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TOXICITY OF LITHIUM BATTERY WASTE ON SELECTED INVERTEBRATES

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ABSTRACT

Electronic waste poses a major menace to ecosystems owing to the toxic properties of materials used for the manufacture of electronic goods. In this present study, the toxicity of lithium battery waste on invertebrates, snails (*Archachatina marginata*) and earthworms (*Apporrectodeal longa*) were evaluated using appropriate concentrations of toxicant. The physicochemical and heavy metal analysis of the toxicant was carried out according to the method of APHA (2008). The standard protocol obtained from the Organization for Economic Cooperation and Development (OECD) and the protocol obtained from the International Organization for Standardization (ISO) were adopted for the 14-day exposure to varying concentrations of the toxicant (0.3125, 0.625, 1.25, 2.5 and 5.0 mg/kg) for earthworm and (3.125,6.25, 12.5, 25 and 50 mg/kg) for snail respectively. The pH, Electrical conductivity. Total dissolved solids, Lithium, cadmium and mercury results of the toxicant were (2.6, 13500, 8640, 36.60, 2.03 and 10.48mg/L) respectively. The result also shows an increased in the mortality of test organisms with increase in toxicant concentration. LC_{50}, LOEC, NOEC, TUc and TUa with exposure time for snails and earthworms were (1.05, 0.86,0.77,94.88, 129.87 mg/kg) and (0.68, 0.41,0.31, 147.06, 322.58.mg/kg), respectively. The study established that the toxicant (lithium battery) is considered a high risk to animals, plants and the environment as it adversely affects soil invertebrates which bring about soil fertility if not properly disposed of.

Keywords: E-waste, Lithium battery waste, invertebrate, Toxicity

INTRODUCTION

The remarkable technological developments in modern times have undeniably improved the quality of our lives. Development in technology has led to the utilization of Electrical and Electronics Equipment (EEE) that epitomizes the modern way of life, and with this has come diverse problems, including the problem of massive amounts of hazardous waste and other wastes generated from electric products called electronic waste. Electronic waste or E-waste describes any electronic products, or products containing electrical components, that have reached the finality of their usable life cycle (Sthiannopkao & Wong, 2013).

As with all other items, EEE becomes technologically obsolete with time warranting the production of improved models which keeps production high and in a continuum. The enormity of yearly global waste from EEE is around 50 million metric tons (Electronics Takeback Coalition, 2010; Kumer, Houskz & Espinosa 2017), and this waste harbors noxious chemicals with environmental consequences (Agnihotri, 2011; Saoji, 2012), making e-waste an emerging global problem.

Electronic wastes are constitutively non-biodegradable since the principal components are themselves non-biodegradable. Thermal degradation of e-waste in landfill terminal points leads to a release of high amounts of toxic compounds, which are linked to sundry health effects and developmental defects and anomalies (Chen, Dietrich, Huo & Ho 2011). Product recovery from e-waste or recycling is sustainable, yet only about 13-18% of e-waste is currently being recycled (Kumar, Holuszko & Espinosa 2017). This implies that the bulk of the waste ends up in the environment and would inevitably poses problems to flora and fauna. Leaching of chemicals occurs while e-wastes is disposed into open dumps or fields as is the pervasive practice for disposing of solid waste in poor countries that on their own also receive e-waste from developed nations for disposal under questionable circumstances.

E-waste disposal (burning, burying and dumping) releases inherent components into the soil. The heavy metal components of e-waste can alter soil heavy metals balance to levels of injuries to metabolic functions of all forms of life including plants and microorganisms. (Yao, Xu and Huang, 2003).

Unsafe discarding of e-waste is a modern-day problem of growing proportion relative to all the myriads of environmental pollutants that man and the eco-network have to grapple with. Much consideration has been centered on studying the toxicity of e-waste on organisms at higher trophic levels. This study is turning the searchlight on the toxicity of e-waste on invertebrates as the key mass of soil environment and critical players in nutrient cycling.

