

# UTILIZATION OF WASTE IN SOLVING ENVIRONMENTAL PROBLEM: APPLICATION OF BANANA AND ORANGE PEELS FOR THE REMOVAL OF LEAD (II) IONS FROM AQUEOUS SOLUTION OF LEAD NITRATE

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## ABSTRACT

Heavy metals are released into the environment as a result of rapid industrialization. This work focuses on the use of orange and banana peel as adsorbents for the removal of lead ion ( $Pb^{2+}$ ) from aqueous system specifically Wastewater. Effect of pH, adsorbent dose and contact time and initial metal ion concentration on the adsorption behavior of the adsorbents were investigated to determine optimum conditions for the adsorption process (purification). The functional group, morphology and pore structure characteristic of the adsorbents were analyzed using FTIR, SEM and EDX respectively. FTIR results showed the presence of  $-C=O$ ,  $O-H$ ,  $C-N$  and  $=CH_3$  functional groups on the surfaces of the adsorbents before and after adsorption process. The surface morphology for both adsorbents showed an irregular and porous surface. EDX analysis of banana peel showed the percentage weight compositions of 48.35% for C, 8.43% for N and 4.79% for O available on the surface of the peel. Similarly, 53.02 % for C and 23.87% for O were available on the surface of orange peel. The optimum pH for  $Pb^{2+}$  ion adsorption for both banana and orange peels was pH 6.0, with  $Pb^{2+}$  adsorption capacity of 30.54 mg/l and 23.81 mg/l respectively. The optimum adsorbent dosage was 0.1 g for both adsorbents with banana peels having adsorption capacity of 18.24 mg/l and orange peels had 11.16 mg/l as adsorption capacity at 0.1 g dosage. The optimum contact time in the experiment was found to be 60 minutes, where banana peel had removal efficiency of 73.93% corresponding to 29.57 mg/l adsorption capacity and orange peel had removal efficiency of 59.87 % corresponding to 23.95 mg/l adsorption capacity.

**Key Words:** lead ion, Orange peel, Banana peel, Adsorbent, Adsorption, Morphology and pore structure

## 1 INTRODUCTION

Heavy metals have been excessively released into the environment due to rapid industrialization and have created a major global concern. Cadmium, zinc, copper, nickel, lead, mercury and chromium are often detected in industrial wastewaters, which originate from metal plating, mining activities, smelting, battery manufacture, tanneries, petroleum refining, paint manufacture, fertilizer, pigment manufacture, printing and photographic industries and so on [1]. Unlike organic wastes, heavy metals are non-biodegradable and they can be accumulated in living tissues, causing various diseases and disorders; therefore, they must be removed before discharge. Accumulation of heavy metals in soils and water is of particular importance because it can impact negatively on human health through possible contamination of food [2]. With the increasing demand for water for agricultural, domestic, industrial, and recreational purposes, remediation and reuse of contaminated waters currently receive prime attention globally [3]. Research interest into the production of cheaper adsorbents to replace costly wastewater treatment methods such as chemical precipitation, ion-exchange, electroflotation, membrane separation, reverse osmosis, electrodialysis, solvent extraction and many more are attracting attention of scientists [4]. These methods are also associated with the generation of secondary waste which present treatment

problems such as the large quantity of sludge generated by precipitation processes. On the other hand, ion exchange and reverse osmosis are attractive because the metals can be recovered. However, reverse osmosis and ion exchange do not seem to be economically feasible due to their relatively high investment and operational cost. Adsorption is one of the physico-chemical treatment processes found to be effective in removing heavy metals from aqueous solutions. According to [5], an adsorbent can be considered as cheap or low-cost if it is abundant in nature, requires little processing and is a byproduct of waste material from waste industry. Plant wastes are inexpensive as they have no or very low economic value. Most of the adsorption studies have been focused on untreated plant wastes such as papaya wood [6], maize leaf [6] teak leaf powder [7], lalang (*Imperata cylindrica*) leaf powder [8], rubber (*Hevea brasiliensis*) leaf powder [8], *Coriandrum sativum* [9], peanut hull pellets [10] sago waste [11], saltbush (*Atriplex canescens*) leaves [12], tree fern [7]; rice husk ash and neem bark [4], grape stalk wastes [4]. Some of the advantages of using plant wastes for wastewater treatment include simple technique, requires little processing, good adsorption capacity, selective adsorption of heavy metal ions, low cost, readily available and easy regeneration. However, the application of untreated plant wastes as adsorbents can also generate several problems such as low adsorption capacity, high chemical oxygen demand (COD) and biological chemical demand (BOD) as well as total organic carbon (TOC) due to release of soluble organic compounds contained in the plant materials [13]. The increase of the COD, BOD and TOC can cause depletion of oxygen content in water and can threaten the aquatic life. Therefore, plant wastes need to be modified or treated before the heavy metals can be removed. Banana and Orange peels are abundantly available and cheap. They contain mainly cellulose, pectin (galacturonic acid), hemicellulose, lignin, chlorophyll and other low molecular weight compounds. The residue of banana and orange can be processed and converted to be adsorbent because they have large surface areas, high swelling capacities, excellent mechanical strengths, and are convenient to use and have great potential to adsorb harmful contaminant such as heavy metals. Due to the carboxyl functions of galacturonic acid, pectin substance present in fruit peels are known to strongly bind with metal cations in aqueous solutions. In addition, they can be easily combined with each other which gives better result when compared to individual performance as adsorbent [2, 3]. This study seeks to understand the concept of adsorption with the goal of producing a low cost adsorbent for lead nitrate treatment such as banana and orange peels to remove lead (II) ions in the aqueous solution and by assessing the impacts of several environmental factors such as; pH, adsorbent dose and contact time and initial metal ion concentration on the adsorption behavior of the adsorbents. This research is significant because continuous research and development efforts are essential for improving and optimizing the effectiveness of mixture of heavy metals adsorption process by banana and orange peels.

## 2. MATERIALS AND METHODS

### 2.1 Preparation of Lead (II) Ion Solution

1000 mg/L of Pb(II) solution was prepared by dissolving 1.5986 g of Lead (II) trioxonitrate (V) ( $Pb(NO_3)_2$ ) in 200 ml of distilled deionized water in a beaker. Then 1.5 ml of concentrated nitric acid ( $HNO_3$ ) was added. The solution was then transferred into 1L volumetric flask and diluted to the mark with distilled water. Concentrations of 10 to 80ppm of the metal of Pb(II) ions solution were prepared using the serial dilution equations as shown in Equation 1:

$$C_1V_1 = C_2V_2 \quad (1)$$

Where  $C_1$  is the concentration of stock solution,  $V_1$  is the volume of stock needed to make the expected working solution,  $C_2$  is the concentration of the expected working solution and  $V_2$  is the volume of the volumetric flask used to prepare the working solution. The pH of working solution was adjusted to desired values with 0.1 M hydrochloric acid (HCl) or 0.1 M sodium hydroxide (NaOH).

