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## Recyclability Potentials of Beryllium Oxide from E-waste Items in Nigeria

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**Abstract:** E-waste has become a serious issue to engage African scholarship because the region has become a dumping ground for e-waste, which often contains toxic and hazardous chemical and other components, thereby posing environmental sustainability challenges. Chemistry could play a key role in the management and control of this waste now growing exponentially. This study investigated the recyclability potentials of beryllium oxide—a hazardous chemical compound found in significant quantity in e-waste items. The possibility of recovering the compound from some e-waste items and converting it to beryllium chloride for use as catalyst in laboratories and industry were studied.

**Key words:** Recycling, hazardous chemicals, electronic waste

### INTRODUCTION

E-waste is being sent, sometimes illegally, to China, Malaysia, India and various African countries, for processing. Many surplus laptops are routed to developing countries as dumping grounds for e-waste (Morgan, 2006). E-waste is routinely exported by developed countries to developing ones, often in violation of international law. Inspections of 18 European seaports in 2005 found as much as 47% of illegal waste, including e-waste, destined for export. In the United Kingdom (UK) alone, at least 23,000 metric tons of undeclared or grey market electronic waste was illegally shipped in 2003 to Asia (China and India) and also to Africa. In the United States of America (USA), it is estimated that 50-80% of the waste collected for recycling is being exported in this way (Forge, 2007).

Mountains of e-wastes are found in major ICTs trading centres in Africa, such as The Computer Village in Lagos, Nigeria. The throw-away mentality and mobile consumption habit of Africans, fueled by weak and/or absence of waste management infrastructure, combine to worsen matters. The local government authorities and companies dump e-waste in open fields near residences or at best incinerate them. In some cases, they are pushed to landfills, thereby posing serious health and environmental hazard to the people and environment, because toxic chemicals in e-waste can leach into the land over time or are released in the atmosphere, impacting nearby communities and the environment. While legislations are used in the developed countries to control this manner of disposal, Africa lacks the capacity for such enforcement, as even some multinationals that contribute to the environmental degradation are more powerful than some African countries (Slade, 2006; Nkamnebe, 2010; Forge, 2007).

Another e-waste processing and handling practice in Africa is tossing e-waste equipment into an open fire in order to melt plastics and to burn away invaluable metals. This is more harmful and wasteful because the process of burning e-wastes releases carcinogens and neurotoxins into the air, contributing to acrid, lingering smog. These noxious fumes include dioxin and furans, which largely consist of incineration residues or waste placed in landfill sites, coming from households, offices and commercial activities and may contain toxic or hazardous materials (Nkamnebe, 2010).

In Nigeria, for instance, bonfire refuse and other e-wastes are discarded into drainage ditches or water ways feeding the ocean or local water supplies. This does not only contaminate water bodies, but also results to blockage of drainages, leading to flooding, destroying lives and properties within flooded areas, causing diseases and economic wastes (Murali, 2009).

According to Murali (2009) and ITA (2009), up to 38 separate chemical substances or elements are incorporated into e-waste items. They can be classified according to their quantities in e-waste and into hazardous and non-hazardous components of e-waste. Accordingly, beryllium oxide (BeO) is not only hazardous, but also found in significant quantity in e-waste items. It is applied as filter in some interface materials (e.g., thermal grease used on heat sinks for computer processing units, CPUs and power transistors), magnetrons, x-ray transparent windows, heat transfer fins in vacuum tubes and glass lasers.

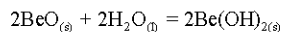
E-waste processing usually first involves recovery of the items from consumers and services providers. The equipment are dismantled into various parts (metal frames, power supplies, circuit boards, plastics), often by hand. This enables recognition of working and repairable parts, including chips, transistors, RAMs, etc. The alternative

process obtained in technologically advanced countries is the bulk system practice involving sophisticated shredding, separating, screening and granulating machines. Metal and plastic fractions are obtained, sold to smelters or plastic recyclers. Magnets, eddy currents and trammel screens are employed to separate glass, plastic and ferrous and non-ferrous metals, which can be further separated at a smelter. Leaded glass from Cathode Ray Tubes (CRTs) is reused in car batteries, ammunition and lead wheel weights, or sold to foundries as a fluxing agent in processing raw lead ore. Copper, gold, palladium, silver and tin are valuable metals sold to smelters for recycling. Hazardous smoke and gases are captured, contained and treated to mitigate environmental threat (Wikipedia, 2010a).

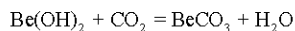
According to the report issued by the United Nations Environmental Programme (UNEP), e-waste from products, such as old computers, printers, mobile phones, pagers, digital photo and music devices, refrigerators, toys and televisions, are set to rise sharply in tandem with growth in sales in countries like China and India and in Latin America over the next 10 years. With the mountains of hazardous waste from electronic products growing exponentially in developing countries, sometimes by as much as 500%, the United Nations on 22 February 2010 called for new recycling technologies and regulations to safeguard both public health and the environment (United States Environmental Protection Agency, 2010).

