CADMIUM, LEAD AND MERCURY CONTENTS IN SOME KEYPADS OF CELLULAR PHONES SOLD IN ZARIA, NIGERIA

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Abstract: The aim of this research work is to determine the levels of cadmium, lead and mercury in some keypads of cellular phones sold in the market within Zaria, Nigeria. The keypads of some cellular phones coded NK, TN, SS and LF were obtained from phones market within Zaria metropolis. Samples were digested with strong acids (mixture of H_2SO_4 and HNO_3 ratio 1:1). The concentration of cadmium and lead were determined using Atomic absorption Spectrophotometer, while mercury was determined using cold vapour Atomic absorption Spectrophotometry. The results obtained showed that concentrations of cadmium in the various keypads were: SS (2.10±0.06 mg/kg), NK (1.90±0.05 mg/kg), TN (1.40±0.04 mg/kg) and LF (BDL); Lead concentrations were: SS (20.20±0.04 mg/kg), NK (26.10±0.04 mg/kg), TN (26.00±0.04 mg/kg) and LF (26.50±0.10 mg/kg); Mercury concentrations were: SS (160.70±0.15 mg/kg), NK (197.70±0.09 mg/kg), TN (140.60±0.04 mg/kg) and LF (156.60±0.10 mg/kg). The metals levels were found to be lower than the recommended standard given by the Directorate for the Restriction of Hazardous Substance (RoHS) for components of electronic products. Continuous use of these keypads can lead to greater absorption of the metals into the human body which can pose health risk. When cell phones are improperly recycled or end up in landfills, it can leak into the groundwater and bioaccumulate in the food chain causing detrimental damage to the soil, water supply, vegetation, animals and humans.

Keywords: Absorption, cell phones, health risk, heavy metals, keypads, toxins

Introduction

Cellular phones are growing fast and powerful and are most likely going to become the dominant device for communication, computing and content. An indispensable part of the civilization development is the development of industries related to electronic devices. Using them makes everyday life easier and more convenient. Besides functionality parameters, the aesthetic design of a cellular phone continuously changes, as it is considered a fashion icon which expresses the owner's character. That is one more reason why people purchase latest production mobile phones even more frequently than they should (Lim *et al*., 2010) shortening, consequently, even more the life cycle of a cellular phone, which is nowadays estimated to 9 – 18 months (Kasper *et al*., 2011). As a result, large amounts of waste from end-of-life (EoL) cellular phones are generated.

A single mobile phone, with an average weight of about 75-100 g, contains more than 40 elements of the periodic table in its components (Schluep *et al.*, 2009). Regardless of manufacturer, a cellular phone device typically consists of an electronic circuitry, a printed circuit board (PCB), a liquid crystal display (LCD), a battery (nickel-cadmium, nickel metal hydride or lithium ion/polymer technology), a keyboard, an antenna (which is occasionally an integrated circuit) and a plastic case (which sometimes coexists with metal coating or lining).

The PCB represents 20-35% of a mobile phone's weight (Stutz *et al.* 2002). According to Zhang *et al*. (2004), it consists of a non-conductive substrate or laminate with the printed circuit conductors upon (or within) the substrate and the components mounted to it (chips, connectors, capacitors, processors etc). In general, the average distribution of these materials, in terms of weight, is approximately 30% of polymers, 30% of refractory oxides and 40% of metals (Kasper *et al*., 2011).

Along with PCBs, the liquid crystal display (LCD) of a cellular phone represents 98% (59 and 39%, respectively) of the handsets' environmental impact in production and recycling chain (Fishbein, 2002). There are two kinds of LCDs used in cellular phones; the TFT-LCD (thin film transistor technology), and the IPS-LCD (in-plane switching) which is found in high end mobile phones and portable devices, as in Apple's iPhone and iPad. Although there are few studies that have been done concerning their toxicity, there is suspicion about liquid crystal's hazardousness (Tsydenova & Bengtsson, 2011). Liquid crystals are a solid form of polycyclic aromatic hydrocarbon (PAHs) which under uncontrolled incineration could be released. According to Lin *et al*. (2009) TFT-LCD waste glass contain heavy metals such as zinc, copper, chromium and lead.

