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Well of Hazards in E-Waste: A Review

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Abstract:*The rise in the production of newest electronics has led to the older ones becoming outdated. The discarded obsolete electronics known as electronic waste or e-waste are disposed indiscriminately into the landfills where scavengers use crude methods of extraction to recover valuable parts of the e-waste. These crude methods such as open-burning and acid baths lead to the release of toxic substances into the environment. Most of these toxic substances persist in the environment and are non-biodegradable while some change into other substances that are more hazardous to man and his environment. These toxic substances include heavy metals, polybrominated diphenyl (PBDs), polychlorinated biphenyls (PCBs) and Brominated Flame Retardants (BFRs). This review presents a general overview of crude recycling methods and their negative effects; toxic substances that can be generated from e-waste during crude recycling, their sources in e-waste and potential health implication to man and his environment*.
Keywords: *e-waste, e-waste management, health hazards, Heavy metals, Poly-aromatic Hydrocarbons, recycling and reuse, toxic substances.*

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I. INTRODUCTION

There is a drastic increase in the production and use of electronics, which has resulted in electronics, especially personal devices, becoming obsolete at an exceedingly rapid pace [1]. Thus, e-waste is one of the fastest growing waste streams [1], [2]-[3], and is composed of different components, which includeiron and steel, used for casings and frames; non-ferrous metals, mainly copper used in cables, and aluminum. Others are glass, used for screens (cathode ray tubes), which contains lead while the fluorescent material in screen contain cadmium (Cd), Zinc (Zn), etc.; plastic for casing, in cables and for circuit boards; printed circuit boards for mounting electronic devices and others such as rubber, wood, ceramic etc. E-wastes contain persistent organic pollutants (POP) which include: brominated flame retardants (BFRs), dioxins, poly-aromatics hydrocarbons (PAHs) and heavy metals [4]. These toxic compounds are found in different components of the electronics. Printed circuit boards contain solders which are made of tin and lead while Semi-conductors contain boron (B), gallium (Ga), indium (In), arsenic (As), and flame retardants. Mercury is found in batteries, switches and fluorescent tubes while plastic used for casing contains pigments and stabilizers, flame-retardants, antimony oxide, phosphorous organic compounds and other materials. The cooling circuit and insulation foam of freezers and refrigerators are made ofchloroflorocarbons (CFCs), which add greatly to global warming. These hazardous compounds present in waste electronics are released when these obsolete electronics are dumped, disposed of or processed inappropriately using crude methods. The recycling and management of e-waste result to issues that affect the environment and human health negatively, as it contains a well of hazardous compounds with more toxic compounds generated during the recycling procedures [5]- [8]. This has caused most developed countries to export the e-waste to the developing counties [9]. In developing countries, e-waste is recycled in unregulated manners with the application of crude methods [10], involving children and adults at the family workshops, dump sites and other recycling sites [1], [11]-[12]. The crude recycling and management include manual dismantling, open burning, toner sweeping, stripping and dumping of residues, heating and acid bathing/leaching valuable parts. [1], [13]-[15]. These crude methods of recycling via open burning, acid baths, and cooking circuit boards are hazardous in nature [16]. Children and adults who work at e-waste recycling site are engaged in the manual sorting, dismantling and recycling of e-waste. These children are a source of cheap labour and are not given good working conditions but are particularly at risk of chemical burns during stripping of wire; unintentional poisoning from corrosive agents such as acid used to leach precious metals from circuit boards; and cuts and falls from handling dismantled e-waste and heavy metals contamination [17]. *This review presents a general overview of crude recycling methods and their negative effects; toxic substances that can be* *generated from e-waste and during recycling, their sources in e-waste and potential health implication to man and his environment.*

II. Crude Methods of E-Waste Recycling/Management

Characteristic emissions result from different disposal and e-waste management styles, which involve crude methods of managing e-waste as discussed below.

