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Extraction of Silver from Waste X-Ray Films by Coconut (*Cocos Nucifera L.*) Coir

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Abstract: ***In this work potassium ions present in coconut (cocos nucifera L.) coir was used for the extraction of silver from waste x-ray films. Alkaline solutions of coconut coir ash were prepared by dissolving, 20, 40, 60, 80 and 100g of ash separately in 500ml of distilled water for 48 hours with stirring at intervals, followed by filtration. pH of the alkaline solutions obtained after standardization were 12.0, 12.4, 12.5, 12.5 and 12.7 respectively. These solutions were used to leach silver from the x ray films. Addition of 100ml of 1.5M sodium sulphide to the extracts produced precipitates in each beaker which were analyzed using Atomic Absorption Spectrophotometer model GBC Avanta Version 2.02. Silver ion concentration in each extract was obtained as 3.757, 3.989, 4.059, 4.317 and 4.876ppm respectively. The results show that more grams of the coconut coir ash produce more aqueous extracts which eventually stripped higher quantity of silver from the x-ray films. This work has therefore shown utility of a waste material for extraction of silver from waste x-ray films.***

Keywords: Coconut coir ash extract; waste x-ray films; silver; AAS; potassium ion

1. Introduction

The high photosensitivity characteristic of silver makes it an invaluable raw material for the radiographic and photographic industries. It is applied in different forms in electronics, pulp, jewelries. Pure Silver metal is often extracted from its ore deposit, mixed with other elements, in the earth crust (Radha and Arun, 2010). The amount of silver produced in the world is reported to be insufficient compared with the demand which steadily increases by 2 to 2.5% yearly (Samson and Edison, 2014). This has necessitated the recycling of waste materials to obtain silver to feed these industries. In this aspect the photographic and radiographic industries are chief sources of silver recovery. It has been reported that 25% of the world's silver needs are supplied by recycling out of which 75% is obtained from photographic waste (Shankar *et al*., 2010; Okorosaye – Orubite and Don-Lawson, 2016). Photographic films contain black metallic silver spread in gelatin and are very good sources for silver recovery. (Ajiwe and Anyadiegwu, 2000; Shankar *et al*., 2010). X-ray films used in medical applications are made of a plastic sheet (polyester film) coated with a thin coating of gelatin (protein) impregnated with silver grain (Radha and Arun, 2010). Increase in demand for silver in industrial circles has necessitated intensive studies for its extraction from every form of waste and ore (Orubite-Okorosaye and Jack 2011, Orubite-Okorosaye and Don–Lawson 2016, Orubite-Okorosaye and Gbarakoro 2018). Coconut is of the family *Arecaceae* and native to coastal areas (the littoral zone) of Southeast Asia (Malaysia, Indonesia, Philippines). It grows as a slender (12-30m) tall tree widely spread throughout the tropical areas of the world, particularly along sandy shorelines. Coconut is eaten all over the tropical and subtropical regions; the coir is discarded as waste. Coconut coir is the fibrous material found between the hard, internal shell and the outer coat of the coconut. It is the durable fiber extracted from discarded coconut husks. There are two ways of categorizing coir fibers, which serve as raw materials for the preparation of various products: ripe and immature (unripe) coconut husks. Ripe coconuts yield thick, strong brown coir, which is typically used in brushes, floor mats and upholstery padding. Unripe coconuts have fine, white or light brown coir, which is used as the raw material for the manufacture of a variety of household products such as coir yarn, coir mats, carpets, brushes, belts, strings, ropes and fishing nets (Kavitha, 2015). Viju *et al.*, (2012) reported that the aqueous extract of the coconut husk has antimicrobial activity. Maji *et al.*, (2014) studied antimicrobial properties of coconut (*Cocos nucifera L.*) husk and noted that the inhabitants of rural areas of Dakshina Kannada district of Karnataka, South India used fibrous husk of coconut as herbal chewing sticks instead of plastic bristle brushes to maintain oral health and hygiene. George *et al*., (2014) carried out studies on dry ash of red mangrove bark, an agricultural waste, to determine the potassium ion concentration in it, by titratory and spectrophotometric methods.