### 2.2 Preparation of the Adsorbent

The Banana and Orange peels were collected from various juice centres in Abuja, washed with hot deionized water to remove dirt and oven dried at 100°C for 24 hours to remove other low molecular weight

organic compounds such as methane. The dried residue was thereafter pulverized using a porcelain mortar and pestle. Particle size separation of the residues was carried out by sequential sieving wherein an appropriate amount of the pulverized residue was sieved using a laboratory test sieve shaker. Subsequent steps will be carried using standard methods such as ASTM as presented in [1, 2, 3].

### 2.3 Batch Adsorption Studies

Batch adsorption equilibrium experiments was conducted for the adsorption of lead on banana and orange peels as a function of initial pH, initial Pb(II) concentration, adsorbent dose and contact time. All the experiments were carried out at room temperature. The reactor for the experiment was basically 100 ml conical holding 40 ml of the working solutions placed in a thermo-stated water bath equipped with a mechanical shaker at a constant shaking speed of 150 rpm. The reactor content was mechanically agitated and after equilibration, reactor contents were separately filtered into a bottle using Whatman No. 1 filter paper. The effect of pH on the adsorption of Pb(II) was studied at pH values of 2 to 6 as pH. The concentrations of Pb(II) ions in solution before and after adsorption were determined using atomic absorption spectrophotometer (AAS) by monitoring the absorbance of lead (II) ion.

### 2.4 Characterization of the Adsorbent

The spectral characteristics and functional groups on the banana and orange peels i.e. the adsorbent (bio-sorbent) were determined using Fourier Transform Infra-Red Spectrophotometer (FTIR) while the surface structures of the banana and orange peels were determined using Scanning Electron Microscopy (SEM) at selected magnifications. Energy-dispersive X-ray (EDX) was used to analyze the percentage weight of chemical compositions available on the surface of the adsorbent banana and orange peels.

### 2.5 Effect of Adsorbent Dosage on Adsorption of Pb<sup>2+</sup> Ion.

The effect of adsorbent dose on adsorption of Pb<sup>2+</sup> ion by the adsorbent was studied by contacting different portions of the adsorbents i.e. 0.1, 0.5, 1 and 2g with a known concentration of Pb<sup>2+</sup> ion solution. In this study, 100 mg/L Pb<sup>2+</sup> ion solution was used. 40 ml of the solution was measured into 100 ml conical flask and the required adsorbent dose was transferred into this conical flask. The flask was agitated at 120 rpm for 2 hours and allowed to stand for 24 hours. The mixture was filtered through Whatman No.1 filter paper into a 120 cm<sup>3</sup> polyethylene bottle. The concentration of Pb<sup>2+</sup> ion remaining in the solution (filtrate) after equilibration (removal) was determined with AAS. The removal efficiency of the adsorbent (percentage removal) was estimated using Equation 2.

$$\%RE = \frac{(C_o - C_e)}{C_o} \times 100 \quad (2)$$

Where; C<sub>o</sub> is Initial Pb<sup>2+</sup> ion concentration in solution used in this study (100 mg/L) and C<sub>e</sub> is the final concentration remaining in the solution after adsorption experiment (mg/L). The amount of metal ion removed (mg/g) by the adsorbent representing the adsorption capacity of the adsorbent was calculated using Equation 3.

$$Q_e = \frac{v(C_o - C_e)}{M} \quad (3)$$

Where is the amount of Pb<sup>2+</sup> ion concentrated on the adsorbent (mg/g), C<sub>o</sub> and C<sub>e</sub> were as defined in Equation 2. V is volume of initial metal solution used (0.04 L) and M is Mass of adsorbent used in gram (g).

### 2.6 Effect of pH on Adsorption of Pb<sup>2+</sup> Ion

The effect of pH was studied by adjusting the pH of the solution to 2, 4 and 6 using 0.1 M HCl and 0.1M NaOH solutions. The experiment was carried out by measuring 40 ml of the working solution of 100 mg/L of Pb<sup>2+</sup> ion in 100 ml conical flask. The solution was adjusted appropriately and 0.1g of the adsorbents was transferred into this conical flask. The flask was agitated for 2 hours and allowed to stand for 24 hours in order for the system to equilibrate. Then, the adsorbent was separated from the solution by filtering

through Whatman 1 filter paper into polyethylene bottle. The concentration of  $Pb^{2+}$  ion remaining in the solution (filtrate) after equilibration (removal) was determined with AAS. Then percentage removal (%RE) and  $Q_e$  were calculated using Equations 2 and 3 respectively.

### 2.7 Effect of Contact Time on Adsorption of $Pb^{2+}$ Ion.

The effect of contact time on the adsorption of  $Pb^{2+}$  ion was carried out by agitating 40ml of 100mg/L  $Pb^{2+}$  ion solution at pH of 6 (optimum pH obtained in this study) with 0.1g of adsorbent in 100 ml conical flask. Contact times of 15, 30, 60, 90 and 120 minutes were used. After agitation, the adsorbent was separated from the solution by filtering through Whatman 1 filter paper into polyethylene bottle. The concentration of  $Pb^{2+}$  ion remaining in the solution (filtrate) after equilibration (removal) was determined with AAS. Then, %RE was calculated from equation 2 and the amount of  $Pb^{2+}$  ion adsorbed by the adsorbent as time varies  $Q_t$  (mg/L) was calculated from equation 4:

$$Q_t = \frac{v(C_0 - C_e)}{M} \quad (4)$$

In equation 4,  $Q_t$  is the amount of  $Pb^{2+}$  ion concentrated on the adsorbent (mg/g) as time varies,  $C_0$ ;  $C_e$ ;  $V$  and  $M$  were as defined in Equation 3.

### 2.8 Effect of metal ion Concentration on Adsorption of $Pb^{2+}$ Ion

Different concentrations of  $Pb^{2+}$  ions (10, 20, 40, 60, 80 and 100 mg/L) were prepared from the stock of 1000 mg/L  $Pb^{2+}$  ion solution. The effect of metal ion concentration on adsorption was obtained by measuring 40ml of these different concentrations into 100 ml conical flask. The pH of the solution was adjusted to 6 (optimum pH in this study) with 0.1 M NaOH and 0.1 M HCl. 0.1g of the adsorbent was added into the flask and the mixture was agitated for 60 minutes (optimum time in this study). After agitation, the adsorbent was separated from the solution by filtering through Whatman 1 filter paper into polyethylene bottle. The concentration of  $Pb^{2+}$  ion remaining in the solution (filtrate) after equilibration (removal) was determined with AAS, %RE and  $Q_e$  were calculated from Equations 2 and 3 respectively.

