



## Use of Pelletized Waste Electronic Plastic Casings in Sorbing Metals from Water

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### Abstract

Discarded electronic waste is an emerging global source of waste concern. In Nigeria, monthly consignments of 400,000 used electronics arrive Lagos ports monthly. Most of these electronics have plastic casings which are usually high density polyethylene (HDPE). Plastics possess basic properties needed for adsorptive treatment of water, due to their high carbon content. Therefore, the current study aims at investigating the usefulness of pelletized discarded electrical fittings for the removal of heavy metals from water and wastewater. The plastic case of some electronic wastes were pelletized, sieved and mixed with contaminated borehole, river and pharmaceutical effluent samples for treatment purposes. The water samples were sourced from Ota, Ogun State, Nigeria. The initial and post-treatment metal concentrations in the water samples were determined using atomic adsorption spectrophotometer. The river water sample was found to contain chromium and nickel concentrations which exceeded national standard of 0.05 and 0.02 mg/l respectively. The borehole water sample contained iron levels of 0.357 mg/l, which slightly exceeded the national limit of 0.3 mg/l. The pharmaceutical effluent was also found to contain cadmium and nickel contaminant levels of 0.015 and 0.0228 mg/l respectively which exceeded national standard limits of 0.003 and 0.02 mg/l respectively. After treatment with pelletized electrical plastics (PEP), all water and wastewater samples had metal removal rates of 93 – 100%, thereby demonstrating that PEP has a high potential for removal of heavy metals.

*Keywords:* water, adsorption, metals, electronic plastic pellets, treatment

### 1. Introduction

Electronic and electrical (E & E) items have become indispensable to daily living. Thus, millions of electronic units are sold every day [1]. A downside to this high demand for E & E products is that associated wastes are fast becoming environmental threat [2]. The larger percentage of E & E items such as televisions, computers, and cell phones are made up of components such as circuit boards and cables enclosed in high density polyethylene (HDPE plastic). Plastics are non-biodegradable, thus constituting major sources of municipal wastes. When these items are disused, the components are often separated by scavengers and recyclers who try to retrieve precious metals such as gold, lead, silver and copper from them [2]. In high concentrations, these metals are deleterious to public health and the environment in general, thereby causing most E & E wastes to be classified as toxic wastes [3]. In Nigeria, over 400, 000 used electrical components arrive Lagos ports on a monthly basis [3,4]. When improperly disposed, metals from such components are leached into water bodies, thus becoming a major source of heavy metal pollution to the environment. According to Li, Richardson, Walker and Youn [5], 27% of lead found in the environment originate from E & E wastes. The HDPE plastic casings, on the other hand, constitute another form of municipal waste. However, due to its high carbon contents, E & E plastic casings may be re-used in the removal of heavy metals from the environment thereby addressing the dual problems of waste reduction and removal of heavy metals originating from E & E components. The removal of heavy metals from water and wastewater using adsorptive materials is a widely known technique. Much research has gone into finding the ultimate adsorptive material and the optimum conditions for such material, thereby leading to scores of published results [6-11]. The common factor in the

selection of any adsorptive material, however, is the potential for carbon content of the material. Virtually all materials used in adsorptive studies have high carbon content, which is often enhanced through carbonization, which is the burning of the adsorptive material at temperatures ranging from 200°C - 800°C (when using chemical activation) or 800°C to 1000°C (for physical activation) [9]. The carbon content of such materials are increased in the process of charring, while the newly produced pores are widened and sensitized through an oxidation process which is also known as activation. Adsorptive materials that have been utilized for water and wastewater treatment are waste automotive tires, red mud, limestone, pine needles, kaolin, wood, clay, goethite, humic acid, human hair, hematite or feldspar, blast furnace slags, cactus leaves, polymer materials, tea leaves, tree fern, leather waste, orange juice residue, coconut coir pith, ferruginous manganese ore, peat, dry plants, fly ash, zeolites, hydrotalcites, hydroxides among others [7,12,13]. Aside from the materials used, varied experimental methods and conditions are also reported to have direct impact on treatment efficiency. Such conditions include pH, initial concentration of metal, temperature [14], pore volume of adsorbent, pore volume distribution [15], Brunauer-Emmett Teller (BET) surface area of the adsorbent [6], activation technique, activating reagent, dosage of adsorbent, contact time of water with adsorptive material, etc [6]. Therefore, the current study aims at investigating the usefulness of pelletized discarded electrical fittings for the removal of heavy metals from water and wastewater using pelletized HDPE.