MATERIALS AND METHODS

Source of Samples (Toxicants)

The toxicant used in this study was Lithium batteries from e-waste. They were sourced from e-waste dump sites, which consists of sundry e-waste compositions e.g. Television, radio, fridges, laptops, battery, micro waves etc. in scrap yard Effurun Warri Sapele road, Warri Delta state.

Physicochemical Composition of Toxicant Media

The physicochemical composition of the toxicant media was determined using parameters such as pH, Electrical conductivity and total dissolved solid (TDS). Testing was done using Hanna in-situ meter.

Heavy Metal Composition of Toxicant

The heavy metal (Lithium, Lead, Cadmium and mercury) composition of the toxicant was carried out according to the method of APHA (2008).

Earthworms and Snails are Employed for Toxicity Tests.

The earthworm used was *Apporrectodea longa* with a mean weight of 1.2 ± 0.01g and length of 11.90 ± 0.02cm and the African land snails (*Archachatina marginata*) with a mean weight of 1.1 ± 0.2g and length of 0.90 ± 0.03 cm. Healthy test species of earthworm and snail were collected from farms around Army Housing Estate Warri Delta state. They were well-cleaned and transferred to large plastic holding troughs. A total of 180 earthworms and snails was used for this experiment.

Toxicant Preparation

Lithium battery waste where shredded and Pre-determined amounts were weighed. The weighed sample was suspended in a small quantity of deionized water and the solution was made up to a fixed volume by adding an appropriate volume of deionized water as diluents to achieve a 1000 mg/L solution. From the stock solution, various concentration was prepared for the range finding and definitive tests.

Acclimatization of Test Organism

Healthy test species of snails and earthworms were collected from uncultured environments, cleared and each placed in a large plastic trough containing unspiked soil from the habitat environment for period of seven days before the commencement of the bioassay. *Carica papaya* (pawpaw) leaves were used to feed the Snail while the earthworms was fed with cellulose. The plastic trough containing the unspiked soil and test organism where kept under a Laboratory condition with a controlled lightning system.

Experimental Bioassay Procedure

The 14-day experimental procedure for snail and earthworm was carried out using the ISO protocol # 15952(2006) and OECD # 207(1984) respectively and (Ogelaka, Onwuemene & Okieimen, 2017). Method.

Range Finding Test

A range-finding test was performed to establish a preliminary working range by obtaining the least concentration that gives no effect and the maximum concentration that gives 100% death. This process was done to determine the concentrations to be used in the definitive test. “From the prepared Stock solution 100, 10 and 1.0 mg L^{-1} concentration each was added to an amber glass vessel containing 1kg of soil and was properly mixed to obtain a moisture content. To each of the vessels containing the toxicant concentration 10 voided test organisms snails and earthworms were added and observed for 24hrs for 0 and 100% death. The vessel was covered with a net to prevent the test organisms from escaping” (Ogeleka, Ugwueze & Okieimen,2016).

Definitive Test

The definitive concentrations (3.125,6.25, 12.5, 25 and 50 mg/kg) and (0.3125, 0.625, 1.25, 2.5 and 5 mg/kg) were chosen after the range finding experiment for snail and earthworm respectively.

For each test concentration, 1kg of natural soil from the test organism habitant was placed into the test tank. Five grams of *Carica papaya* (pawpaw) leaves were placed in the test tanks for snail and five-gram cellulose was placed in the test tanks used for Earthworms. Each medium was spiked with 100 mL (test solution) containing the pre-determined concentration of the test chemicals (Lithium battery) homogenized in a 2000 mL amber glass vessel to obtain a moisture content of 35%. The test organism was kept on moist filter paper for 3h to void the contents of the stomach and intestinal tract before being placed in the test jars. The control setup was prepared with the test chemicals as described above except that 100 mL of deionized water was used in place for the toxicant. The setup was covered with wire mesh to prevent the test medium from drying. The whole test procedure was conducted at a temperature of 28 ± 1°C in natural soils with pH 6.20 (Ogeleka et al. 2016).

