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An Appraisal of the Environmental Health Significance of Crude Beryllium Oxide-extract from Waste Electrical and Electronic Equipment

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ABSTRACT

Increasing integration of information communications technology is responsible for rapid generation of Waste Electrical and Electronic Equipment (WEEE) in developing countries. WEEE contains beryllium oxide (BeO) with environmental health significance that can be measured through its acute toxicity. This study aimed to determine the acute toxicity of BeO-extract from interface materials of WEEE. Dil. HCl and diethyl ether tests confirmed the presence of BeO in the extract. Single linear regression of mortality against dose was done. Results showed that the extract contained BeO. There was a perfect correlation between the log dose of crude BeO-extract and %mortality of rats. The relationship between them was significant at 0.01, with 0.99 degree of confidence. The R^2 (0.885) and significant F (0.017) showed high reliability. The high LD_{50} (1,600 mg kg^{-1}) showed that the environmental health significance of the emission of BeO from WEEE materials may be too little for concern. Sensitizing the people on disposal of WEEE from homes, offices and workshops, proper sanitation practices and policy-making and implementation were recommended.

Key words: Hazardous chemical, electrical waste, electronic equipment, acute toxicity

INTRODUCTION

Reasons have been advanced for the rapid rate of generation of Waste Electrical and Electronic Equipment (WEEE) in developing countries. In the bid to bridge the information gap and the resultant marginalization in the global market system, developing countries, hitherto known for information poverty, are hurriedly adopting ICT (Mutula, 2005).

The citizens of developing countries with very high level of poverty (ADB, 2007) can only afford the cheap, inferior and second-hand ICT facilities, which soon spoil and are discarded. Again, developed countries take advantage of weak regulation in developing countries to dump outright e-wastes or those disguised in form of fairly used ICT products (Forge, 2007).

Furthermore, ICT products manufacture is designed to increasingly reduce the life-cycle of the products. Thus, new models of software and their service parts are made incompatible with old ones to render older versions obsolete. This systematically discourages the usage of even functional old products and panders to the throw-away mentality of Africans with the attendant hazardous environment health implications (Nkamnebe, 2010).

The United Nations Environment Programme (UNEP) estimates that as much as 50 million tons of e-wastes are generated worldwide each year. Increasing at a rate of 3-5% per year (faster than any other category of waste), the global volume of e-wastes produced annually is expected to double soon. The volume of e-wastes being generated grossly outweighs the existing capacity to manage it in an environmentally sustainable way (Walraven, 2007).

Beryllium oxide (BeO) is one of the hazardous chemical compounds contained in significant quantity in WEEE materials. It is applied as filter in the interface materials in virtually all Information Communications Technology (ICT) products found in homes, offices, workshops and indiscriminately dumped in public sites by local waste and environmental sanitation authorities in Nigeria (Eneh, 2011; Eneh and Agunwamba, 2011).

BeO is a highly toxic cancer agent. It has the same effects on health as asbestos, makes pollution worse, is extremely toxic by inhalation and ingestion and comparable with potassium cyanide-a highly poisonous compound. Beryllium compounds are probable human carcinogens, serious respiratory irritants and may be harmful by skin contact. Therefore, emission of toxic BeO may be environmentally significant, especially for Electrical and Electronic Equipment (EEE) repairers and vendors and the general public that inhale the toxic chemical gases released in the atmosphere from WEEE improperly disposed of by local solid waste management authorities (Aldrich, 1997; Forge, 2007; Lacombe, 2001).

The purpose of the study was to establish the environmental health significance of beryllium oxide contained in significant quantity in WEEE, which abound in homes and offices and litter the city landscape or public dumpsites in developing countries, where environmental regulations and compliance are weak. The specific objectives were to carry out the acute toxicity test with crude beryllium oxide-extract from WEEE materials. The study assumed that a dose of crude beryllium oxide-extract from WEEE would not be significantly related to the number of deaths of experimental rats to which it was acutely exposed.

Definitions have been given for electronic waste (e-waste) or electronic scrap (e-scrap) or waste electrical and electronic equipment (WEEE or W-EEE) (Prashant, 2008), hazardous waste (EEA, 2006), pollution (Williams, 2001), pollutants (Van-Loon and Duffy, 2000), toxicity test (Randhawa, 2009), acute exposure (Akah *et al.*, 2009), chronic exposure (Akah *et al.*, 2009), exposure time (Akah *et al.*, 2009), lethal dose 50 or LD_{50} (Randhawa, 2009) and lethal concentration 50 or LC_{50} (Akah *et al.*, 2009).

MATERIALS AND METHODS

The study was conducted between February and August 2011. Rats, chemicals (analytical reagent grade) and laboratory equipment were obtained from the laboratory of the Department of Medical Laboratory Sciences, Faculty of Health Sciences and Technology, College of Medicine, Enugu Campus, University of Nigeria, Nsukka. WEEE materials were collected from vendors of ICTs spare-parts and ICT products repairers in C-To-C Business Plaza, Nkpokiti Street, Enugu, Nigeria.