## 2. Materials and methods

### 2.1 Study Area

The Study was conducted in Ota, an industrial-cum-residential settlement in Ogun State, Nigeria [16,17]. Ota is the most populated municipal authority in Ogun State while Ogun State is the only land boundary to Lagos State. This makes Ogun State the gateway between Lagos (one of the world's mega cities) and the rest of the country. Being one of such boundary communities with Lagos state, Ota serves as host to industrial concerns and residents, who primarily work or trade in Lagos State. Due to the industrial presence, much untreated effluents are discharged into the environment [17,18]. This has had a lot of impact on surface water bodies, groundwater bodies, and the surrounding soil, thereby placing public health at risk.

### 2.2 Preparation of Adsorptive material

Pelletized electrical plastics (PEP) were purchased from local plastic recyclers situated in Ota, Ogun State, Nigeria (Fig. 1a). Recyclers obtained the discarded plastics from scavengers who source them from open dumps and construction waste sites. Plastic pellets which passed through 2.38 mm sieve (standard mesh no. 8) (Fig. 1b) were soaked in 1 N sodium hydroxide (NaOH) solution for two hours [6]. While being soaked, the temperature was gradually increased from the original room temperature of 27°C to 54°C. Subsequently, the soaked plastic pellets was sieved from the NaOH solution and dried in an oven (Fig. 2b), with incremental temperature of 40°C at 15-minute intervals until a temperature of 200°C was achieved at the end of 1 hour. After drying, the pellets were rinsed twice with 0.5 N hydrochloric acid (HCL). Thereafter, the pellets were rinsed again with distilled water to remove any leftover chemical from the process of activation. The washed pellets were dried again in the oven for 1 hour at a temperature of 120°C [8] before use in water treatment (Fig. 2b).



**Figure 1(a):** PEP after sieving



**Figure 1(b):** The mechanical sieve shaker



**Figure 2 (a):** PEP is dried in oven



**Figure 2(b):** PEP being used to treat the water sample with the aid of a magnetic stirrer

### 2.3 Preparation of water samples

Water samples were obtained in Ota from three different sources: River Atuwara, borehole located on Covenant University campus and effluent sample from a pharmaceutical company. All three samples were collected in three different 4-litre plastic containers and transported to the Environmental Engineering laboratory of Covenant University. All water samples were tested for heavy metal contaminants such as Iron, Cadmium, Chromium, Copper, Zinc, Sodium, Potassium, Magnesium, Calcium and Nickel, with the aid of an atomic absorption spectroscopy (AAS). For this experiment, only two factors (dosage of adsorbent and contact time of adsorbent with water samples) were varied. At a constant time of 15 minutes of continuous stirring, a dosage of 20 g, 40 g, and 60 g was added to the water sample being treated (Fig. 2b). Subsequently, the dosage was held constant at 30 g while contact time between the adsorbent and water samples was varied at 10 minutes, 20 minutes, and 30 minutes respectively. At the end of each experiment, the pellets were sieved out from the water samples. All experiments were conducted in duplicates and an average value was taken per experiment. A total of 60 treated water samples (inclusive of duplicates) were generated. All the samples were stored in sterilized plastic containers and sealed. All water samples were labelled appropriately and tested for percentage removal of metals using AAS.

## 3. Results and discussion

### 3.1 Laboratory Results

Due to the adverse effect of heavy and trace metals on humans and other living things, different countries have evolved maximum contaminant limits (MCL) for different elements and compounds. The MCL for drinking water in Nigeria is known as National Standard for Drinking Water Quality (NSDWQ) and it is published by the Standards Organization of Nigeria (SON) [19]. The results of chemical analysis of the surface, groundwater and wastewater and the equivalent SON limits are presented in Table 1.