## 3 RESULTS AND DISCUSSION

### 3.1 Adsorbent Surface Characterization with FT-IR

The results of the FT-IR spectra before and after the adsorption experiment are presented in Figures 1 to 4. Different functional groups on the surface of the banana and orange peels were assigned to the peaks observed in FT-IR spectra and presented in Table 1. The broad peaks around 3529.28- 3853.27  $cm^{-1}$  in the spectra were due to the stretching vibrations of the O-H bonds. The band around 1718.91 – 1545.21  $cm^{-1}$  was caused by the stretching vibration of C=O in ketones, aldehydes, lactones, lignin and carboxyl groups. The bands centered at the 3336.81 – 3372.63  $cm^{-1}$  are due to N-H stretching of amines, while those centered on 2345.46 – 2345.53 may be attributed to O-H stretching of carboxylic acid. The bands centered at 1419 – 1458.61  $cm^{-1}$  region could be attributed to aliphatic stretching and symmetric bending of  $=CH_3$ . These functional groups could act as chemical binding agents where carboxyl, hydroxyl, and amine groups could dissociate negatively charged active surface. This means that these functional groups could attract the positively charge objects such as heavy metal ions. The FT-IR spectra for banana and orange peels used in this study were within transmission wave number ranging from 500 to 4000  $cm^{-1}$ .