Crude beryllium oxide-extract was obtained from WEEE materials, which were first hand-dismantled into various parts, while the parts containing beryllium oxide was mechanically separated and extracted by scraping the filter in the interface materials. To confirm that the crude extract contained beryllium oxide, it was tested qualitatively by treatment with dil. HCl (to see if it would form white-yellow crystals) followed by addition of diethyl ether to the crystal (to see if it would dissolve) (Ababio, 2005; Kneen, 1972).

The modified method of Miller and Tainter (1944) was used for the acute toxicity tests of crude beryllium oxide-extract from WEEE materials. In the preliminary studies carried out to determine the dose range to be used in the acute toxicity tests, animals in groups of close weight ranges (n = 20 for each group) were exposed to doses of 50, 100, 200, 400, 800, 1600, 3200, 6400, 12800 and 25600 mg kg^{-1} of the crude beryllium oxide-extract in NaOH (1 N) solvent for 24 h. The control set was exposed to the solvent without the extract. After oral administration, the animals were observed regularly and mortality recorded at 3, 6, 12 and 24 h. Subsequently, a series of five doses (800, 1600, 3200, 6400 and 12800 mg kg^{-1}), between the dose that killed a few or none of the animals and all or most of the animals, were selected and used for acute toxicity tests (Randhawa, 2009).

The percentage of animals that had died at each dose level was then transformed to probit. The probits for 0 and 100% were corrected, using the formula (Randhawa, 2009).

Corrected % formula for 0 and 100% mortality:

$$\text{Mortality (0\%)} = \frac{0.25}{n}\times 100$$

$$\text{Mortality (100\%)} = \frac{n-0.25}{n}\times 100$$

Statistical analysis: The probit values (y) were plotted against log-doses (x). The log dose corresponding to probit 5 was traced and the anti-log noted as the value for LD_{50}, lethal dose, which killed 50% of the animals (Randhawa, 2009).

The data were correlated using the Single Linear Regression (SLR) analysis of the Statistical Package for Social Sciences (SPSS), involving the dependent variable (y) as the % dead against the independent variable (x) as the log dose of crude beryllium oxide-extract from WEEE materials (Nwabuokei, 2001).

RESULTS

Tests for beryllium oxide in crude extract from WEEE materials: The crude beryllium oxide-extract reacted with dil. HCl to form yellowish white crystals, which dissolved on addition of diethyl ether. This confirmed that the extract contained beryllium (II) oxide (Ababio, 2005; Daintith, 2000; Kneen, 1972), as illustrated in the reaction equation below:

$$BeO_{(s)}+2HCl = BeCl_{2\,(s)}+H_2O$$

Acute toxicity test: Table 1 contains the data from the acute toxicity tests with crude BeO-extract on rats. Doses of 800, 1600, 3200, 6400 and 12800 mg kg^{-1} killed 0, 10, 16, 18 and 20 rats, respectively. The corrected % values for 0 and 100% were 1.25 and 99.94%, respectively. From the plot of probit values of the % dead (y) against log-doses (x) (Fig. 1), the log dose corresponding to probit 5 was 3.20 and its anti-log was 1,600. Therefore, LD_{50} was 1,600 mg kg^{-1}.

Correlation of data and test of hypothesis: Table 2 shows selected data from the SLR of %dead (y) against log dose (x). The Pearson correlation value between the log dose of crude BeO-extract and % dead of experimental rats is 0.941, showing a perfect positive correlation. The one-tailed significance value is 0.009, showing that the relationship between %dead and log dose is significant at 0.01, with 0.99 degree of confidence. The R^2 (0.885) and the significant F (0.017), showed high reliability.

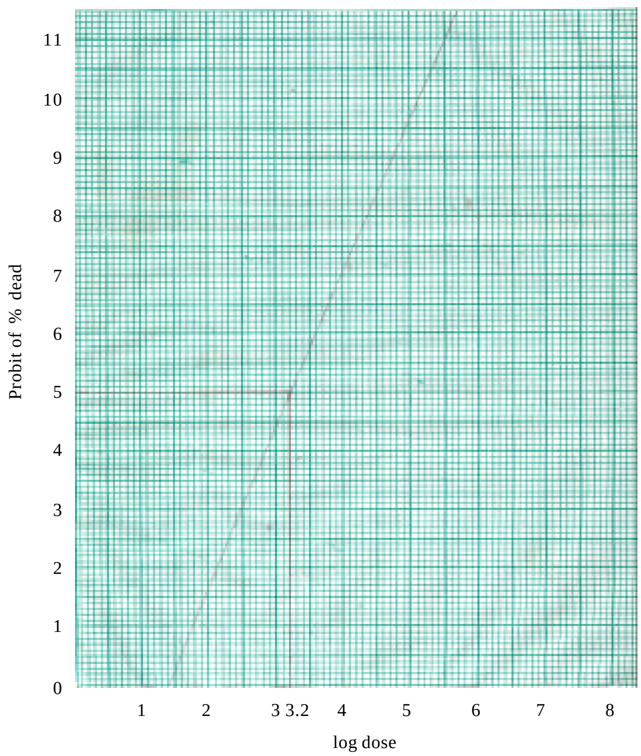

Fig. 1: Plot of probit of % dead against log dose for crude beryllium oxide-extract, LD_{50} of beryllium oxide-extract from e-waste materials