Recovering Silver from photographic and x-ray films using various plant materials has been reported (Jayant *et al*., 2015; Okorosaye-Orubite and Don-Lawson, 2016; Okorosaye-Orubite and Gbarakoro 2018). However there is no report on the use of coconut coir in recovering precious metals like silver which are highly needed in various industries. Orubite- Okorosaye and Don- Lawson (2016) reported that the extractant for silver in agricultural waste is the presence of potassium ion, K^+ which replaces the silver ion, Ag^+ in solution and precipitates as silver hydroxide $Ag(OH)^+$. Plants take in potassium, sodium and calcium as nutrients. Plant ash solutions therefore contain potassium ion as hydroxide, calcium hydroxide and sodium hydroxide. Calcium hydroxide is sparingly soluble and since plants take in more Potassium than Sodium, the ash solution is mainly Potassium hydroxide (Ronald and Hansford, 1988). Therefore, this work seeks to determine potassium ion concentration in coconut coir ash aqueous extract solution and subsequent extraction of silver from x-ray films using this solution. The study proposes an alternative source of silver recovery and disposal of x- ray films which are enriched with silver.

2. Materials and Methods

2.1 Materials

Coconut coir was collected from local coconut growers in Wiiyaakara town in Khana Local Government Area, Rivers State, Nigeria while the x-ray films were collected from the radiological unit of the General Hospital, Bori in Rivers State, Nigeria. All the chemicals and reagents used were of analytical grade. Model GBC Avanta version 2.02 Atomic Absorption Spectrophotometer was used.

2.2 Methods

2.2.1 Sample Preparation

Preparation of Coconut Coir Aqueous Extracts (CCAE)

Coconut coir fibers were stripped from the outer coat of the coconut, and washed with distilled water. They were sun dried for 48 hours and further oven dried at 80°C for 48hrs. The dried samples were burnt to obtain fine ash. Five different grams (20, 40, 60, 80 and 100g) of the dried ash were weighed into five separate beakers. Each grams of the dried ash were dissolved in 500ml of distilled water and left for 48 hours to homogenize. Thereafter, the resultant mixtures were filtered using Whatman filter paper and the coconut coir aqueous extracts (CCAE) stored in corked conical flasks.

2.2.2 Titrimetric Analysis

In order to check for the potassium ion concentration of the coconut coir aqueous extract, the different concentrations of the coconut coir aqueous extract were titrated with 1M HCl using methyl red as the indicator.

2.2.3 Preparation of X-ray Films

The x-ray films collected were washed with distilled water and wiped with cotton wool saturated with ethanol. The long sheets of film were dried in an oven at 60°C for 30 minutes and cut into 3x3 cm^2 sizes.

2.2.4 Recovery of Silver from X-Ray Films

Into the five beakers labeled (20, 40, 60, 80 and 100g) were added 300ml each of CCAE. The cut x-ray films (30 pieces each) were placed into each of the beakers. The beakers were heated in a water bath at 100ºC for 55 minutes with occasional stirring. The resultant extracts solutions were allowed to cool for 15 minutes. Then 100ml of 1.5M solution of sodium sulphide was added to each beaker containing the extracts. The precipitates formed were analyzed for silver ion concentration using Atomic Absorption Spectrophotometer model GBC Avanta Version 2.02.

2.2.5 AAS Analysis

The silver lamp used was sensitive to only silver. Each sample was placed in a test tube and the capillary tube of the AAS machine was put into one. The flame was ignited so the sample will be aspirated into the flame and then be atomized. This made the excited silver atoms in the sample to absorb the emitted light from the lamp and on return to ground state; emitted light was transduced and quantified as a concentration of silver present.