2.1*Dismantling*:

Dismantling is an e-waste recycling and management method, which is aimed at recovering the precious and valuable components of the e-waste such as gold, copper, steel and iron; remove hazardous substances and parts such as CFCs, mercury, printed circuit boards and switches. During the crude dismantling and recycling, the well of hazards contained in e-waste are released into the environment [1], [18]. Dismantling releases particulates matter ofcoarse and fine particles [10]. Improper handling of volatile fluids during dismantling causes health risk to the e–waste workers and contaminates the atmosphere while inappropriate storage of the e-waste parts after dismantling can cause leaching of toxic substances into the soil, leading to contamination [19]-[20]. Fine particulates of dust are produced during dismantling [21] and contains plastics, ceramics, and heavy metals [22] which are transported via winds and waters. Heavy metals released during dismantling includecadmium, chromium, copper, lead, nickel, mercury and zinc [23]. E-waste workers used stones, hammers and chisels [24]- [25] to hit the e-waste items. They use bare hands to sort, dismantle and recover useful components of e-waste [24]. These crude methods cause musculoskeletal injuries, laceration to their hands, body pain, hearing loss, cuts, and coughs due to manual processes during recycling [26] and release of hazardous materials which cause health risk to the e-waste workers [6], [27]-[28]

2.2*Open burning*

Open burning of e-waste is a common practice [29], which has caused the emission of harmful POPs, dioxins, furans, polycyclic aromatic hydrocarbon (PAHs), polyhalogenated aromatic hydrocarbon (PHAHs) and hydrogen halides, BFRs and heavy metals (such as mercury, lead cadmium) [1], [30]-[32]. Also, fine particles of black carbon which pollute the atmosphere, causing air pollution [33] are emitted and later settles on and bio-accumulates in soil [34]. These compounds pose risks to the human health, especially the recycling workers and the environment [13], [35]-[36].

The BFRs and heavy metals have been found in plastics of waste mobile phones [37]-[38]. The open burning of these plastics parts of e-waste releases Hg, Cr, Pb, and Br, which pose both environmental and health hazards [37]. Thus, segregating and sorting of plastics from the non-plastics part of the electronic waste should be carried out [39] to create environmentally friendly management of the e-waste and reduce the risk on human health [37]. Open burning of halogenated components of circuit boards/wires releases chlorinated and brominated dioxin compounds such as mixed halogenated dibenzo-p-dioxins/dibenzofuran [30]. Open burning of monitors and cables lead to the release of harmful substances into the soil [40]. These toxic compounds released during open burning initiates the irritation of the eye, asthma and other respiratory tract infections [25]. De-soldering and burning releases fly ashes, bottom ashes and fumes into the environment [10].

2.3*Toners Sweeping*

Black and coloured (cyan, yellow and magenta) *toners are contained in* plastic printer and photocopiers cartridge, which is part of printer scraps. The toners contain heavy metals [41]. These toners can either be dry or wet toners. The dry toners contain organic acrylic and styrene powders while the wet toners contain only acrylic resins. However, either form contains colour pigments, which are inorganic oxides of metals and nonmetals and carbon black substances [42]. Also, toners contain metals and semiconductors to induce triboelectric and super flow properties [43]. Scavengers and e-waste workers recycle the toner waste using unhealthy and environmentally unfriendly methods due to its economic gains [44] however, only about 20–30% of toner waste is recycled and the rest dumped in landfills [45]. Recovered toner waste is used as a carbon source for the synthesis of multi-walled carbon nanotubes using a chemical vapour deposition process [46]. It can also be used to synthesize graphene oxide quantum dots [47]; as a filler to enhance the electrical conductivity of polymer blends by several orders of magnitude [48] and to synthesize nanomaterials for detecting DNA damage [45]. The substances in the toners make the waste toner environmentally unfriendly and almost non-biodegradable, causing serious environmental and health risks [49]. Inhalation is the primary source of exposure due to its dusty nature and causes respiratory tract health issues [45]. The printer inks and toners are known to cause DNA damage [50]. The International Agency for Research on Cancer has classified carbon black as a class 2B carcinogen, possibly carcinogenic to humans [45].