So far, environmental development intervention efforts concentrate on erosion control, petroleum gas flaring and other factors of environmental degradation in Nigeria. There is the need to study the recyclability potentials of BeO for a more environmentally sustainable Africa. Accordingly, this study aimed at extracting BeO from e-waste and converting it to beryllium chloride for use as catalyst in schools and industry.

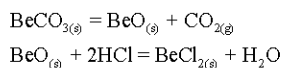
Beryllium(II) oxide reacts readily with water to form the hydroxide (alkali) (Kneen *et al.*, 1972):



The solution of the alkali picks carbon (IV) oxide from the air to form beryllium (II) trioxocarbonate (IV) (Kneen *et al.*, 1972):



The resulting beryllium (II) trioxocarbonate (IV) is decomposed by heating to carbon (IV) oxide gas and beryllium (II) oxide, BeO, which reacts with dilute hydrochloric acid to form the beryllium chloride, as follows:



Beryllium chloride is white or yellow crystal with melting point of 399°C, boiling point of 482°C and solubility in water of 15.1 g/100 mL (20°C). It is soluble in alcohol, ether and pyridine, but insoluble in benzene, chloroform, acetone and ammonia (Wikipedia, 2010b). According to hazard database (online), it is soluble in benzene, ether, chloroform and carbon disulphide and insoluble in ammonia and acetone. It emits toxic fumes of hydrochloric acid and other chlorinated compounds. The primary routes of potential human exposure to beryllium and certain beryllium compounds are inhalation and dermal contact.

## MATERIALS AND METHODS

**Materials:** All chemicals (analytical reagent grade) and laboratory wares and equipment were available in the Department of Pure and Industrial Chemistry, University of Nigeria, Nsukka; Project Development Institute (PRODA), Emene-Enugu; Faculty of Health Sciences and Technology and the Chemical Pathology Laboratory in the Department of Biochemistry, College of Medicine, Enugu Campus, University of Nigeria, Nsukka. E-waste items were collected from computer vendors in C-To-C Business Plaza, Nkpokiti Street, Enugu, Nigeria. Mechanical crusher and pulverizer were sourced from industrial machine fabricators and industrial support services providers at the Eastern Nigeria Industrial Estate, 30 Zik Avenue, Uwani, Enugu, Nigeria.

**Methods:** Beryllium (II) oxide serves as filter in some thermal interface materials, such as thermal grease used on heat sinks for Central Processing Units (CPUs) and power transistors, magnetrons, x-rays-transparent ceramic windows, heat transfer fins in vacuum tubes and glass lasers. E-waste items containing these materials were recovered from electronic services providers and consumers. The thermal interface materials were extracted mechanically from these items, crushed and powdered.

**Chemical recycling of beryllium(II) oxide from e-waste items:** Twenty grams of the crushed and powdered e-waste items containing beryllium (II) oxide was hydrolysed to beryllium hydroxide (alkali) by soaking and shaking for 2 h in 100 mL distilled deionised water containing 10 mL emulsifying agent (previously prepared by soaking overnight 1 g granule in 100 mL distilled deionised water).

The resulting alkali was allowed to stand in open bath for 6 hours to pick carbon (IV) oxide from the air to form beryllium (II) trioxocarbonate (IV).

The carbonate was decomposed by heating in the reactor until gas (which turned lime water milky) stopped

escaping and solid, beryllium (II) oxide, BeO, stopped forming.

The resulting BeO was reacted with 40 mL dilute hydrochloric acid to form beryllium chloride.

### Characterization of beryllium chloride

**Physical inspection:** The solid product was inspected for colour and nature.

**Solubility test in water:** About 15.1 g of the solid product was dissolved in 100 mL distilled deionised water in 250 mL conical flask, cooled in a refrigerator to 20°C and observed for solubility in water at 20°C. To 100 mL of alcohol, benzene, ether, chloroform, carbon disulphide, pyridine, acetone and ammonia contained in separate 250 mL conical flask, spatula-full of the solid was added and the flask was shaken to dissolve the solid.

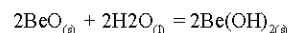
**Melting point test:** Using melting point apparatus, the melting point of the solid was obtained.

**Boiling point test:** Using boiling point apparatus, the boiling point of the melted solid was obtained.

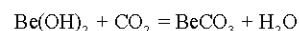
## RESULTS AND DISCUSSION

**Reactions of BeO:** The reactions of the powdered thermal interface materials from the e-waste items containing BeO

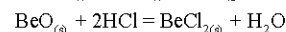
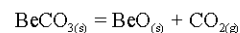
obeyed the established reactions of BeO as outlined by Kneen *et al.* (1972). Hence, under stipulated conditions, the powder reacted at various stages until the formation of BeCl<sub>2</sub>. Thus, the powdered material reacted readily with water to form the beryllium hydroxide (alkali):



Also, the solution of the alkali picked carbon (IV) oxide from the air to form beryllium (II) trioxocarbonate (IV):