3. Results and Discussion

The results of the titrimetric analysis are presented in Table 1. pH and concentration of the resultant CCAE solution are also given in Table 1. The neutralization reaction was according to the reaction,

$$KOH_{(aq)} + HCl_{(aq)} \rightarrow KCl_{(aq)} + H_2O.$$

Therefore using the expression,
$M_aV_a x\ n_b = M_bV_b\ x\ n_a$ where n_a(mole ratio =1), M_a and M_b are concentrations of acid and concentration of K^+ base, V_a and V_b are volumes of acid and base respectively, concentration of K^+ in CCAE solution was obtained.

Table 1: Titre values, pH and concentration of CCAE

Weight of CCA dissolved in 500ml of distilled water (g)	Conc. of Acid Used (M)	Titre (cm^3)			Vol. of Acid used (cm^3)	Conc. Of K^+(mol /dm^3) in CCAE solution	pH of CCAE solution
		1st	2nd	3rd			
20.00	1.00	6.70	6.50	6.10	6.43	0.26	12.00
40.00	1.00	11.90	11.40	11.10	11.47	0.46	12.40
60.00	1.00	16.10	16.00	16.30	16.33	0.65	12.50
80.00	1.00	18.80	18.90	19.00	18.90	0.76	12.50
100.00	1.00	22.60	22.80	22.50	22.63	0.91	12.70

Table 1 is an indication that the contents in CCAE neutralized 0.1M HCl. This confirms the availability of alkaline potassium ion as one of the constituents

Titrimetric Analysis

In Table 1, concentration of (K^+) in CCAE solution was obtained as 0.26, 0.46, 0.65, 0.76 and 0.91 mol/dm^3 for dissolved ash, 20, 40, 60, 80 and 100g respectively. Increase in quantity of ash got more concentrated solution as expected. More ash in solution means more constituent ions (K^+) hence the higher concentration.

Table 2: Concentration of silver in each extracts from AAS Analysis

Grams of ash dissolved	Conc. of K^+ (mol/dm^3)	Conc. of Silver (ppm)
20	0.26	3.757
40	0.46	3.989
60	0.65	4.059
80	0.76	4.317
100	0.91	4.876

The concentration of silver ions in the extracts as measured by the AAS instrument is presented in Table 2. The values further confirm that CCAE actually stripped the films of silver. Since silver lamp sensitive to only silver was used in the AAS, it can be deduced that the exact amount of silver in the CCAE was correctly measured by the instrument. Further examination of Table 2 reveals that amount of silver recovered increased as concentration of CCAE increased. However, this increase is not proportional to the amount of ash dissolved in each instance. 20g of ash extracted 3.757g; one would have expected the 100g to extract 5 x 3.757 or 18.785g of silver ions instead of 4.876g (same for other grams of ash). It is therefore obvious that higher concentration of CCAE extract more impurities in addition to silver. In other words the higher the concentration of extract the more impurities extracted along with silver ion. This observation has been reported in our earlier work (Orubite and Don- Lawson 2016 and Okorosaye - Orubite and Gbarakoro 2018). The complex formation properties of silver in the presence of the OH^- have always been implicated for the reduction of free Ag+ ions in solution through the formation of the two coordinate complex, $[Ag(OH)_2\ ]^{2+}$.

4. Conclusion

The determination of potassium ion concentration in coconut coir and its application in the recovery of silver from x-ray films has been reported. CCAE contains K^+ ions as evident in the titrimetric analysis. Concentrations of K^+ in different grams of CCAE used, ranged from 0.26 - 0.91 mol/dm^3. These solutions were efficient in the stripping silver from the x-ray films (3.757 – 4.876 g).The concentration of silver recovered increased slightly as CCAE concentration increased but was not proportional to amount of ash dissolved. Although, more ash meant more K^+, more OH^- was also available for complex formation with Ag^+ ions which subsequently limited the availability of free Ag^+ ions.

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