2.4*Open dumping*

The management of e-waste containing volatile, non-biodegradable and persistent organic pollutants via: open dumping is environmentally unfriendly particularly due to the leaching behaviour of metals and other pollutants. The inorganic and organic components of the e-waste dissolve during rainfall, releasing toxic chemicals, which leach into the underground water, increasing the metal content and toxicity of the water, causing detrimental health effects on aquatic organisms [51] and renders water unfit for human consumption. The breeding of rodents increases in open dumping of e-waste [52], which may stray into residential homes. Open dumping of e-waste with other household waste leads to the emission of greenhouse gases, such as Methane (CH_4) [53], carbon dioxide (CO_2) and carbon IV oxide, Sulphur dioxide (SO_2), and nitrogen dioxide (NO_2) and come from the degradation process of the degradable waste [54]. In developing countries, e-wastes are dumped openly and crude methods used for recycling because they do not have the technical-know-how on the green management of e-waste [55]-[56]. Also, crude methods such as: acid leaching and open-burning pollute dumpsites and cause damage to the environment [6]. The incombustible part of e–waste from incineration are disposed openly on lands.

2.5 Acid bath (Leaching with acids)

In small family recycling-workshops, little fund and simple tools are used to recover metals from e-waste, making contamination inevitable due to crude recycling methods such as acid leaching [57]-[58]. Recycling workers use acid leaching methods to recover metals such as palladium, copper, gold, silver, platinum, iron [59]-[60]. The Parts of the e-waste leached into acid bath include printed circuit boards, memory banks or chips, etc. [61]. Leaching involves immersing the e-waste part in an acid-bath to break down the waste, with the use of mineral acids, oxidizing acids, non-oxidizing acid, cyanide and ammonia-ammonium [62]-[63]. These leaching agents include H_2SO_4 [64], H2SO4 and H_2O_2 [63], H_2SO_4-HNO_3-H_2O-NaOH and H_2SO_4-HNO_3-H_2ONO_x. H2SO4 [65], NaCI, and aqua regia [60], ligand [66]. The concentrations and temperature of leaching are of vital and depends on the metal to be leached [60], [67]. The use of all these corrosive and hazardous reagents during the recovery treatment cause serious environmental and health risk to all living organisms, including man [10], [60]. Children and pregnant women are mostly at risk [61]. Crude acid bath can cause fire explosions, corrode and burn the skin and eyes, cause respiratory and gastrointestinal system problems [68], [69].

III. HAZARDS IN E-WASTES

Exposure to toxic substances in e-waste vary by substance, concentration and duration of exposure and causes adverse health hazard to the e-waste workers, who are directly exposed at dumping/recycling site and others who are exposed to the toxics in the contaminated environment [70]. The numerous and dozens of hazards in e-waste are discussed below.

3.1 Persistent organic pollutants (POPs)

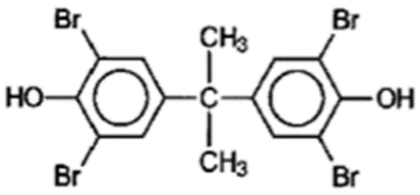
E-wastes contain Persistent organic pollutants (POPs) which are mostly the pollutants that have long half-lives, thus are difficult to degrade in the environment and include: Polychlorinated biphenyls (PCBs), polybrominated biphenyls (PBBs), PCDDs, PCDFs, and Brominated Flame Retardants (BFRs) [71]. They are organo-halogens, which are persistent in the environment, bio-accumulate in living organisms, have long-range transport beyond the regions of their use, and long-term health effects in wildlife and humans. They pose an environmental and human risk, being highly toxic with different chronic effects, causing endocrine dysfunction, mutagenesis and carcinogenesis [72]. In the environment, most POPs reside in soils and sediments where they primarily separate into organic matter [72].