When compared with the National Standards for Drinking Water Quality, the results of the drinking water samples indicated that water sample from the river exceeded the SON limit [19] for Chromium and Nickel by 642% and 560% respectively. All tested parameters in the borehole sample, however, met the SON limit [19] with the exception of Iron which exceeded the limit by 119%. The metals of concern in the effluent were Cadmium and Nickel. When compared with SON limit for drinking water, both exceeded the MCL by 500% and 114% respectively. However, when compared with Federal Environmental Protection Agency industrial guidelines for effluent discharge [20], Cadmium exceeded the national standard limit of 0.01 mg/l while nickel was below the national limit of 1.0 mg/l.

### 3.2 Removal of Nickel

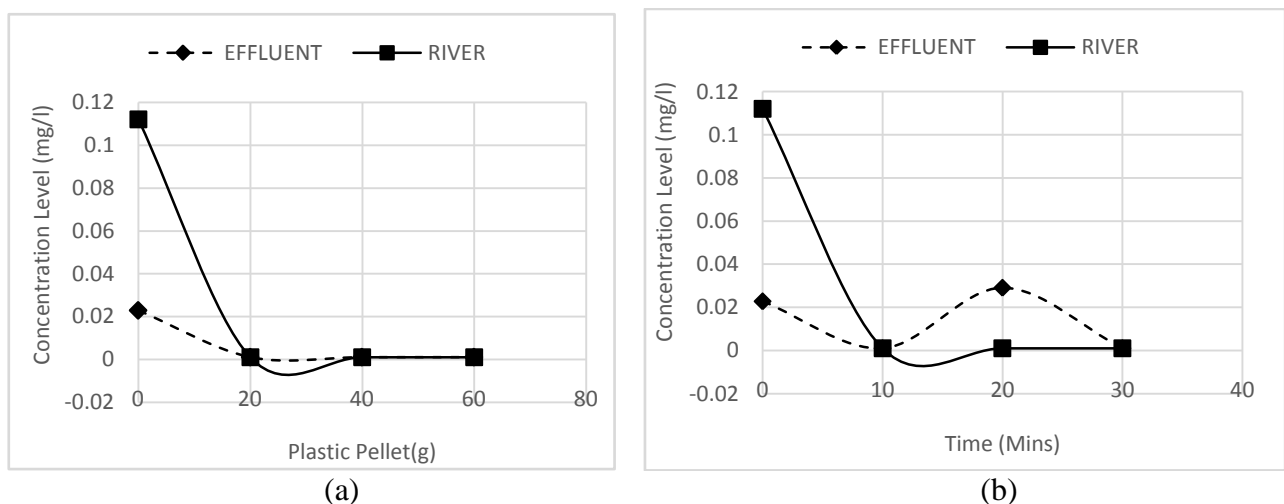
Nickel is abundant in the environment because of its relevance in the manufacturing sector. Duda-Chodak and Blaszczyk [21] stated that as much as 150,000 to 180,000 metric tons of Nickel is generated globally from natural and anthropogenic sources annually. It is used as catalyst and pigment in metallurgical, chemical and

food processing industries [22]. Nickel is vital in the production of stainless steel and other metallic alloys having high corrosion and temperature resistance [23].

**Table 1:** Detected metals in water samples prior to treatment

Parameters (mg/l)	River	Borehole	Pharmaceutica l Effluent	SON (limit)
Iron	0.119	0.357	0.2	0.3
Cadmium	<0.001	<0.001	0.015	0.003
Chromium	0.321	<0.001	0.006	0.05
Copper	<0.001	<0.001	0.03	1.0
Zinc	0.137	0.003	0.117	3.0
Sodium	190.97	186.058	ND	200
Potassium	0.194	0.010	ND	20
Magnesium	0.119	0.056	ND	0.2
Calcium	<0.001	0.024	ND	200
Nickel	0.112	0.002	0.0228	0.02