The resulting beryllium (II) trioxocarbonate (IV) decomposed on heating to carbon (IV) oxide gas and beryllium (II) oxide, BeO, which reacted with dilute hydrochloric acid to form the beryllium chloride, as follows:



**Conversion of BeCO<sub>3</sub> to BeCl<sub>2</sub>:** On heating, the beryllium (II) trioxocarbonate (IV) decomposed and decrepitated to beryllium oxide and carbon dioxide, as follows:

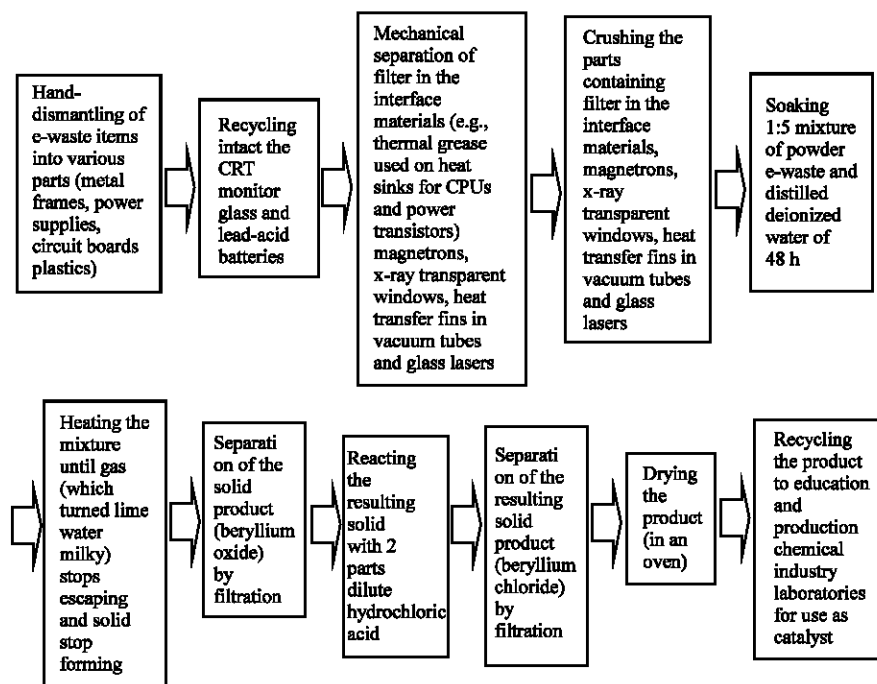
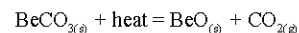


Fig. 1: Process chart for the extraction and recycling of beryllium oxide from e-waste items

Ababio (1993) reports that beryllium (II) trioxocarbonate(IV) decomposed and decrepitated on heating to beryllium oxide and carbon dioxide.

**Characterization of BeCl<sub>2</sub>:** The product was yellowish white crystal with melting point of 399°C, boiling point of 482°C and solubility in water of 15.1 g/100 mL (20°C). It was also soluble in alcohol, ether, benzene, chloroform, carbon disulphide and pyridine, but insoluble in, acetone and ammonia. The results conformed to the literature stipulations (Wikipedia 2010c; Ababio, 1993; Daintith, 2000; Kneen *et al.*, 1972; Ohia *et al.*, 2005) and agreed in most part with the claim of hazard database (online) that BeCl<sub>2</sub> was soluble in benzene, ether, chloroform and carbon disulphide, but insoluble in ammonia and acetone. The finding on solubility did not conform, however, with the claim of Wikipedia (2010b) that BeCl<sub>2</sub> is soluble in alcohol, ether and pyridine, but insoluble in benzene, chloroform, acetone and ammonia. This discrepancy cannot be explained, yet.

**Process chart for the extraction and recycling of BeO from e-waste items:** The process chart for the extraction and recycling of beryllium oxide from e-waste item is given in Fig. 1.

## CONCLUSION AND RECOMMENDATIONS

ICTs have become the highway through which nation states and global citizens can access the global market system. In the belief that ICTs infusion would leverage them developmentally in the information milieu, Nigeria and other developing countries in Africa are fast adopting ICTs for development leapfrogging. Only the inferior and secondhand ICTs facilities flow in these countries because of affordability in the midst of pervading poverty. Therefore, the facilities soon outlive their usefulness and are discarded, albeit improperly, leading to environmental hazards growing with the exponential growth of e-waste items in these countries.

BeO is a hazardous chemical compound contained in significant quantity in e-waste items. This study investigated the recyclability potentials of BeO in e-waste items in Nigeria. The BeO-rich thermal interface materials in e-waste items were extracted mechanically, crushed, powdered and converted to BeCl<sub>2</sub> channeled to schools and industry for use as catalyst in some organic reactions.

It is recommended that e-waste items containing BeO should be recovered and converted to BeCl<sub>2</sub> for recycling. This will help in reducing health hazards and environmental unsustainability arising from discarded e-waste containing BeO.

## ACKNOWLEDGMENT

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