3.1.1. **Brominated Flame Retardants (BFRs)**

Brominated flame retardants are compounds used as additives in manufacturing electronics to ensure that the action of flame on the electronics equipment is resisted and retarded [73]-[77]. The various applications of BFR are electronics and electrical, Building/construction, Textile and Transportation. The printed wiring board, cables, housings and connectors of some electronics such as cell phones, computers, television set, etc., contain plastics, which are made of BFRs to reduce the action of flame on the electronic equipment [4]. Most common electronic products with BFRs include: computers, television sets, mobile phones, furniture, and carpet pads [78]. These BFRs include Polybrominated diphenyl ethers (PBDEs), Tetrabromobisphenol A (TBBPA), hexabromocyclodecane (HBCD), decabromodiphenyl ether (deca-BDE), Polybrominated biphenyls (PBBs), Per- and polyfluoroalkyl substances (PFAS) etc. From literature, about 25- 30 wt. percentageof e-waste plasticscontains BFR [79]; BFR in form of tetrabromobisphenol-A (TBBPA) was used in the producing mobile phones in 2004 [80]-[81]. The presence of these compounds in electronic and e-wastes have increased their concentrations in the environment. Indiscriminate disposal and thermal decomposition of e-waste plastics via open burning generate toxic brominated aromatic compounds which are precursors to pollutants such as: the

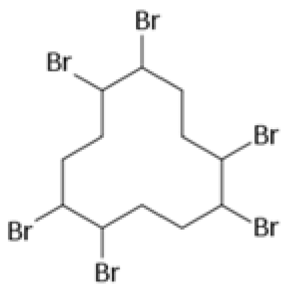
polybrominated dibenzo-p-dioxins (PBDD) and polybrominated dibenzo furans (PBDF) [51], [82]-[83]. Bromides generated during recycling persist in the environment in form of bromide or bromo-organic compounds such as: hydrogenbromide, bromomethane, and bromophenol, which are hazardous to human health [74]. All BFRs bio-accumulate, persist and are toxic in nature [73], [84]-[85]. Therefore, there is need to remove these toxins before recycling the e-waste plastics to prevent pollution of the environment and increase the purity of the plastics for recycling [4].
Human contamination of BFRs is via the air, dust, food, water, soil [17]**.** These BFRs especially PBDEs cause thyroid cancer, since their structures look like those of the thyroid’s hormones (triiodothyronine and thyroxin) [84], [86]-[87]. They also, affect the immune systems, growth hormones, sexual development, and brain development in animals [88]-[89] and are endocrine disruptors [73], [90]-[91]. They interfere with neurodevelopment [90] and hormone function and cause behavioral disorders, cancer [92] and DNA damage [93]. Glucocorticoids which are steroid hormones produced by the adrenal gland in response to both environmental and psychological stress[94], regulate the immune system, cell proliferation and differentiation, brain function, energy metabolism, heart, stomach, uterus, muscles, liver, adipose tissues, blood pressure and electrolyte balance [94]-[95]. However, chemicals such as BFRs disrupt the actions of glucocorticoids [96], causing asthma, skin infections or rheumatoid arthritis [97].

Some of the BFRs that are majorly used include: tetrabromobisphenol A and derivatives, Hexabromocyclododecane, Polybrominated diphenyl ethers, Polybrominated biphenyls.Aromatic BFRs include: tetrabromobisphenol A (TBBPA), polybrominated diphenyl ethers (PBDEs) and polybrominated biphenyls (PBBs) while the aliphatic, generally used in relatively small quantities, are cycloaliphatic, including hexabromocyclododecane (HBCD). Their structures are shown below.



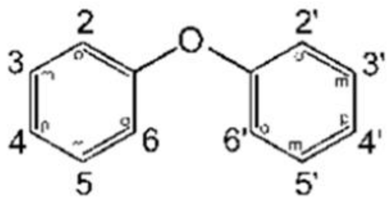
TBBPA

Tetrabromobisphenol-A (TBBPA):

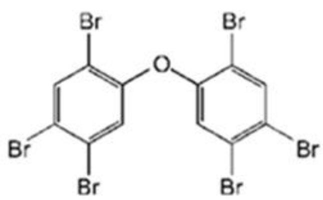


Hexabromocyclododecane

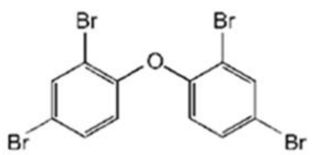
Other BFRs are Brominated diphenyl ethers, a group of aromatic brominated compounds in which one to ten hydrogens in the diphenyl oxide structure are replaced by bromine. The polybrominated diphenyl ethers (PBDEs) with three to ten bromine atoms are used in commercial flame retardants. The compounds are designated tri (3), tetra (4), penta (5), hexa (6), hepta (7), octa (8), nona (9) and decabromodiphenyl ether. They are made up of two phenyl rings linked by an oxygen molecule (thus the designation as “ether”). The phenyl rings may have 1 to 10 bromine atoms. Examples include 2, 2’, 4, 4’, 5, 5’-Hexabromodiphenyl ether, 2, 2’, 4, 4’ -Tetrabromodiphenyl ether, 2, 2’, 3, 3’-Tetrabromodiphenyl ether.