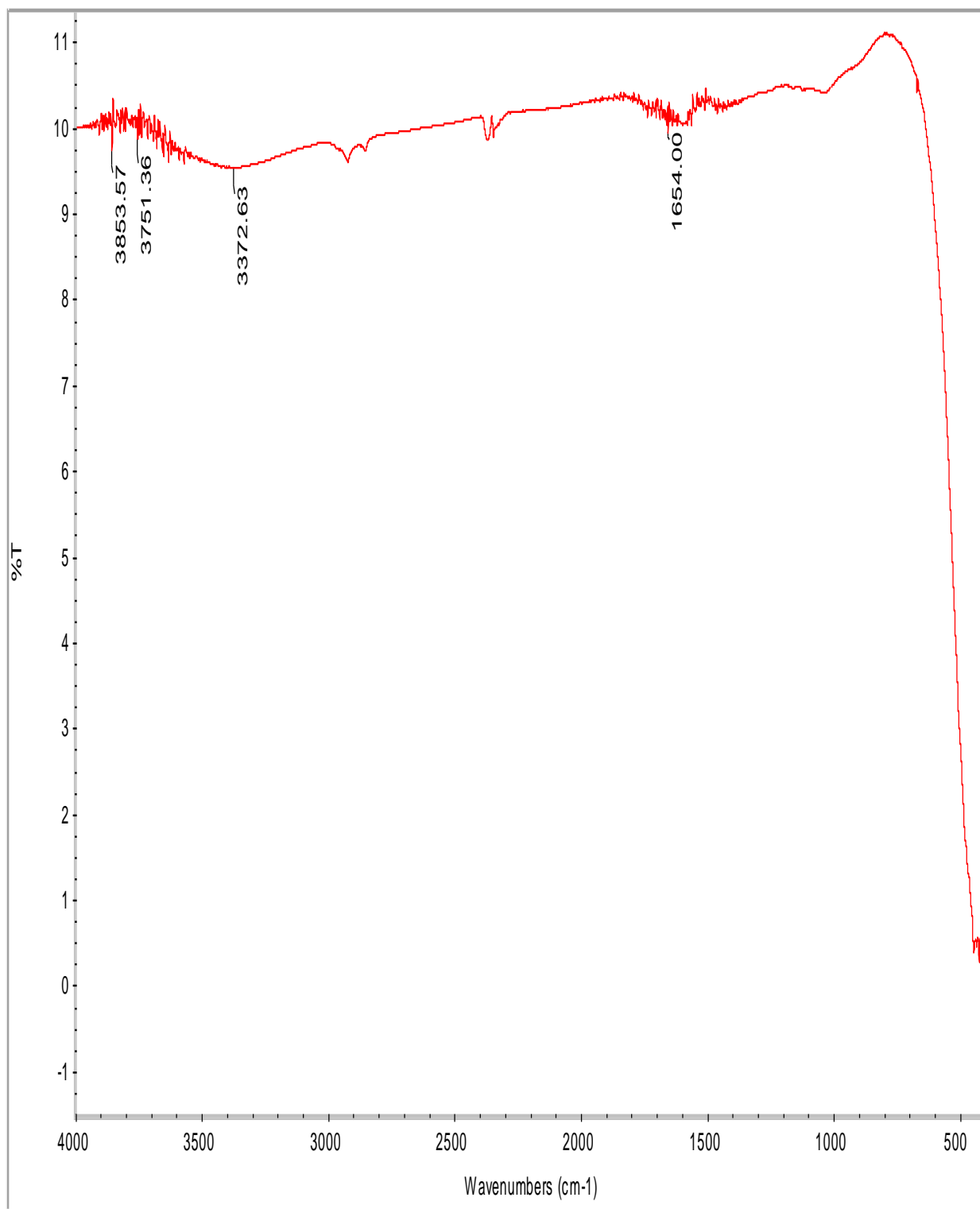


Figure 1. FT-IR spectrum for banana peels before adsorption experiment

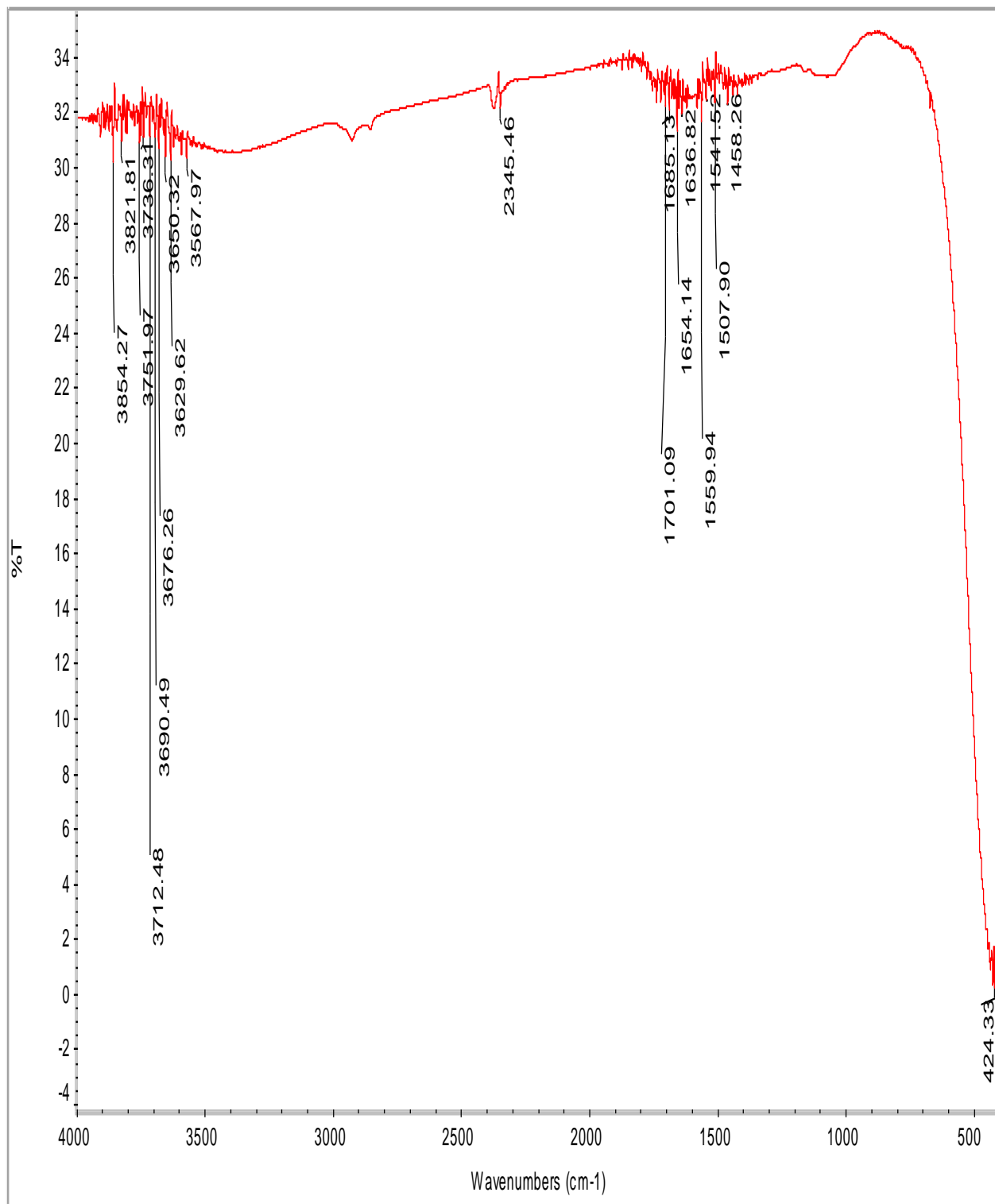


Figure 2. FT-IR spectrum for banana peels after adsorption experiment

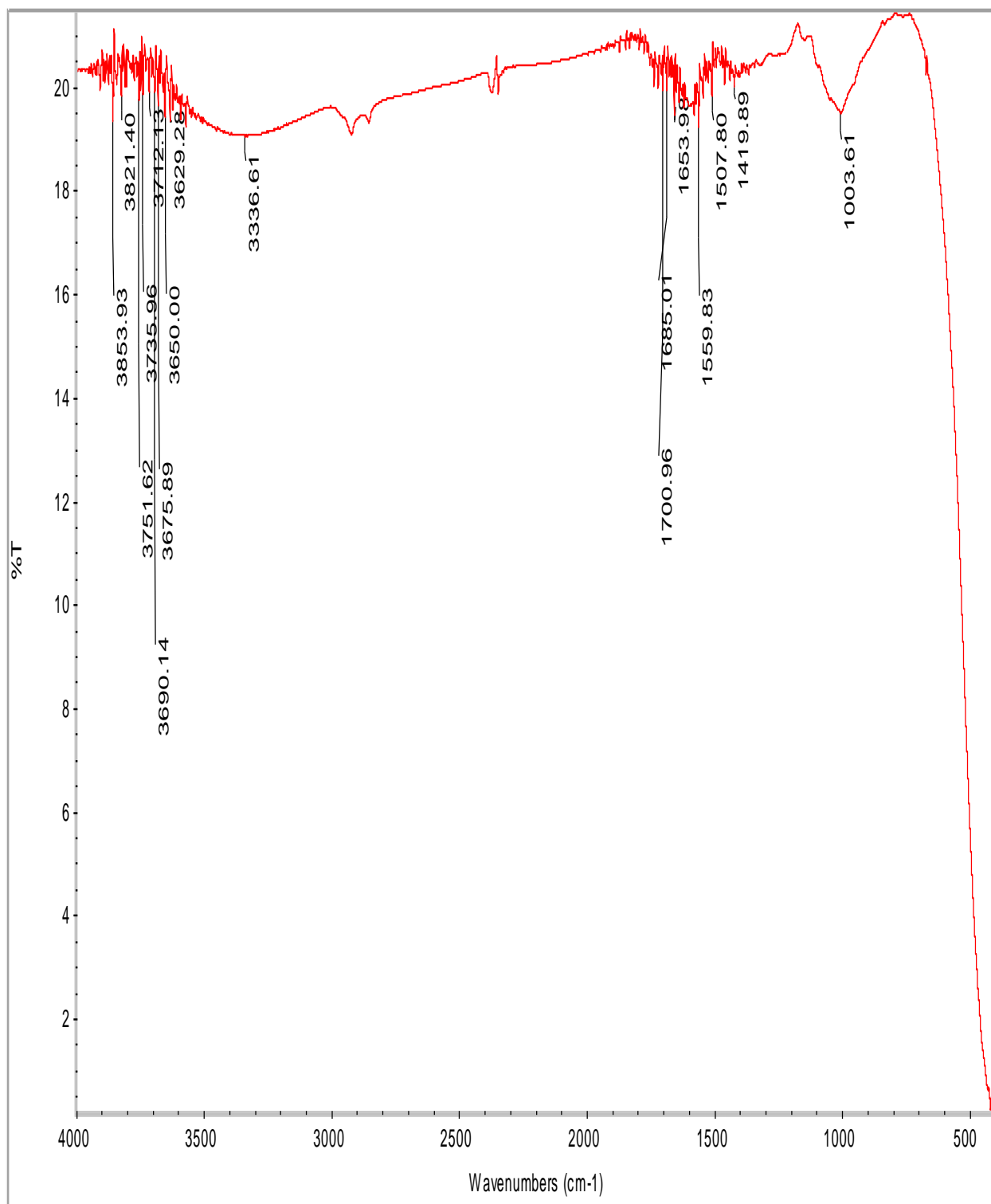


Figure 3. FT-IR spectrum for orange peels before adsorption experiment

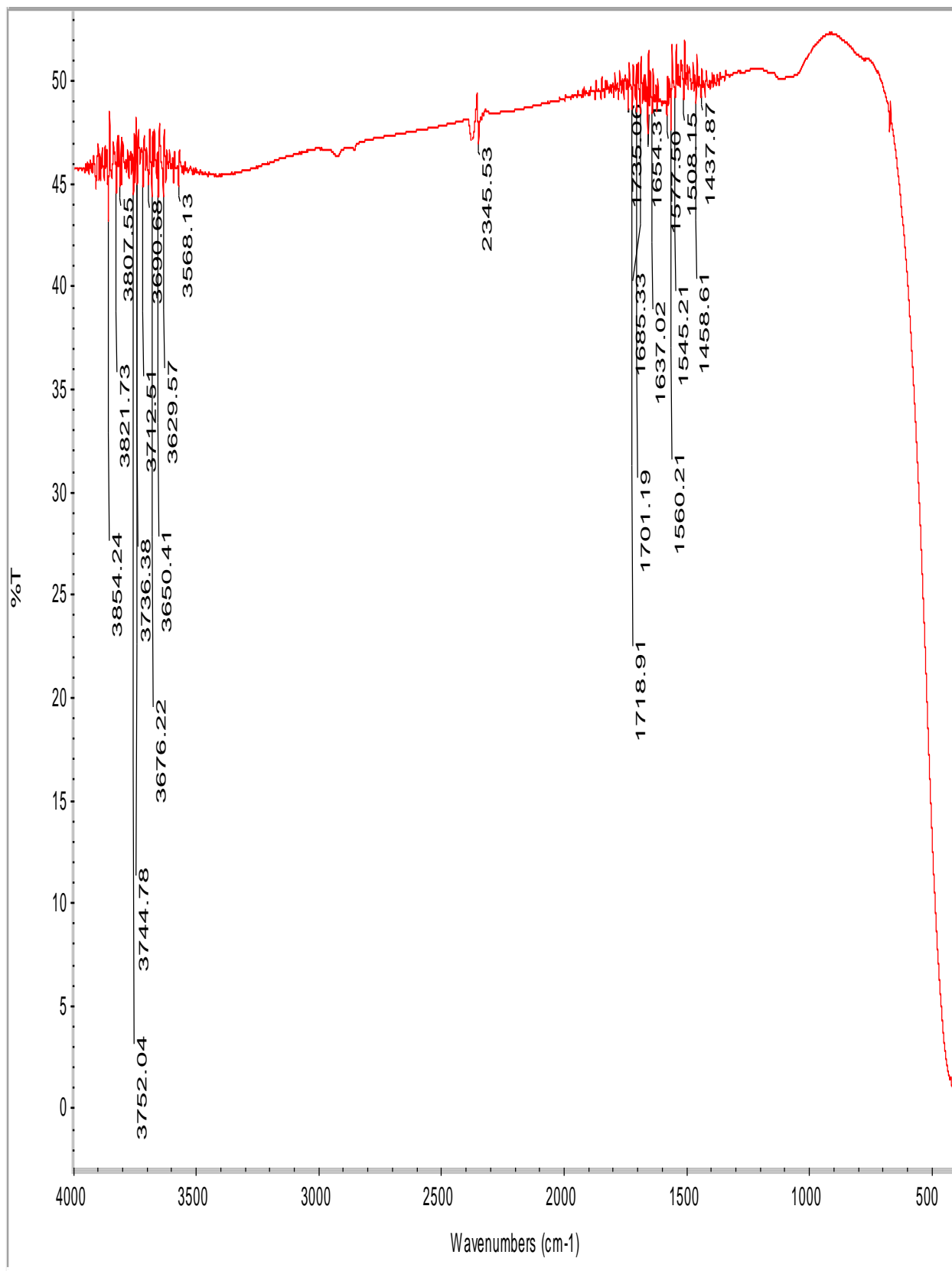


Figure 4. FT-IR spectrum for orange peels after adsorption experiment.



Table 1. FTIR characterization of the banana and orange peels

Freq.(cm <sup>-1</sup> )	Functional group	Observed frequency (cm <sup>-1</sup> )				Assignment
		BPF	BPA	OPF	OPA	
4000 – 3500	Alcohols	3853.57 -	3854.27 -	3853.93 -	3854.24 -	O-H stretch
		3751.36	3567.97	3529.28	3588.13	
3499 – 3000	Amines	3372.63		3336.61		N-H stretch
2499 – 2000	Carboxylic acids		2345.46		2345.53	O-H stretch
1999 – 1500	Carbonyl					
	Ketones/Esters		1701.08	1700.98	1718.91	C=O stretch
	Aldehydes	1654.00	1664.14	1685.01	1701.19	C=O stretch
				1653.96		
	Carboxylic		1638.82	1559.83	1637.02	C=O stretch
	Carboxylic		1507.90	1507.80	1560.21	C=O stretch
	Carboxylic				1545.21	C=O stretch
1470 - 1430	Alkenes		1458.26	1419.89	1458.61	=-CH <sub>3</sub>
					1437.87	=-CH <sub>3</sub>

BPF is banana peels before adsorption, BPA is banana peels after adsorption, OPF is orange peels before adsorption and OPA is orange peels after adsorption study

### 3.2 Adsorbent Characterization using Scanning Electron Microscopy (SEM)

Characterization of the banana and orange peels were studied using SEM micro graph has shown in (Figures5 and6). It showed the morphology behavior of banana peel and orange peel. These figures show that the peels have an irregular and porous surface. This is similar to the structure and morphology of orange peel observed by [14].