A reduction in Nickel concentration in both effluent and river water samples was observed, following treatment using PEP. When 20 g of PEP was added to the river water sample while holding the treatment time constant at 15 minutes, the Nickel content of the sample was reduced by 100%. Thus, the subsequent dosages of 40 and 60 g respectively were unnecessary as the treatment was complete at the initial dosage of 20 g (Fig. 3a). Similarly, the Nickel concentration in the pharmaceutical effluent was reduced by 100% after the initial dosage of 20 g of PEP (Fig. 3a). Again, when the dosage was held constant at 30 g, and time varied, the treatment became complete at the initial time of 10 minutes for both the effluent and river water samples (Fig. 3b). The observed rise in Nickel concentration in the effluent sample after 20 minutes could be due measurement error (Fig. 3b).



**Figure 3:** Comparative pre-treatment and post-treatment concentration of Nickel in effluent and river water samples with (a) varied dosage-constant time (b) constant dosage-varied time.

Therefore, it could be deduced that Nickel was completely removed from both effluent and river water within 15 minutes when 20 g of PEP was used for treatment.

Nickel has serious adverse effects on human health, especially when inhaled [21]. Nickel causes peripheral neuropathy and brain damage in humans [17]. It is also a carcinogen [19]. However, the highest volume of Nickel found in the human body is traceable to food and drinks [22]. Other effects of Nickel in the human body

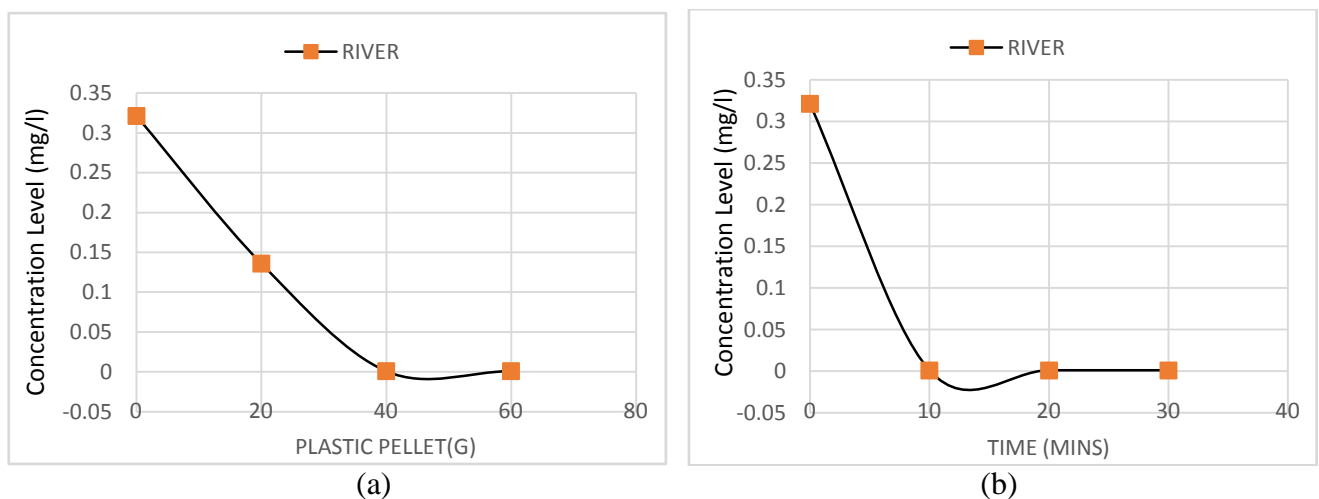


include cancer of the respiratory tract and skin allergies such as dermatitis and eczema [22]. Studies also showed that women are five times more susceptible to nickel poisoning than men, possibly because women make more contact with nickel-laden jewelries, pigmented shampoos and detergents than men [21,22]. Excess Nickel is often expelled from the human body and traces of this can be found in human hair, saliva, urine, breast milk and excreta [21].

### 3.3 Removal of Chromium

Sodium chromate and sodium dichromate are two of the most common salts which are often used in leather tanning, corrosion control and manufacture of chromic acid, and pigments [24,25].