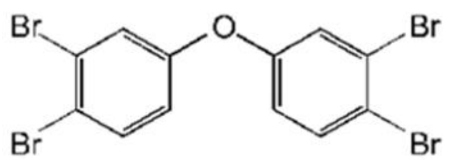
General structure of PBDEs



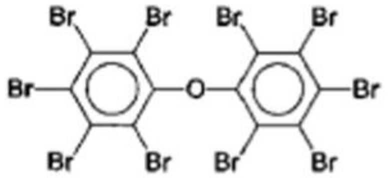
2, 2′, 4, 4′, 5, 5′-Hexabromodiphenyl ether
(PBDE-153)



2, 2′, 4, 4′-Tetrabromodiphenyl ether
(PBDE-47)



3, 3′, 4, 4′-Tetrabromodiphenyl ether (PBDE-77)



2, 2′, 3, 3′, 4, 4′, 5, 5′, 6, 6′-Decabromodiphenyl ether (decaBDE)

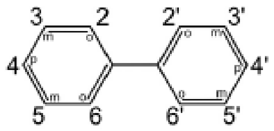
In addition, Polybrominated dioxins, (PBDDs)/dibenzofurans (PBDFs) are formed during open burning or incineration of BFRs, and as toxic as their chlorinated homologs [98]. The open burning of e-waste emits PBDD/Fs of about 50–500 times higher than PCDD/Fs, since e-waste contains enough bromine [99], with a concentration order of PBDFs > PCDFs > PXDFs [30]. Tens of thousands of tons of plastic electronic wastes containing BFRs are better disposed and treated in metal smelters [99].

3.1.2. **Polychlorinated biphenyls (PCBs)**

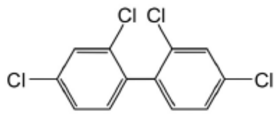
Polychlorinated biphenyls (PCBs) are persistent organic pollutants that are composed of two benzene rings, with a chemical formula of $C_{12}H_{10-x}Cl_x$, where x = 1-10 [100]-[101]. Theoretically, 209 different congeners are possible, but only about 130 of these have been identified in commercial products [73]. Their physicochemical properties, such as metabolism, solubility and volatility, depend on the number and positions of chlorine atoms in the biphenyl. Their metabolisms are faster and volatility higher with smaller number of chlorine atoms while solubility in lipid increases with increase in the number of chlorine atoms [73], [102]. They have high flash points of about 170–380 °C [103], which makes them poorly and slowly heated, decay slowly, non-flammable and thus reduce explosion and sparks, hence have insulating ability, thermal stability, resistance to acids, non-flammability and can undergo oxidation, hydrolysis [73], [104]. Therefore, they are ideal insulators, controlling the transfer of heat from the inner to the outer part of the electrical equipment. These properties make them persist in the environment and essentially useful in varying industrial applications [78]. PCBs are used as dielectric fluids, [101], used in high voltage appliances such as: transformers, capacitors, high voltage cables, and switchgear [72]; serving as a coolant in such electrical application [103], [105] and found in fluorescent lights, ceiling fan, dishwashers, and electric motors [105].