Plastic housing braces all the other components of a cellular phone by creating a protective shell. Plastic case represents 15-55% of the weight of the handset without the battery placed (Stutz *et al.,* 2002). Polymers used at the housing of mobile phones are mostly polycarbonate (PC), acrylonitrile butadiene styrene (ABS) or a combination of them (Fishbein, 2002). Plastics from Waste electric and electronic equipment (WEEE), may contain numerous hazardous substances, including heavy metals, and because of their toxicity several studies have been reported (Dimitrakakis *et al*., 2009; Nnorom & Osibanjo, 2009). Some of them, such as lead, cadmium, chromium, mercury and tin are or have been used as pigments, fillers or UV stabilizers in polymers (Nnorom & Osibanjo, 2009). It is expected that the human body gets infected with the heavy metals through constant contact with our fingers without taking the appropriate measures.

The aim of this research work is to determine the concentrations of the heavy metals such as Cd, Pb and Hg in the plastic keypads of various products of cellular phones NK, SS, TN and LF using AAS machine.

Materials and Methods

Sample collection and preparation

All glassware and plastic containers used were washed with liquid soap, rinsed with water, soaked in 10% volume/volume nitric acid for 24 h, cleaned thoroughly with distilled water and dried in such a manner to ensure that any contamination does not occur.

A total of twelve (12) samples of each of different plastic keypads of cellular phones coded NK, TN, SS, LF were bought from phones markets within Zaria Nigeria. The keypads for the four different cellular phones were washed with de-ionized water, dried and cut into smaller sizes using stainless scissors.

Sample analysis

One gram (1 g) of each sample was weighed into four different 250 ml beakers using an analytical balance and 100 ml mixture of 1:1 H_2SO_4:HNO_3 were added into the samples and kept in contact for 72 hrs to dissolve as much particles as possible (Konstantinos, 2013). The samples were heated at 100°C, in order to obtain slow evaporation and the heating continued till it approached dryness. Then the solutions were diluted with 20 ml of de-ionized water, subsequently, filtered through Whatman filter paper no. 42 into a 100 ml volumetric flask and made up to the mark with de-ionized water. The concentrations of the heavy metals (cadmium and lead) were determined using AAS, while mercury was determined using cold vapour AAS (CVAAS). The analysis was done in triplicate and subjected to one-way ANOVA using SPSS v20 software.

Results and Discussion

The mean concentrations (mg/kg) of the metals analysed in the four different plastic keypads are presented in Figs. 1 – 4. The mean concentration (mg/kg) of cadmium in the different keypads (Fig. 1) was found to be in the order: SS – 2.10±0.06 mg/kg, NK – 1.90±0.05 mg/kg, TN – 1.40±0.04 mg/kg and LF –BDL. The concentration of cadmium in the various samples is below the limit (100 mg/kg) given by the directive for restriction hazardous substances (EC-RoHS Directive, 2011).

Cadmium, a heavy metal found naturally in soils and rocks, is soft in texture and silver in color. Cadmium is primarily and increasingly used in Ni-Cd batteries, and followed by consumption in the traditional markets of pigments, stabilizers, coatings, alloys and electronic compounds such as cadmium telluride. Its use in consumer industry in cordless power tools, cell phones, and portable computers. These batteries are cost-effective and have high life-spans. Cadmium is classified by the EPA (1994) as a Group B1, probable human carcinogen; the acute human effects of cadmium are primarily on the lungs. Chronic inhalation of this metal leads up to a build of the substance in the kidneys and can cause kidney disease and lung cancer.

The concentration of lead (Pb) was found to be highest in keypad of LF (26.50±0.10 mg/kg), followed by NK (26.10±0.04 mg/kg), TN (26.00±0.04 mg/kg) and lastly SS (20.20±0.04 mg/kg) as shown in Fig. 2. The concentration of lead in the various samples is below the limit given by the directive for restriction hazardous substances (EC-RoHS Directive, 2011) which stated the limits for components of electronic products to be 1000 mg/kg for Pb.