A removal rate of 100% was achieved for chromium contaminant found in the river water sample using PEP. The treatment process showed a progressive reduction in the contaminant level of chromium in the water sample in direct response to increment in PEP dosage (Fig. 4a). The 100% removal was achieved after the addition of 40 g dosage at a constant treatment time of 15 minutes (Fig. 4a). Furthermore, when the PEP dosage was held constant, 100% removal of chromium was achieved after 10 minutes of treatment, using 30 g of plastic pellets. Thus, the optimum chromium removal condition identified through this experiment was achieved when 40 g of PEP was applied to the water sample in 15 minutes or 30 g of PEP in 10 minutes.



**Figure 4:** Pre-treatment and post-treatment concentration of Chromium in river water sample with (a) varied dosage-constant time and (b) constant dosage-varied time.

Chromium is a carcinogen and therefore deleterious to public health [19]. Some of the reported adverse health effects include necrosis of vital internal organs such as liver and kidneys, internal bleeding, ulcers, corrosion of the respiratory tract and dermatitis [24].

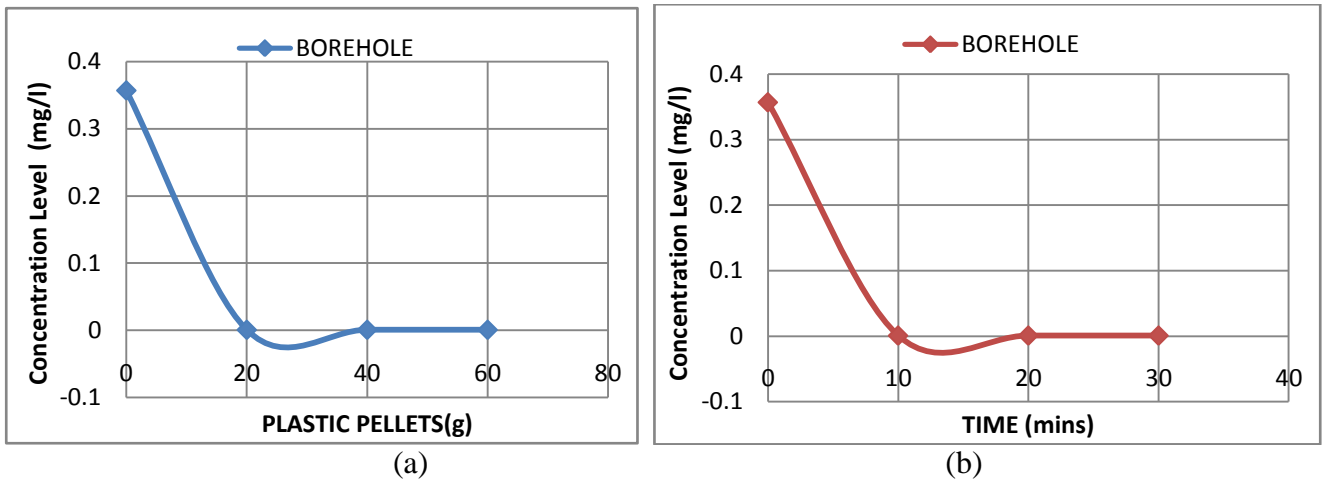
### 3.4 Removal of Iron

Lateritic soils, such as found in Ota, contain Iron minerals in abundance [26]. This is easily leached into groundwater and transferred into households. In this study, the iron content in the borehole water sample was removed 100% at the initial treatment PEP dosage of 20 g and stirring time of 15 minutes (Fig. 5a). Also, when a constant dosage of 30 g was used, the iron was reduced to 0 mg/l within 10 minutes (Fig. 5b).