Toxicological Responses of Snails and Earthworm (Mortality)

Snail and Earthworm mortality count was evaluated on days 7 and 14 of the experiment in all the triplicates in the natural soil. “Direct contact was avoided so as not to induce stress on snails. Percentage survival (endpoint of lethal toxicity) was estimated while physical changes (morphology) were also noted. Some organisms were observed to hibernate secreting a mucus calcareous substance. Snail and earthworm were considered dead if there was no movement when the foot region of the animal was prodded with a metal rod (platinum wire) or if there was no activity after sprinkling the snail and earthworm with water and then placing them on a moist white filter paper for five minutes.

Statistical Analysis

LC_{50}, EC_{50}, LOEC, NOEC, TUa and TUc at exposure time was calculated using Probit analysis for the invertebrate. The analysis of variance (ANOVA) test was performed using SPSS V 21.0 to ascertain the notable variance betwixt effects at significance levels of $p < 0.05$.

RESULT AND DISCUSSION

Table 1: Result of the Physicochemical composition of the toxicant (Lithium battery waste)

Parameters	Concentrations
pH	2.60
Electrical Conductivity (µS/m)	13500.00
Total Dissolved solids (mg/L)	8640.00
Lithium (mg/kg)	36.60
Cadmium (mg/kg)	2.03
Mercury (mg/kg)	10.48

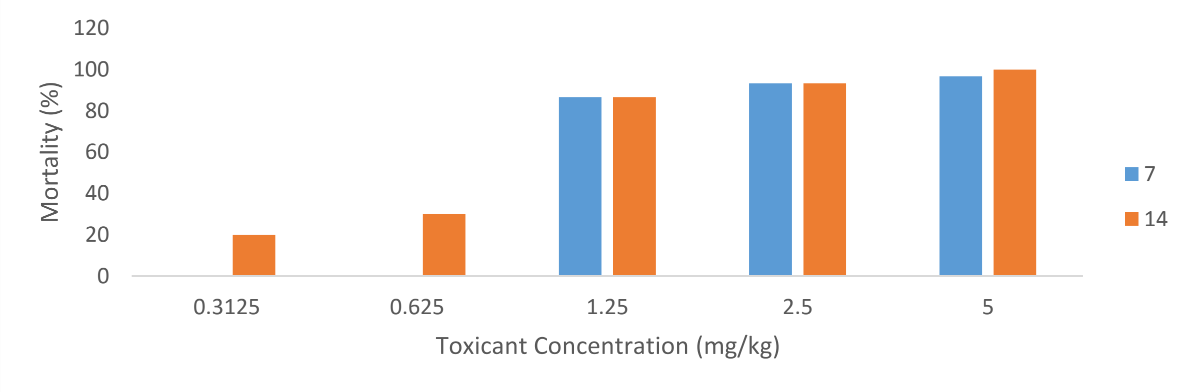

Figure 1. Mean % mortality of Earthworms exposed to the toxicant at 7 and 14 days.