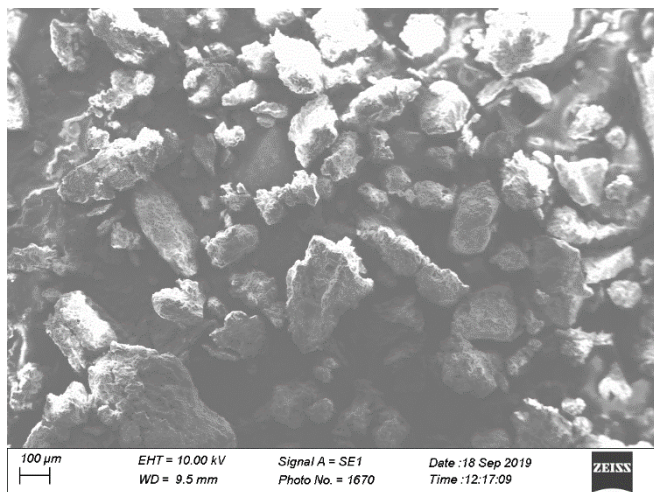


Figure5. SEM of banana peel

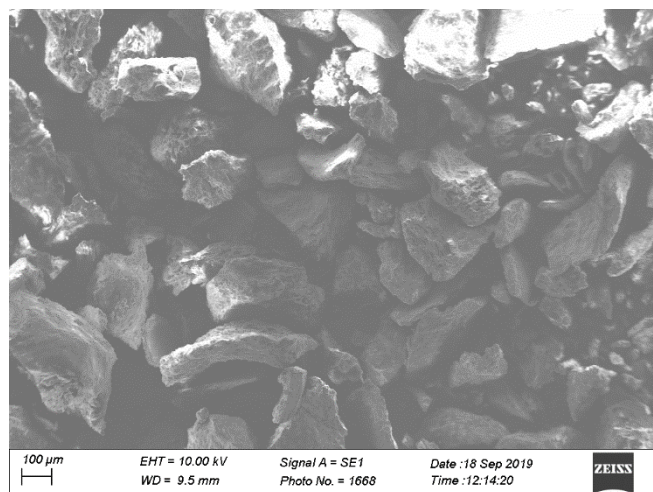


Figure6. SEM of orange peel

### 3.3 EDX analysis

EDX analysis of banana and orange peels are shown in Figures7 and 8 respectively. Figure 7 showed that the percentage weight of chemical compositions available on the surface of banana peel were as follows: 48.35% of C, 8.43% of N, 4.79% of O, 8.48% of K, 0.2% of Si, 5.14 % of Cl, 3.81 % of Sn, 0.8 %, of Mg while that of orange peels as shown in Figure 8 are 53.02 % of C, 23.87% of O, 7.28% of Sn. This shows in existence of protein and polysaccharides in the peels.

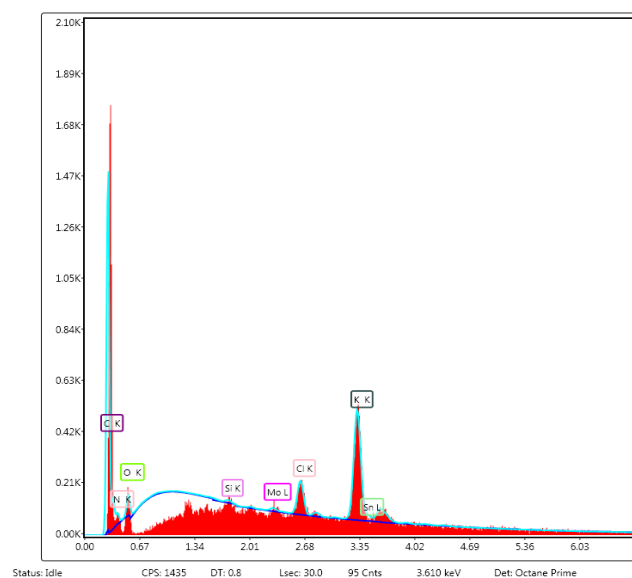


Figure 7. EDX analysis of banana peel

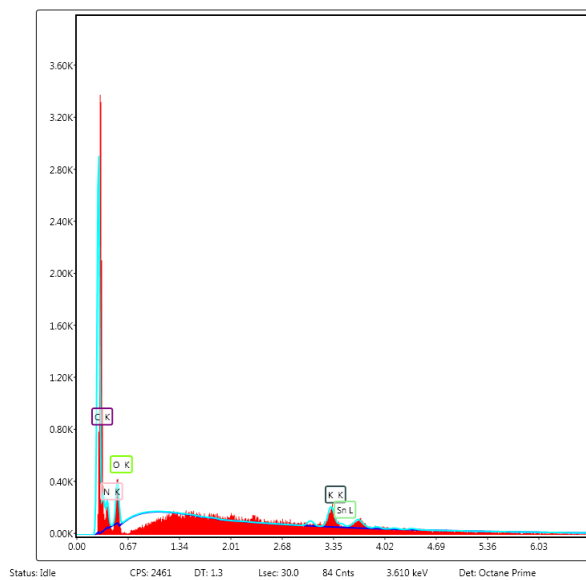


Figure 8. EDX analysis of Orange peel

### 3.4 Adsorption Experiment

#### 3.4.1 Effect of adsorbent dosage

The effect of dosage on sorption gives the capacity of an adsorbent for an adsorbate at a given concentration. Moreover, the mass of adsorbent is an important factor in large scale industrial application of adsorbent in the removal of metal ions from solution [15]. The results of the effect of the

banana and orange peels dosage used in this study for the removal of  $Pb^{2+}$  ion from aqueous system is reported in Table 2. Here, the percentage removal of the  $Pb^{2+}$  also known as removal efficiency (%RE) increased with increase in dosage. This observation is expected because with indiscriminate increment in dosage, sites available for adsorption also increase indefinitely [16, 17]. However, the amount of  $Pb^{2+}$  adsorbed per gram of the adsorbent at equilibrium ( $Q_e$  (mg/g)) decrease with increment in adsorbent dosage as shown in Figure 9. Similar results were obtained by [18] for the removal of ions from aqueous system using rice husk. Hence, adsorbent dose of 0.1 g which had the highest  $Q_e$  (mg/g) value of 11.16 (Table 2) was chosen as the optimum dosage for subsequent experiments.

Table 2. Effect of adsorbent dosage on adsorption of  $Pb^{2+}$  from aqueous system

Dose(g)	$C_e$ (mg/L)	$C_0-C_e$	% RE	$Q_e$ (mg/g)	$C_e$ (mg/L)	$C_0-C_e$	% RE	$Q_e$ (mg/g)
	Banana peel				Orange peel			
0.1	53.15	46.85	46.85	18.74	72.11	27.89	27.89	11.16
0.5	47.17	52.83	52.83	4.23	58.02	41.98	41.98	3.36
1	26.07	73.93	73.93	2.96	46.47	53.53	53.53	2.14
2	20.32	79.69	79.69	1.59	40.33	59.67	59.67	1.19

Note: initial concentration  $C_0$  was 100 mg/L

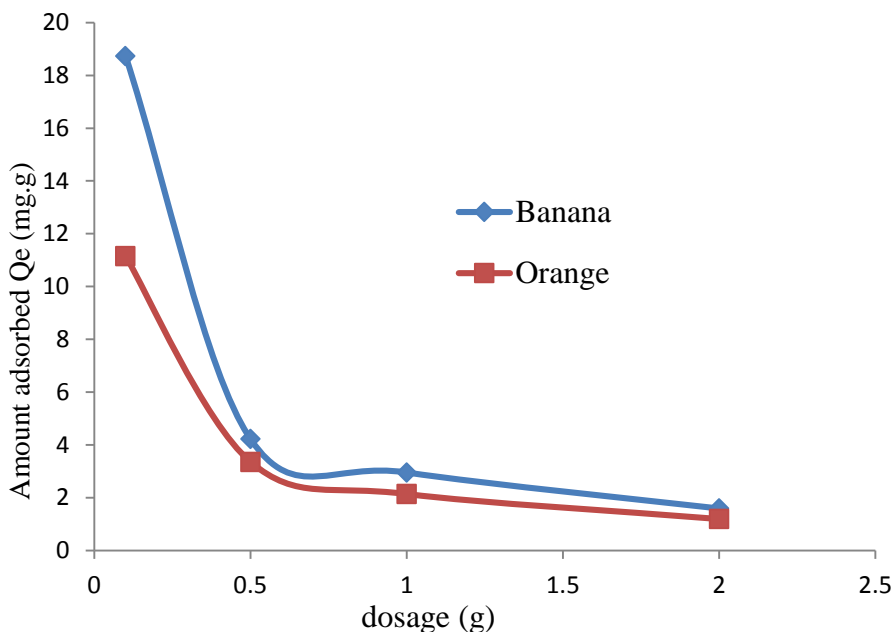


Figure 9. Variation of the amount  $Pb^{2+}$  adsorbed with increment in adsorbent dosage