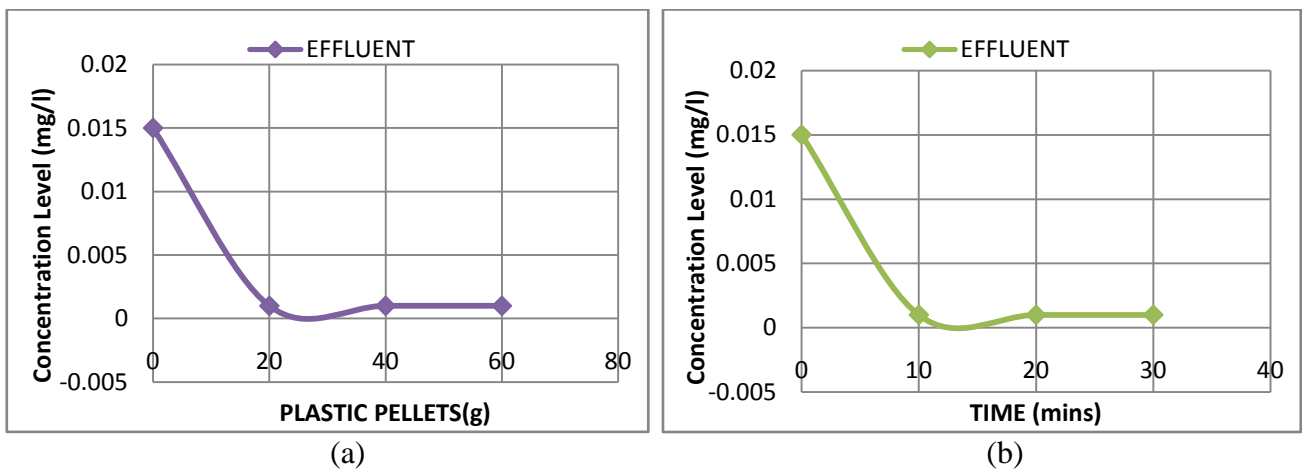
While iron may not be of significant health hazard, excess iron in domestic water supply create other forms of nuisances such as stains on human teeth and on sanitary ceramic wares used in homes [26].

### 3.5 Removal of Cadmium

Cadmium is a highly toxic metal that is used in the manufacture of nickel-cadmium batteries, paint pigments, polyvinyl chloride plastics, electroplating, fungicides, pesticides and several metallurgical activities [26-28]. The cadmium contaminant found in the pharmaceutical effluent in Ota was reduced by 93.3 % (0.015 mg/l to 0.001 mg/l), at the initial PEP dosage of 20 g at constant stirring time of 15 minutes (Fig. 6a). Likewise, the same rate of removal of 93.3% was achieved within 10 minutes when the effluent was treated with 30 g of PEP (Fig. 6b).



**Figure 5:** Pre-treatment and post-treatment concentration of Iron in borehole water sample with (a) varied dosage-constant time (b) constant dosage-varied time



**Figure 6:** Pre-treatment and post-treatment concentration of Cadmium in Effluent sample with (a) varied dosage-constant time and (b) constant dosage-varied time

When ingested, Cadmium primarily leads to formation of kidney stones and osteoporosis [27]. There is also evidence that tobacco leaves are high absorbents for cadmium, thus placing smokers at high risk of cadmium poisoning [27].

### Conclusion

This study demonstrated the potential of PEP as a good material in the removal of metals from drinking and wastewater. Significant removal of metals such as cadmium, iron, chromium and nickel was observed mostly within 10 minutes of stirring, using PEP dosage of 20 mg. However, further studies need to be carried out in order to establish the capacity and optimum conditions for treatment of water using PEP. Such study should explore the performance of PEP vis-à-vis pollutant concentration. It was observed from this study that although the treatment efficiency was 100% in most of the water samples used, the metal concentration in all samples could be considered as relatively low. Thus, future researchers may consider synthesizing the metal pollutants in the laboratory in order to investigate the rate of metal removal at higher concentrations and maximum adsorbing capacity of PEP for various metals. Furthermore, future studies should include an investigation into the effect of PEP particle size, PEP surface morphology, mode of activation (chemical and physical), activation temperature, pH, and PEP pore volume on optimum adsorptive conditions. If found to be a good metal adsorptive material, PEP could be find better use in water treatment, thereby constituting less environmental nuisance.

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