Lead is present in almost all electronic products including cell phones. Lead is found in the glass panels of computer monitors and in the lead soldering of printed circuit boards/wiring boards. Approximately 100,000 to 125,000 tons of lead solder have been estimated to be produced globally each year for the electronics industry (Townsend *et al.*, 2003). The quantity of lead found in cell phones is small, compared to large electronic products such as TVs and computer monitors (Yazici & Deveci, 2013). The printed wiring boards (PWB) of a cell phone contain about 50 grams per square meter of lead (Fishbein, 2002). Compared to the amount of lead, 4 to 8 pounds, contained in a single TV picture tube, the amount found in cell phones can be negligible. However, the short life span of cell phones dictates a larger number of discarded products each year, and therefore there is considerable potential for the lead to end up in an incinerator and/or a landfill. Lead is regarded as a dangerous metal that has significant health hazards. Cell phone contains lead, which is a toxic metal that can result in adverse health effects when exposed to it in high levels.

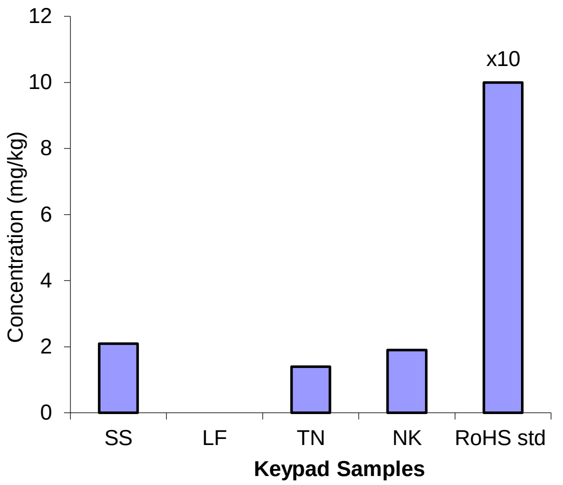

Fig. 1: Concentration of cadmium in different plastic keypads of cellular phones

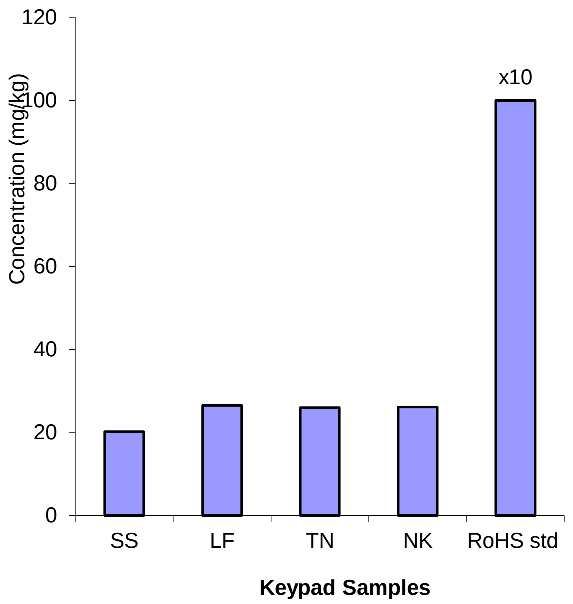

Fig. 2: Concentration of lead in different plastic keypads of cellular phones

According to the Environmental Protection Agency's Office of Solid Waste, lead is a bioaccumulative element which is known to cause significant damage to the human central and peripheral nervous system, blood system, kidneys and especially on children's brain development. The primary route of lead found in the environment is via landfill leaching and water contamination. This is especially disconcerting since consumer electronic products are known to be responsible for nearly 40% of the lead found in landfills (Maroqkos *et al.*, 2013).

Mercury (Hg) has the highest concentration in keypad of NK (197.70±0.09 mg/kg), followed by SS (160.70±0.15 mg/kg), LF (156.60±0.10 mg/kg) and TN (140.60±0.04 mg/kg), Fig. 3.

The concentration of mercury in the various samples is below the limit given by the directive for restriction hazardous substances (EC-RoHS Directive, 2011) which stated the limits for components of electronic products to be 1000 mg/kg for Hg (Hester and Harrison, 2009). Mercury is a heavy metal that is used Liquid Crystal Displays. Mercury is used in the cell phone's battery, crystal displays and circuit boards. A single cell phone contains up to 2 grams of mercury. Mercury exposure contributes to brain and kidney damage (Garber, 2012).