The half-lives of PCBs in soil and sediment range from months to years [100], thus. These contaminants are not easily degraded [72]. Indiscriminate disposal of e-waste parts containing PCBs and leakage of PCBs from e-waste parts releases PCBs into water bodies and soil. Also, the crude dismantling and management of e-waste such as open burning of e-waste can released PCBs. The manufacture and applications, accidental spills and leaks during transportation of products [103], [106]-[107] and disposed industrial waste [101] can release PCBs. The release of PCBs into the environment during these different activities increases their concentration and cause human health hazards [106], [107]. Once released into the environment, they do not break down readily and hence persist for very long time [78]. PCBs bio-accumulate in human liver, adipose tissues, skin and breast milk which are rich in lipids and become carcinogenic [73], [100]. More so, they bio-accumulate in diverse lower trophic organisms such as plankton and move up the food chain, which is basically due to their persistent and lipophilic properties [78]. The children of women exposed to high PCBs via the consumption of PCB-contaminated fish were observed to have severe developmental issue such as low birth-weight, behavioral disorder, learning problems and hearing loss [101], [108], low head circumference and intrauterine growth restriction [5]. PCB exposures lead to Yusho disease with symptoms such as: acne form eruptions, pigmentation of the skin, nails, and conjunctivae, increased discharge from the eyes, and numbness of the limbs [78]. It affects the immune hormone, nervous, and enzyme systems and are carcinogens for humans [17], [109], causing damages to the reproductive and nervous systems, liver and can suppress immunity; immune hormone and enzyme [109]-[110]and disrupt the endocrine system [111]. Generally, the methods for PCBs remediation include: biological, chemical, physical and thermal, phytoremediation and use of activated carbon [101]). Incineration instead of open burning methods are implored o manage e-waste [101].

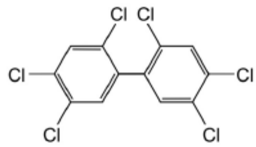
Structures of some PCBs



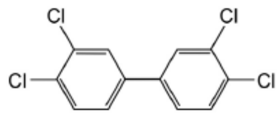
Generalized structure of PCB



2,2',4,4'-Tetrachlorobiphenyl
(PCB-47)



2,2',4,4',5,5'-Hexachlorobiphenyl
(PCB-153)



3,3',4,4'-Tetrachlorobiphenyl
(PCB-77)

3.1.3. **Polycyclic aromatic hydrocarbons (PAHs)**

Polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins and dibenzofurans are toxic pollutants produced in the process of e-waste incineration as combustion byproducts [17]. More so, incomplete combustion of coal, gas, oil, etc. produce PAHs [112], which increases the risk of skin, lung, and bladder cancer [17].

Some Poly-Aromatic Hydrocarbons (PAHs) discharged into the atmosphere during thermal treatment of e-waste include: Naphthalene, acenaphthylene, acenaphthene,phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene [17]. Fetal growth and development (low birth weight, low head circumference, intrauterine growth restriction) by PAHs [5].

Behavioural effects (shortened attention span, reduced ability to deal with frustration, hyperactivity, antisocial behaviour, depression) have been linked to PAHs [110]. In the literature, preschool children with exposures to PAHs in e-waste have been associated to antioxidant alterations [1], cardiovascular endothelial inflammation [113] and alterations in platelets indices [104]. Also, PAHs are environmental carcinogenic factors, impairing the structure of DNA and consequently leading to mutation [114].

3.2. Heavy metals.

E-waste is composed of different metals such as silver, gold, copper, lead, mercury, palladium, cadmium, nickel, chromium, arsenic, etc. [62]. About 40 % of waste printed circuit boards (PCBs) are made up of metals, which accounts for about 3% of nearly 50 Mt/year global WEEE generation [115]-[116]. Precious metals are among other metals found in high concentrations in printed circuit boards than those found in the natural deposits [117]. In addition, PCBs contain heavy metals such as lead, copper, Zn, Ni, Fe, Br, Mn, and Mg [118]. The plastic component of e-waste contain heavy metals, such as Pb, Hg, Cd etc., and brominated flame retardants (BFRs), [4], [31], [119]. From literature, analyses of soil samples from e-waste dumping/recycling site have shown high heavy metal contamination [31], [120]-[122]. These heavy metals including arsenic, lead, mercury, and cadmium are released during indiscriminate open burning and land-filling [123]. Exposures to high concentrations of heavy metals cause several health hazards to the scavengers, recycling workers and those living around the vicinity. Exposure to heavy metals can take place through ingestion, dermal contact and inhalation. Some heavy metal found in e-waste and their hazardous effect are discussed below.

