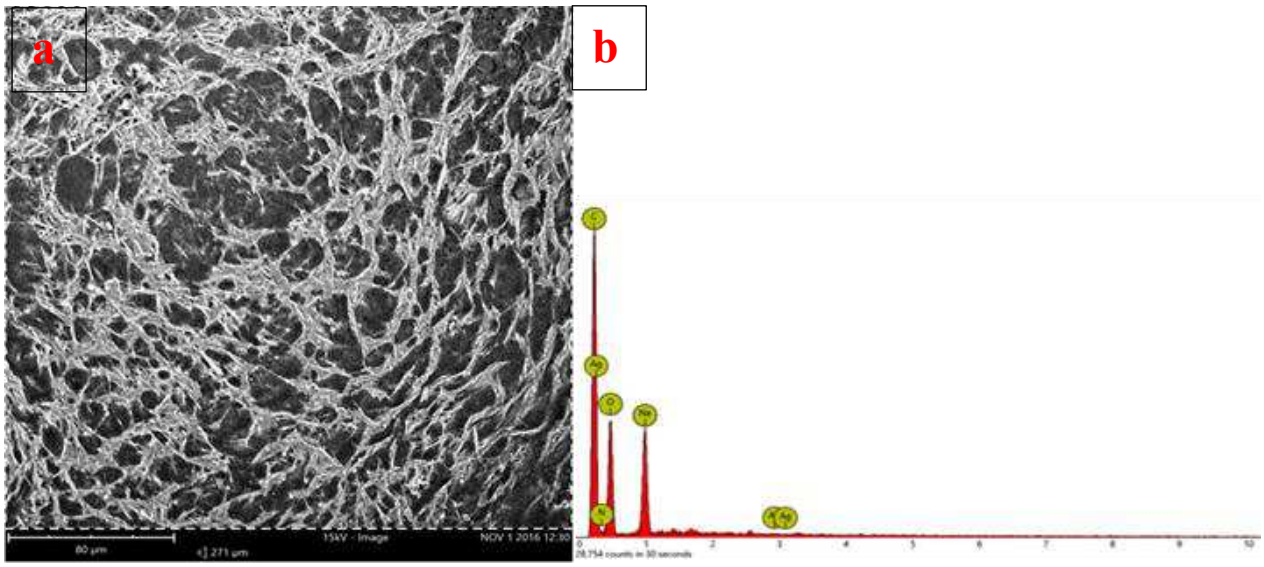


Fig. 10 Zerovalent silver-curcumin nanocomposite **(a)** SEM micrograph **(b)** EDX

3.3 Result on UV-Vis monitoring of Application of the Chemosensor

The Uv-Vis spectra (Fig. 12), the spectra revealed comparison of the interaction of the zerovalent silver –curcumin nanocomposite in cadmium spiked solution with when it was added to water effluent from the steel mining industry which shows an absorption band around 350 nm when the zerovalent silver –curcumin nanocomposite was added to the water effluent which gave the same absorption band with orange colour observed same as when it was applied to cadmium standard solution and this shows

that cadmium was present in the water effluent waste released to the environment by the steel mining industries in which the atomic absorption spectroscopy (Table 1), confirmed the presence of 0.0013 ppm of cadmium in every 100 mL of the water effluent released to the environment which is possible to get into the nearby stream or well around the steel mining industry compared to the 0.005 ppm limit approved by WHO (World Health Organization) in drinking water and the limit of detection (Table 2) reported with the applications of nanomaterials.

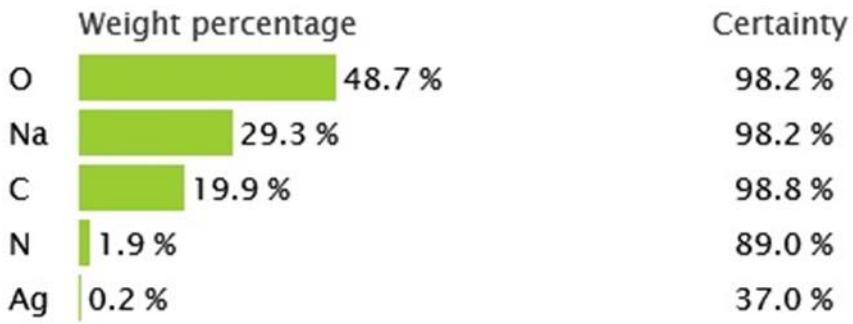


Fig. 11 EDX sample elemental composition result for zerovalent silver-curcumin nanocomposite