Comparing the chemistry of mercury (Hg), and lead (Pb) we can see that Hg has higher concentration than that of Pb which may be attributed to their sizes. The ionic size of Hg (1.50 Å) is lower than that of Pb (1.80 Å). And as a rule, the lower the size the higher the crystal field stabilization energy (CFSE), and the higher the CFSE the easier the metal will complex with the ligand available and consequently the higher the concentration. Also, the higher concentration of Hg compared to that of Cd may be attributed to their variation in size brought about by lanthanide contraction. Both Cd and Hg are in the same group and as we go down the group (going from Cd to Hg) lanthanide contraction becomes more pronounced, as such the size of Hg (1.50 Å) becomes smaller than that of Cd (1.55 Å) and the CFSE increase and therefore, it will easily complex with ligand available and consequently the concentration becomes higher (Kyle, 2012).

The polymer materials use used for the production of the keypads are mostly polycarbonate (PC), acrylonitrile butadiene styrene (ABC) or combination of both (Fishbein, 2002). The keypads contain heavy metals in small quantities that are below the RoHS standard. Both the polycarbonate and acrylonitrile can serve as ligands because of the lone pair of electron in the former and the complexing ability of the latter by pi bonding approach. As a result of their ability to donate electrons for bonding, they can both form a bond with any heavy metal present on the keypads.

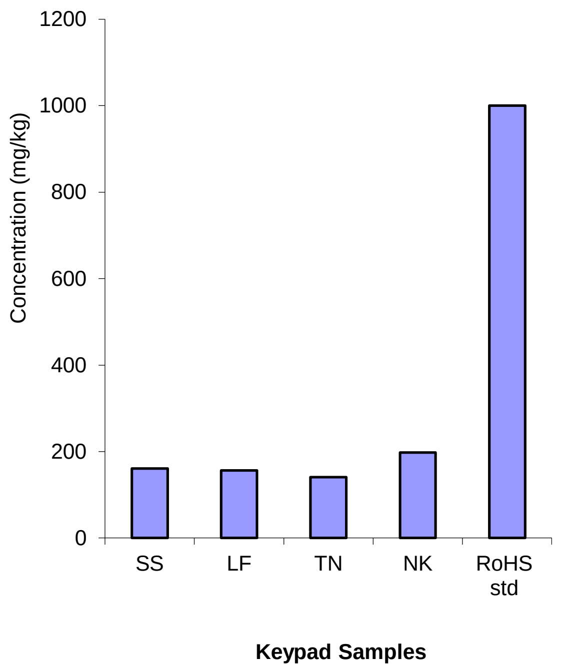

Fig. 3: Concentration of mercury in different plastic keypads of cellular phones

Cell phones in where the keypad had a lot of wear and tear were more likely to test positive for metals (Stenvall *et al*., 2013). Continuously using our phones for 30 minutes plus throughout the day can increase the risk of cell phone-related allergic contact dermatitis (ACD) for those allergic to heavy metals (Lizette, 2014; Hamann *et al*., 2014; Lucente *et al*., 2000).

When cell phones are improperly recycled or end up in landfills, it ultimately causes negative effects to nearly every system in the human body. Mobile phones contain harmful toxins including lead, mercury, arsenic, cadmium, chlorine and bromine, which can leak into the groundwater and bioaccumulate in the food chain causing detrimental damage to the soil, water supply, vegetation, animals and humans (Joaquin *et al*., 2006; THME, 2001).

Conclusion

The results of this study showed that the distribution of heavy metals in the keypads depends on the manufacturer and the heterogeneous nature of their constituents. The concentrations of cadmium, lead and mercury in the various keypads samples varied and were within the acceptable limits set by Directive for Restriction of Hazardous Substances (RoHS). But continuous use or rubbing of these keypads can lead to greater absorption of the metals into the human body which can pose health risk. When cell phones are improperly recycled or end up in landfills, it can leak into the groundwater and bioaccumulate in the food chain causing detrimental damage to the soil, water supply, vegetation, animals and humans.

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