Pollution from Non-Biodegradable Electrical Wastes: Risk Analysis of Lead (Pb) Contaminants

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Abstract. Multi-pollutions from e-wastes are potential source of epidemic in the nearest future. This research considers the main component of e-waste i.e. lead (Pb) contaminants. The analysis of lead contaminants from some devices was used to calculate the risk analysis on four classes of persons. It was observed that the elderly, children, and landfill workers are the most vulnerable class of persons to lead contaminants. The risk analysis on the ecosystem was also carried using the ERICA 1.3 software. It was observed that agricultural production may suffer lower farm yield and there will be high susceptibility to health issues as there will be about a 15-50% decrease of peripheral blood cells in humans.

1. Introduction

Non-biodegradable materials are everywhere around us and while they have their disadvantages; they also have their advantages. Non-biodegradable materials are the types of materials that do not deteriorate or cannot be broken down easily by natural or chemical means. Our surroundings are filled with materials that are either biodegradable or non-biodegradable. Examples of non-biodegradable materials are plastic, rubber, electronics waste, etc.

The need and use of electrical wastes are increasing rapidly as the days go by because people need them for important gadgets for our day-to-day life such as telephones, iPads, laptops, cars, etc. Electrical wastes such as the transistors, resistors, battery, and basic circuit wastes consist of very poisonous compounds like cadmium, lead, flames with bromine, CO, PCBs, etc [1-3]. These dangerous wastes have a negative effect on the soil and water supplies that in turn pollute the air when they are dumped in landfills. Most electronic or electrical components produced before the year 2000 are non-biodegradable just because of the stuff they are made up of. Our surroundings have been contaminated by heavy metals in electrical wastes. Pollution from electronics waste affects the ecosystem and humans (in particular). Aside from the pollution from heavy metals that destroy the soil ecosystem, plastic also is a source of pollution that has been found to affect aquatic and terrestrial habitats [4].

There are several water pollutants and contamination by incessant e-waste dumping. The burning of e-waste is as dangerous as the dumping of it in dumpsites [5]. These e-wastes end up clogging the water bodies. Electrical wastes that contaminate the water bodies actually have a serious effect to all living organisms including the plants that are in the water and the plants that surround the water by transferring their toxicity around the whole water such that small traces of the heavy metals and compounds can be found in every droplet of water. A good example is groundwater pollution. Groundwater pollution from e-waste occurs when the leachate generated within the landfill migrates through the liner material of the surface geographical geology into the underlying aquifers. Ground
pollution by heavy metal contamination remains a major public health concern. For example, lead contamination leads to the following health challenges i.e. damage to the nervous system, circulatory system, and kidney. Cadmium contamination leads to neural damage. Mercury contamination leads to chronic damage to the brain, respiratory, and skin disorders. Plastic contamination leads to reproductory challenges [6]. Sometimes, the lead and mercury contamination in an aquifer (due to the closest landfill) can be as high as 0.04 mg/l and 0.22 mg/l respectively [7]. The long-term impact of landfill leachate on groundwater quality will depend on the quality and quantity of the leachate, performance of the liner material, and the site geo-hydrology. Several mathematical models have been developed to attend to subsurface contaminant transport. Lead is nearly immobile in the soil; however, in groundwater it is mobile. Cadmium is somewhat mobile, and mercury can be very mobile in certain forms. Mercury is highly volatile, while cadmium and lead are not. Luo et al. [8] reported that landfill soil could have concentrations of Cd, Cu, Pb, and Zn with mean values as high as 17.1, 11,140, 4500, and 3690 mg kg−1, respectively. The vegetables planted on the same soil were found to have concentrations of Cd and Pb that exceeded the maximum level permitted for food.