Table 1: Acute toxicity tests with crude beryllium oxide-extract from wastes-EEE (rat, oral)

Group	Dose (mg kg^{-1})	Log dose	N	Death rate	Dead (%)	Corrected (%)	Probits
1	800	2.90	20	0/20	0.00	1.25	2.70
2	1600	3.20	20	10/20	50.00	50.00	5.00
3	3200	3.51	20	16/20	80.00	80.00	5.84
4	6400	3.81	20	18/20	90.00	90.00	6.28
5	12800	4.11	20	20/20	100.00	99.94	7.33

Table 2: Selected statistical data from SLR analysis

Statistics	Parameters	Value
Correlations	Pearson correlation value between the log dose and %dead	0.941
	One-tailed significance	0.009
M/summary	R^2	0.885
	Significance F change	0.017

Source: SLR analysis (SPSS)

The high R^2 (0.885) showed a very high significant relationship between the % dead and log dose. Hence, the null hypothesis, A dose of crude beryllium oxide-extract from WEEE materials is not significantly related to the number of deaths of experimental rats to which it has been acutely exposed, was rejected for the alternative hypothesis, A dose of crude beryllium oxide-extract from WEEE materials is significantly related to the number of deaths of experimental rats to which it has been acutely exposed.

DISCUSSION

Crude BeO-extract from WEEE was mildly toxic, with LD_{50} of 1,600 mg kg^{-1} in rat. The finding was internally validated by a very high R^2 value of 0.885, a high significance F change value of 0.017 and a low significance interval of 0.01 or high 0.99 degree of confidence. For external validity, earlier reports (Aldrich, 1997; Budavari, 1989; Daintith, 2000; Lacombe, 2001) supported the finding by submitting that beryllium oxide had pretty much the same effects on health as asbestos, made pollution worse and was extremely toxic by inhalation and ingestion. Murali (2009) reported that beryllium and its compounds were toxic.

The LD_{50} of 1,600 mg kg^{-1} obtained for crude BeO-extract from WEEE materials differed from the literature range (between 0.5 and 5 mg kg^{-1}) of values for beryllium compounds. The difference may be explained by the fact that the BeO-extract was used in its crude form for the acute toxicity test, in order to represent the actual components of the gaseous mix from the emissions from WEEE containing BeO and other components. Obviously, crude BeO-extract is less toxic than pure beryllium oxide.

Another possible explanation for the difference between the LD_{50} obtained and the literature range of values is that most of the BeO had caked in the WEEE materials prior to its extraction. This suggests a denaturing effect on the BeO applied in EEE, which would alter the toxicity profile of the hazardous oxide. The LD_{50} of 1,600 mg kg^{-1} obtained for crude BeO-extract from waste-EEE materials was far higher than the (of much lower toxicity level) than the literature range (0.5-5 mg kg^{-1}) of values for beryllium compounds. Therefore, there was little or no cause for concern over the toxicity and lethality level of the emissions of beryllium oxide from WEEE materials.

Nonetheless, BeO-extract from WEEE is mildly toxic and a probable carcinogen. Since, no amount of poison is safe, people need to be sensitized on the mild toxicity of BeO in WEEE materials. Citizens of developing countries ought to be encouraged to dispose of WEEE materials from their homes and offices. Government should designate appropriate centres/bins for collection of WEEE materials from homes and offices and arrange to take them to the dumpsites for appropriate handling. Government should make and enforce policies on safety measures, including avoiding eating, smoking, or drinking in contaminated environment; avoiding breathing BeO dust or powder; use of safety glasses, gloves and good ventilation; treating BeO as a probable carcinogen; and preparing full risk assessment before starting to work with BeO.

CONCLUSION

Acute toxicity test showed mild toxicity for crude BeO-extract from WEEE. Pure BeO was more toxic than the crude BeO-extract from WEEE, on account of purity. Again, caked and denatured BeO extracted from WEEE was less toxic than fresh beryllium compounds. At 1,600 mg kg^{-1} (oral, rat), the LD_{50} obtained for crude BeO-extract from WEEE indicated much lower toxicity level than 0.5-5 mg kg^{-1} values obtained for beryllium compounds in the literature. Therefore, only caution was necessary over toxicity and lethality levels of the emissions of beryllium oxide from WEEE.

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