### 3.4.2 Effect of pH on adsorption of $Pb^{2+}$ ion from aqueous system

The pH of solution is an important factor to consider in large scale industrial application of adsorbent, because it affects the surface chemistry of the adsorbent [19]. The effect of pH on the adsorption of  $Pb^{2+}$  ion from aqueous system in this study was done within the pH range of 2 to 6, because at pH value above 6,  $Pb^{2+}$  may precipitate out as  $Pb(OH)_2$ . The result for this study is presented in Table 3 and the variation in amount of  $Pb^{2+}$  ion adsorbed as pH changes was depicted in Figure 10. Thus, the percentage of  $Pb^{2+}$  ion removed increases with increment in pH of the solution for both banana and orange peels. In Figure 8, the low percentage removal observed at low pH is obviously due to the presence of higher concentration of  $H^+$  ions in the solutions competing with  $Pb^{2+}$  ion for adsorption site as reported by [19]. As pH value increases, the solution becomes more basic, thus reducing the concentration of  $H^+$  ion in the solution. This leads to decrease number of positive surface charge in the solution, which results in a lower columbic repulsion of the adsorbing metal ions and thus gave more room for  $Pb^{2+}$  uptake by the adsorbent. In addition, the surface chemistry of the adsorbent changes

towards negative charges, thereby, more attraction for the positively charged  $Pb^{2+}$  will be expected [19]. As shown in Figure 10 both adsorbent had highest adsorption capacity at pH value of 6. Therefore, subsequent experiments were conducted at pH value of 6. Comparing the adsorption capacity of the adsorbents, it was observed that banana peels had better adsorption capacity for  $Pb^{2+}$  ions as reflected in Figure 8.

Table 3: Effect of pH on adsorption of  $Pb^{2+}$  from aqueous system

pH	Banana peel				Orange peel			
	$C_e$ (mg/L)	$C_o - C_e$	% RE	$Q_e$ (mg/g)	$C_e$ (mg/L)	$C_o - C_e$	% RE	$Q_e$ (mg/g)
2	45.30	54.70	54.70	21.88	79.08	20.92	20.92	8.37
4	37.17	62.83	62.83	25.13	45.32	54.69	54.69	21.87
6	22.89	77.11	77.11	30.84	40.47	59.53	59.53	23.81

Note: initial concentration  $C_o$  was 100 mg/L and adsorbent dosage was 0.1 g.

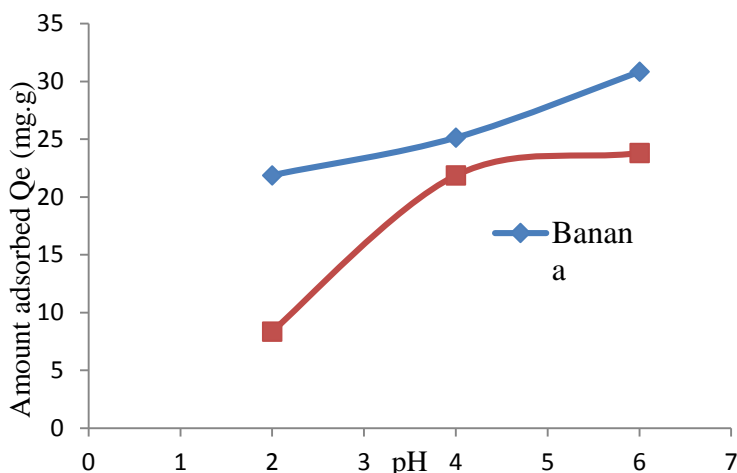


Figure 10. Variation in the amount of  $Pb^{2+}$  adsorbed with changes in pH

### 3.4.3 Variation of $Pb^{2+}$ observed with time

The removal of metal ion from aqueous solution is a dynamic process. Therefore, the removal  $Pb^{2+}$  from aqueous system by banana and orange peels was studied as a function of contact time under constant condition of initial concentration (100 mg/L), adsorbent dosage (0.1 g), pH value of 6 and at room temperature. The final concentration of  $Pb^{2+}$  ions in solution and percentage removal (% RE) by the adsorbents as contact time varies as presented in Table 4. Figure 11 shows the changes in the amount of  $Pb^{2+}$  ion adsorbed by the adsorbents as time changes. It was observed from the figure that the amount of  $Pb^{2+}$  ion adsorbed increased rapidly with time from 0 to 30 minutes. This indicated that initial rate of metal ion removal was very high as depicted by the steep part of the curve. This may be due to the fact that in the beginning, all the adsorption sites on the surface of the adsorbent were vacant and therefore, solute concentration gradient was relatively high. As contact time increased from 30 minutes to 50 minutes the differences in the amount removed reduced as shown by the decrease in the steepness of the curve (figure 11). This could be due to very few number of unsaturated adsorption sites available as contact time increases resulting in decreasing rate of adsorption.

Table 4. Effect of contact time on adsorption of  $Pb^{2+}$  from aqueous system

Time(min)	Banana peel				Orange peel			
	$C_e$ (mg/L)	$C_o - C_e$	% RE	$Q_e$ (mg/g)	$C_e$ (mg/L)	$C_o - C_e$	% RE	$Q_e$ (mg/g)
15	51.54	48.46	48.46	19.39	78.54	21.46	21.46	8.59
30	37.56	62.44	62.44	24.98	49.98	50.02	50.02	20.01
60	26.07	73.93	73.93	29.57	40.13	59.87	59.87	23.95
90	26.17	73.83	73.83	29.53	40.14	59.86	59.86	23.94
120	26.07	73.93	73.93	29.57	40.13	59.87	59.87	23.95