3.2.1. Lead, Pb

Lead is found in computer monitors, bulbs, television and Printed circuit boards, Cathode ray tubes, light bulbs, and batteries, television, electric wires, insulations and some lead compounds are also used as a stabilizer or plasticizer [1], [13], [124]. Exposure to lead is through Air, dust (ashes), water, and soil. High accumulation of Pb can harm the nervous system, damage the brain, DNA and kidney, cause blood disorder and disrupt the reproductive system [125]-[126]. In children, the contamination of Pb leads to delay in neurological development, altering the development of their brain, harming the development of the fetus [109], [127]. This also alters fetal growth and development and gives rise to low birth weight, low head circumference, intrauterine growth restriction [128]. From literature, e-waste Pb toxicity in preschool-age children is connected to DNA methylation and hearing loss [129], difficulties in sensory integration [130]. Pb contamination effects the behaviour of children, causing, reduced attention span and ability to deal with frustration, hyperactivity, antisocial behavior and depression [5]. In Guiyu, about 80 % of their children have respiratory diseases due to Pb poisoning [131]. More so, Pb accumulation in soil environment has caused serious damaging effects on plants.

3.2.2. Cadmium, Cd

The sources of cadmium in electric appliances include: computer monitors, switches, springs, connectors, printed circuit boards, semiconductor chips, photocopy machines (printer drums), cathode ray tubes, batteries, SMD chip resistors, infrared detectors photocopying machine and cell phones [17], [127]. More so, printers ink and toner contain cadmium [10]. Cadmium and its compounds are toxic to human health, accumulating especially in the kidney, causing potential risk of irreversible effects to man and exposures are usually via the air, dust, soil, water, food. High concentrations of Cd in the body, affects the reproductive system and damages the DNA, bone and kidney, causes irritation to the Respiratory system and persistent lung and kidney disease, leads to cancer, [127]. It also affects the neonatal weight and length negatively [132]. Cadmium may be associated with shortened placental length, which is involved in ageing and cancer development [133]. A study in Guiyu showed that significant increase in the concentration of Cd in the blood is linked to reduced cognitive abilities [134]. It may also cause the irritation of the respiratory system, kidney disease [127] and different types of cancer [135]

3.2.3. Arsenic, As

Arsenic is a doping agent in transistors and printed wiring boards and found in integrated circuit and semiconductors and is used in the manufacture of technological electronic [136]. It was found in the waste Gallium arsenide (GaAs) (generated during the production of LEDs) scraps [137] Primarily, man is exposed to arsenic via the ingestion of contaminated food or water [138] and secondarily by inhalation and skin absorption from contaminated sources[139]. The metal, As, is absorbed sufficiently into the blood stream through the alimentary canal and lung; then diffuses to other parts of the body such as the lung, liver, spleen, kidney, intestine, skin, vascular and lymphatic systems, reproductive and nervous systems [138]. The liver converts the absorbed arsenic to less toxic methylated form, which is excreted in the urine [140]. However, it affects the skin, nervous system and can cause lung cancer [109] and skin disorder and damages to the nerves [136]. Arsenic is associated with disturbed Glucocorticoids receptor function in human health and is connected to type 2-diabetes, different forms of cancer in the bladder, kidney, skin, liver, and colon [141], and cardiovascular disease [42].Pregnant e-waste worker with high As concentrations can have As diffused to the fetus via her placenta [138] to cause birth defects, infant mortality, low birth weight, and infertility [143] and may cause infertility via low sperm quality and erectile dysfunction in men [144].