The release of non-biodegradable electronic wastes (burning or refuse dumping) has contaminated the air. This type of air pollution is more dangerous to the health of plants and animals than the atmospheric aerosols from dust and bush burning. There are different ways in which these hazards can be prevented but it can only be effective in countries where e-waste recycling is a priority. Taking developing countries as a case study, the rate at which electronic waste is being dumped is very high because there are no facilities in place to help in recycling some of these wastes. Suggested ways waste can be reduced include incentivize refuse stakeholders to gather specific e-waste; waste reused for other purposes; waste to wealth campaign; recycling e-waste. In this paper, our focus is going to be on how non-biodegradable electrical wastes cause pollution and damage our environment and the planet at large. In this research, the risk analysis for lead pollution was considered.

2. Methodology
The data used was gotten from secondary sources in different regions across the globe as presented in Table 1. The lead (Pb) content printed wiring boards (PWB), computer central processing unit (CPU), and printed circuit board (PCB) were used for this research.

| S/N | Component                  | Heavy metals | Concentration (mg/kg) | Reference |
|-----|----------------------------|--------------|-----------------------|-----------|
| 1   | PWB of CPU                | Lead         | 89,882                | [9]       |
| 2   | PWB of monitor            | Lead         | 47,044                | [9]       |
| 3   | Cathode ray tube          | Lead         | 4,341                 | [9]       |
| 4   | PCB1                      | Lead         | 25,000                | [10]      |
| 5   | PCB2                      | Lead         | 19,000                | [11]      |
| 6   | PCB3                      | Lead         | 27,000                | [12]      |
| 7   | PCB4                      | Lead         | 13,000                | [13]      |
| 8   | PCB5                      | Lead         | 39,300                | [14]      |
The risk analysis was calculated using USEPA exposure factors handbook [16]

\[ \text{ADD} = \frac{C \times \text{IngR} \times \text{EF} \times \text{ED}}{\text{Bw} \times \text{AT}} \]  \hspace{1cm} (1)

Where \( C \) is the mean heavy metal Concentration, \( \text{IngR} \) is the lead ingestion rate (100mg/day for adults and 200mg/day for children), \( \text{EF} \) is the exposure frequency of 365 days per year since the organism drink and eat from the polluted site every day, \( \text{ED} \) is 6 years for children and 24 years for adults, \( \text{Bw} \) is the body weight of 60kg for adults and 15 kg for children was assumed, \( \text{AT} \) is the averaging time of 1300 days in 5 years.

In the risk analysis took account of the inherent properties of lead (Pb). Natural lead is a mixture of four isotopes, \(^{208}\text{Pb} (51–53\%), \(^{206}\text{Pb} (23.5–27\%), \(^{207}\text{Pb} (20.5–23\%)\) and \(^{204}\text{Pb} (1.35–1.5\%)\), which exists in three oxidation states \( \text{Pb}^0, \text{Pb}^{2+}, \) and \( \text{Pb}^{4+} \). The decay coefficient of radiogenic lead (\( \mu \)) varies with 5 each type of isotope. Faure (1986) reported values of \( ^{208}\text{Pb} = 4.948 \times 10^{-11} \) /year, \( ^{207}\text{Pb} = 9.848 \times 10^{-10} \) /year, and \( ^{206}\text{Pb} = 1.551 \times 10^{-10} \) /year. \( ^{204}\text{Pb} \) is not radiogenic [7].

3. Results and discussion

Four cases were considered in the risk analysis i.e. normal adult (averagely at 24 years) and children (averagely at 6 years) as presented in Figure 1a; obese adult and children at the same age as case 1 (Figure 1b); adults working in the local e-waste processing landfill (Figure 1c); and elderly (averagely at 50 years) was considered as presented in Figure 1d.
Figure 1. Risk analysis (a) normal case for adult and children (b) obese case or adult and children (c) workers in landfill case (d) Most venerable case i.e. children and the elderly