Note: initial concentration  $C_o$  was 100 mg/L

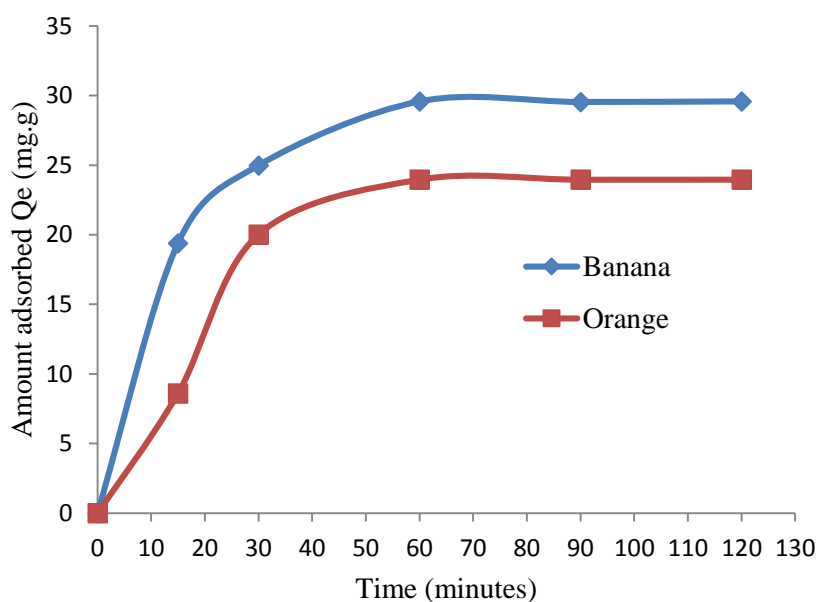


Figure 11. Variation of Pb<sup>2+</sup> adsorbed with time

This behavior is in line with the fact that the adsorption is a surface phenomenon and that the surfaces are readily accessible to the metal ions in the solution [20]. It also suggests the occurrence of a rapid external mass transfer followed by a slower internal diffusion process which could be the rate determining step [21]. The slower internal diffusion process could be due to the slow diffusion of the adsorbed metals from the surface film into the micro pores which are the least accessible sites for adsorption [22]. As time increased from 50 minutes to 60 minutes the curve tends to flattens out, which accounted for the plateau observed in the graphs as time increased from 60 minutes to 120. Based on these results, 60 minutes was considered as the equilibrium time and was used for subsequent experiment.

### 3.4.4 Effect of initial metal ion concentration

Using the optimum conditions obtained in this study, that is, pH value of 6, adsorbent dosage of 0.1 g, contact time of 60 minutes and room temperature (25°C), the effect of initial Pb<sup>2+</sup> ion concentration on adsorption onto banana and orange peels was studied within concentration range of 10 mg/L to 100 mg/L. The results are presented in Table 5. Figure 12 shows the changes in the amount of Pb<sup>2+</sup> ion adsorbed by the adsorbents as initial concentration changes.

Table 5: Effect of initial metal ion concentration

Co(mg/L)	C <sub>e</sub> (mg/L)	C <sub>o</sub> - C <sub>e</sub>	% RE	Q <sub>e</sub> (mg/g)	C <sub>e</sub> (mg/L)	C <sub>o</sub> - C <sub>e</sub>	% RE	Q <sub>e</sub> (mg/g)
	Banana peel				Orange peel			
10	4.93	5.08	50.75	2.03	5.29	4.71	47.13	1.89
20	8.39	11.62	58.08	4.65	11.63	8.37	41.85	3.35
40	18.10	21.90	54.74	8.76	22.68	17.32	43.30	6.93
60	24.53	35.48	59.13	14.19	29.39	30.61	51.02	12.25
80	31.89	48.11	60.13	19.24	40.46	39.54	49.43	15.82
100	42.89	57.11	57.11	22.84	56.47	43.53	43.53	17.41

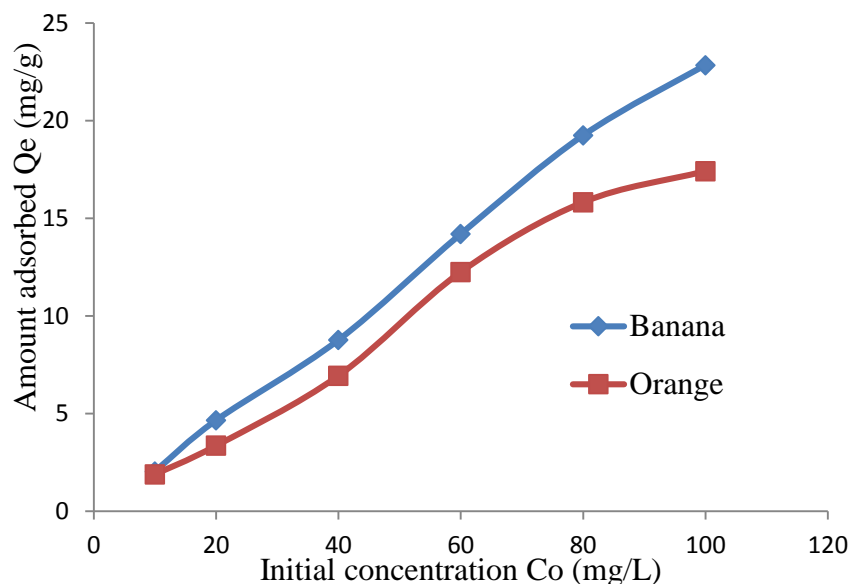


Figure 12. Variation in the amount of  $Pb^{2+}$  adsorbed with changes in initial metal ion concentration

From the Figure, the amount of  $Pb^{2+}$  ion adsorbed increased with increment -in initial concentration. The increase in amount of metal ion adsorbed as initial metal ion concentration in the solution increased was as a result of increase in concentration gradient in the solution which is the driving force for adsorption process. This is in agreement with observations reported by [23; 24 and 25]. Though an increase in metal ion uptake was recorded, the decrease in percentage removal as initial concentration exceeds 60 mg/L (Table 5) may be attributed to lack of sufficient surface area to accommodate more metal ion available in the solution as the concentration increases. At lower concentration, all metal ions present in solution could interact with functional groups and binding sites on the surface of the adsorbent and thus the percentage adsorption was higher than those at higher metal ion concentration. At higher concentration, lower percentage removal is due to the saturation of adsorption sites [26]. Thus, purification yield can be increased by diluting waste water containing high metal ion concentration.

#### 4 CONCLUSION

This study investigated the application of banana and orange peels as adsorbent for the removal of  $Pb^{2+}$  ion from any aqueous system commonly found in industrial wastewater. Results obtained revealed that: The raw materials (banana and orange peels) have the potential to remove  $Pb^{2+}$  from aqueous solution and the adsorption performances are affected by the adsorbent type, adsorbent dosage, pH, contact time and initial metal ion concentration. However, Banana peels have better adsorption capacity compared to orange peels. In addition, the optimum conditions for adsorption were found to be at pH 6, with the adsorbent dosage of 0.1g, and contact time of 60 minutes.

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