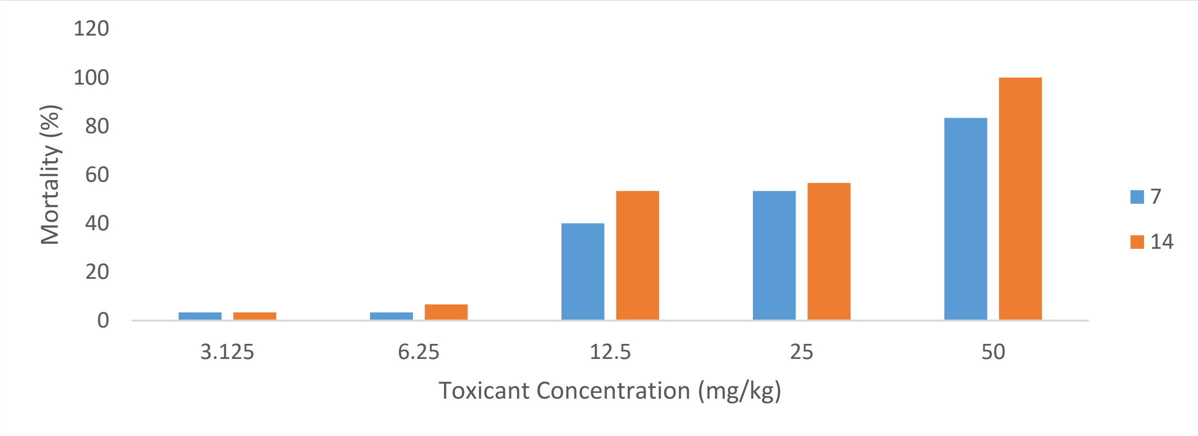

Figure 2. Mortality % of snails exposed to the toxicant at 7 and 14 days

Table 2: Mean LC_{50} for toxicant exposure to snails and earthworms at day 14

Test organism	Time (days)	LC_{50} mg/kg	Safe limit
Snail (*Archachatina marginata*)	14	1.05	0.11
Earthworm (*Apporrectodealonga)*	14	0.68	0.07

Table 3: 14–day toxicity of LOEC, NOEC, TUc and TUa of snails and earthworms

Test organism	Time (days)	LOEC mg/kg	NOEC mg/kg	TUc mg/kg	TUa mg/kg
Snail (*Archachatina marginata*)	14	0.86	0.77	94.88	129.87
Earthworm (*Apporrectodealonga)*	14	0.41	0.31	147.06	322.58

Discussion

Heavy metals (mercury, lithium, cadmium, chromium, lead) are especially toxic to organisms and humans (UNEP, 2007a), the impact of these wastes on soil microorganisms could be devastating since these organisms play a vital role in the Econetwork. Results obtained from Table 1 indicate that the toxicant (e- waste battery) contains heavy metals with lithium having the highest value. This is pinpointing that the Lithium battery waste is largely composed of lithium-ion. When compared with WHO regulatory limits for toxic metals, the metals that exceeded WHO limit indicate that the toxicant is toxic. Similar observations have been reported (Wang, 1984) The result of this research reveals that e-waste batteries had a significant effect on earthworms (*A. longa*) and snails (*A. marginata*) as observed in the sensitivity of the organism on exposure, which led to a drastic decline of these viable species. The results indicate an increase in the concentration of e-waste batteries resulting in an increase in the mortality of earthworm and snail as shown in Fig 1 – Fig 2. This conformed with the work done by Ogeleka, et al. (2017). They reported an increase in mortality with the increase in concentration of Grassate a non-selective herbicide on snails and earthworms. Comparison of the LC_{50} of Earthworm and snail, the mean percentage Mortality as well as Lc_{50} value for e-waste for earthworm and snail shows the e-waste battery was more toxic to earthworms than snails. earthworms are exceedingly important in soil formation (Edwards, 2004). Exposure to e-waste (batteries) of this magnitude could affect their ability to bring about soil formation. Unsafe disposal of e-waste can affect earthworms in three ways. First, they can affect their gene expression and physiology, secondly, they can change their life history traits. Population density and behavior. thirdly it can modify biomas and density of the earthworms population,

E-waste could raise serious health risks and problems which would have great consequences for human exposed to it for prolonged periods since their mode of discarding into the environment is not controlled. However, the toxicology risk assessment /rating point out that the soil-dwelling organism is liable to the toxic upshot of the test toxicant (e-waste).

CONCLUSION

This study revealed that toxic substances are present in Lithium battery waste. Which is capable of causing serious environmental pollution affecting the biotic component of the environment. The results obtained from this study also suggest that autotrophic transformation by nitrifying bacteria which enhances soil fertility (hence significant crop production) may be hindered in an ecosystem polluted with these, Lithium battery waste as nitrification processes will be reduced. Inappropriate dealing and management of Lithium battery waste during reusing and other end-of-life treatment choices may develop conceivably critical dangers to both human health and nature. Further studies should be carried out on the toxic effect of these e-waste components in both aquatic environments and the possible health implications of these e-waste.

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