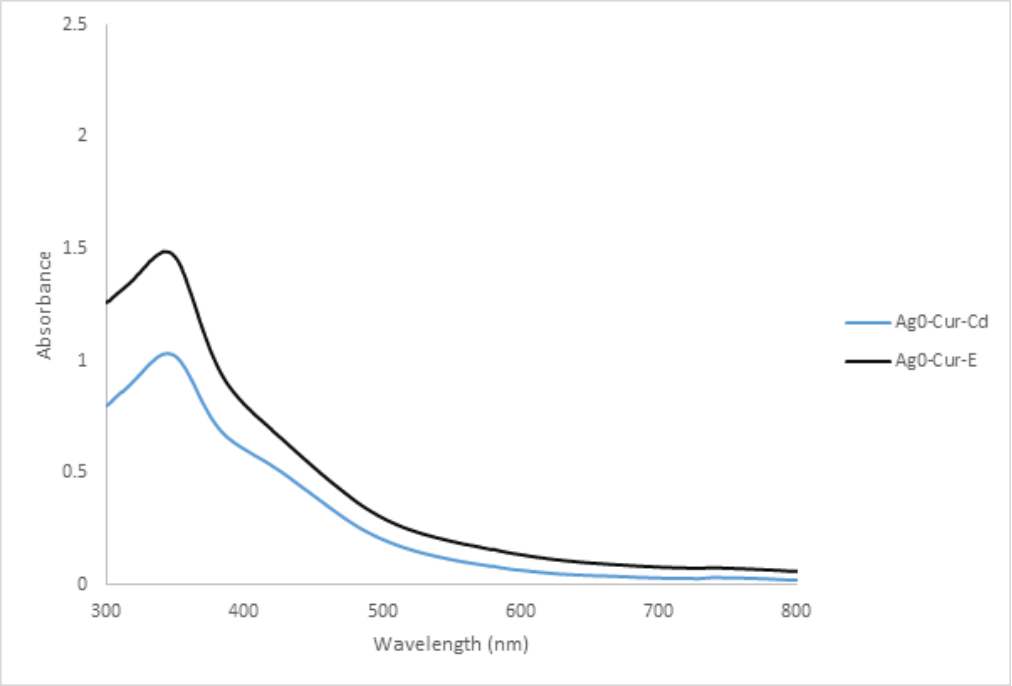


Figure 12: Zerovalent silver-curcumin nanocomposite on water effluent from steel mining industry (E) and cadmium solution

Table 1: AAS analysis of cadmium in water effluent from steel mining industry site at Ikorodu, Lagos State, Nigeria

SAMPLE ID	**RESULT TYPE**	**SIGNAL Abs**	**Rsd FLAGS %**	**CONC. mg/L**	**CORRECTED CONC (mg/L)**
E	Mean	-0.001	17.4	0.0013	0.0013

Table 2: Comparison of the detection limit of Cd(II) in water with nanomaterials

Primary Mechanism	Target-metals	Detection Limit	Ref.
Gold-nanoparticle functionalized β-cyclodextrin-graphene hybrids	Cd(II) Pb(II)	0.04 ppm	[23]
Bacterial biosensor	Cd(II)	25 μM	[24]
Au Nanoparticles Decorated Graphene-Based Hybrid Nanocomposite	As(III)	270 ppb	[25]
Querecetagetin-silver nanoparticles	Cd(II)	2.121 μM	[26]
Curcumin extract-silver nanoparticle nanocomposite	Cd(II)	0.0013 ppm	This study

4.0 Conclusion

This study reveals the use of eco-friendly organic compound from plant which also act as both reducing and stabilizing agent in the synthesis of the zerovalent metal-curcumin nanocomposite. The FT-IR and Uv-Vis reveal the presence of the carbonyl compounds and the conjugated di-ene which was responsible for the sensing activity of the curcumin. The addition of the silver nanoparticles solution to the curcumin extract in acetonitrile which increased the absorbance of the curcumin and shifted the wavelength of absorption around 420 nm to 357 nm for the zerovalent silver-curcumin nanocomposites. The FT-IR and Uv-Vis also reveal the interaction of the cadmium ion in water with the nanocomposites, in which the FT-IR proved that there is ligand to metal charge transfer between the C-O stretch of the nanocomposites and the cadmium ion in water. The zerovalent silver-curcumin was sensitive on the cadmium ion in aqueous medium in which can detect as low as 0.0013 ppm which was lower

than the approved concentration of cadmium in drinking water that was set up by World Health Organisation and United State for Food and Drugs Administration and highly selective on cadmium ion when compared with other heavy metals such as lead and mercury.

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Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Credit Author Statement

M.A.O: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing – original draft.

O.S.O: Data curation, Investigation, Methodology, Validation, Software, Writing – original draft, Writing – review & editing.

T.A.O: Data curation, Investigation, Methodology, Resources, Software, Writing – original draft, review & editing.

E.D.O: Data curation, Investigation, Methodology, Validation, Software, Writing – original draft, Writing – review & editing.

T.F.A: Data curation, Formal analysis, Validation, Methodology, Resources, Software, Writing & editing.

E.O.O: Data curation, Formal analysis, Investigation, Methodology, Resources

S.A.A: Formal analysis, Methodology, Resources, Validation, Visualization, Writing – review & editing.

C.A.A: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Project administration, Writing – review & editing.

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