3.2.4. Chromium, Cr

Chromium is used as anti-corrosion coatings on electronics to hinder corrosion and in the production of data tapes, films, memory (data) tapes and floppy disk, etc. Cr compounds are used as pigments in many electrical and electronic products [16] [57].Exposure to high concentration of chromium is via air, dust, water, soil etc. It passes through cell membranes very well, gets absorbed, contaminates the cell and produces different toxic effects in the affected cells [145]. Outside the cell of an organisms such as in the saliva and gastric juice [146], chromium is less toxic particularly when reduced to Cr^{3+}, however, within the cell environs, Cr of any oxidation state applies its toxic effects [147]-[148]. High levels of chromium causes irritation or injury to the respiratory tract, including the nostrils, throat, and lungs [145] and leads to lung cancer [146], causes damage to the DNA , severe allergic reactions such as asthmatic bronchitis and affects the reproductive system[17]. It can also cause low birth weight, low head circumference and intrauterine growth restriction in fetus [92]. In the literature, increased Cr concentration in infants' umbilical cord blood in Guiyu has been positively correlated to the mother's e-waste exposure [149].

3.2.5. Mercury, Hg

Some electronics and electronic parts are manufactured with mercury. These electronics and parts include thermostats, sensors, LCD monitors, relays and switches on printed circuit boards and sensors. Hg is also applied in measuring equipment and discharge lamps, cathode ray tubes and fluorescent lamps and batteries, data transmission, mobile phones and medical equipment such as thermometer, cells, spent fluorescent lamps (SFLs) which contains low-pressure mercury vapor [150]. The indiscriminate dismantling and open burning of these electronic waste containing mercury leads to environmental pollution with potential health hazards to man [150].The exposure to any form mercury may be via air, vapour, water, soil, food and accumulates in the fatty tissues of man and other animals [1], [151]. Methylmercury bio-accumulates in fish and shellfish, which when consumed by man would cause a potential health risk [17]. Hg Causes chronic damage to the brain [109]. Disruption of the central nervous system causes amyotrophic lateral sclerosis, Parkinson's disease, and Alzheimer's disease [152]. Inhalation and ingestion of Hg causes kidney insomnia, muscle atrophy, weakness and headaches [153]. More exposure to mercury leads to memory loss, immune toxicity, etc. [92]. Hg causes skin irritation, neurological disorder, memory disorder, cognitive debilities, etc. [154].

3.2.6. Nickel, Ni

Nickel as a metal resist corrosion, conducts electricity and heat, hence it is used mostly in electronics battery production [17], such as nickel-hydride batteries [155]-[156] manufacturing cathode ray tubes [17], alloys such as nickel-copper, nickel-chromium, nickel-iron [157], electrodes; heat exchangers, wire and nickel plating [158]. Exposures to Nickle may be through the air, soil, water, food (plants). Indiscriminate mechanical or thermo-mechanical dismantling of the e-waste NiMH (nickel-hydride) battery scrap [156] causes the release of nickel the environment, which impacts negatively to human health. It causes damage to the brain and nervous system, promoting allergy and autoimmunity [159], malignancies and defects in babies [160]. High accumulation of nickel may result to cancer of the prostate, laryngeal, nose and lung [160]-[161]. Contact with nickel may leads to allergy, cardiovascular and kidney diseases [161]. It may cause alterations in functions of the Liver [17],dermatitis, headaches; gastrointestinal manifestations, respiratory manifestations, cardiovascular diseases, epigenetic effects [145].

3.2.7. Copper, Cu

Copper is used in the production of wires and Printed circuit boards. Exposure to copper of high concentration at dismantling yards could be via: inhalation, consumption of contaminated food and water, and skin contact. Ingestion and contact with contaminated soil and plants could also lead to potential health risk to man. High accumulation of copper could be found in the brain, liver and lungs [162]. It makes the kidney and liver to malfunction [163], causing damage to the nervous system, reproductive system, adrenal function, connective tissue, learning ability in new born baby, etc. At very high concentrations copper causes vomiting, abdominal pain and diarrhea, convulsions or paralysis, which may lead to death [164]. Wilson’s disease may also result in case of inherited toxicity [162]-[163]. Nevertheless, copper has not been classified as carcinogenic (cancer causing) to humans [162].

III.CONCLUDING REMARKS

The indiscriminant disposal and the use of crude methods in recovering precious metals, which are eco-unfriendly, lead to the introduction of unthinkable dozens of hazards into the environment and cause health problems to plants, animal and man. Scavengers and e-waste worker should use green methods in recycling e-waste to reduce to the barest minimum, health risk issues. Government should also make polices to stop the importation of unchecked used electronics into Nigeria.

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