Figure 1a revealed that tons of waste from computers have more risk for health than other e-waste. This result is directly proportional to the concentration of lead from each component. Smith et al. [17] reported that lead (Pb) by weight has 8% of the content of cathode ray tubes (CRTs) in computer monitors and TVs. Looking at the weight of lead (Pb) in each component, it is safer to analyze the contamination with respect to their average as presented by the red arrow in Figure 1. Figure 1a shows that children are more at risk than the adult. The same trend appears for obese adults and children (Figure 1b). However, obese adults and children possess low risk when compared to normal adults and children. In reality, since the obese are naturally exposed to health, the lead contamination aggravates their health challenges. Figure 1c shows that the workers in landfill areas are the most vulnerable as the elderly in society (Table 1d). The radioactive risk of the lead (Pb) content, as well as its isotope, was considered for terrestrial animals, birds, amphibians, and aquatic organisms. The dose rate of 40μGyh-1 was used for terrestrial animals, birds, amphibians, and aquatic organisms [18]. The concentrations of the lead content were used for each organism as showed in Table 2.

Table 2. Dose rate of Pb contamination on the ecosystem

| Organism                  | Total Dose Rate per organism [μGy h-1] | Screening Value [μGy h-1] | Risk Quotient (expected value) [unitless] | Risk Quotient (conservative value) [unitless] |
|---------------------------|----------------------------------------|---------------------------|-------------------------------------------|----------------------------------------------|
| Amphibian                 | 0.253320083                           | 40                        | 0.006333002                               | 0.018999006                                  |
| Bird                      | 0.242909327                           | 40                        | 0.006072733                               | 0.0182182                                    |
| Flying insects            | 0.242733028                           | 40                        | 0.006068326                               | 0.0182049                                    |
| Grasses & Herbs           | 0.984176287                           | 400                       | 0.002235441                               | 0.0067063                                    |
| Arthropod - detritivorous | 0.891453102                           | 40                        | 0.022826382                               | 0.0668589                                    |
| Mammal - large            | 0.896895723                           | 40                        | 0.022422393                               | 0.0672671                                    |
| Shrub                     | 0.894173242                           | 400                       | 0.002235433                               | 0.0067062                                    |
| Mammal - small-burrowing  | 0.47651001                            | 40                        | 0.01191275                               | 0.0357382                                    |
| Molluse - gastropod       | 0.470614902                           | 40                        | 0.01765373                               | 0.0352961                                    |
| Reptile                   | 0.101819954                           | 40                        | 0.002545499                               | 0.0076364                                    |
| Tree                      | 0.822495916                           | 400                       | 0.000205624                               | 0.0061687                                    |
| Lichen & Bryophytes       | 0.184116874                           | 400                       | 0.000460292                               | 0.0013808                                    |
| Annelid                   | 0.019613003                           | 40                        | 0.000490325                               | 0.0014709                                    |
The ERICA 1.3 software was used to perform the risk analysis for single-point analysis. A moderate reduction in the number of plants with leaves (22%). Also, there is a major reduction in cumulative stem growth (43% of the control value). There will be a severe increase in the number of chromosomal aberrations (4.3-fold). There will be severe changes in seed lobe colour (7.6-fold) as a significant increase in the number of chlorophyll mutations will be discovered. During this period, plant cultivation will experience a moderate decrease in energy of shooting (25% the control value) and a severe decrease in % seed germination (6.7% the control value) (Chernobyl). For mammals, it was observed that the risk includes minor decrease in body weight (10% reduction). Also, there will be a minor decrease in peripheral blood cells (15-50% reversible reduction) and a moderate decrease of otter population density (33% reduction).

4. Conclusion

It was observed that lead contaminant contributes significantly to air, ground, and groundwater pollution. The elderly, children, and landfill workers are the most vulnerable class of persons to lead contaminants. The ecosystem is found to alter if judging from the radioactivity of lead and its isotopes. Plants, as well as mammals, suffer even at a low dose rate of 0-40 μGyh-1. The danger of high lead content from e-waste includes lower farm yield and high susceptibility to health issues. This research corroborates the possibility of the lead contaminants to significantly alter the chemical content of the food or vegetables from landfills or gardens close to landfills.

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