Toxicity of Chemicals Contained in Everyday Electronic Devices: A European Perspective

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I. Introduction

WHY toxicity in everyday electronics matters ? Most of our electronic devices contains chemicals. Some are inoffensive and other can be harmful. Harmful chemicals are widely used and sometimes for security concern. In Europe, we have a policy to regulate the amount of the toxic known chemicals. Despite this regulation, we are still exposed to these chemicals. This review will focus on the toxicity of chemicals contained in everyday electronic devices from a European perspective. The purpose of this work is to give an overview of the most common toxic chemicals in electronic devices and how they can affect humans.

II. Toxic Substances in Everyday Electronics

Electronic devices can be toxic in multiple ways and we use them everyday. This state of the art report will only treat about the toxicity of the chemicals contained in the devices. It is important to know that not only the electronic components themselves contain toxic compounds but also the metal or plastic casing, the wiring, the solder and other mechanical or electrical items that could be included in most of the electronic devices.

The most common and well-known toxic chemicals are listed in Table I. Brominated Flame Retardants (BFR) are a big concern since they are used in most of electronic device for safety policies imposed by EU [1]. The BFRs are extremely present in our lives and are able to bioaccumulate. They are dangerous for most of the living beings as they are endocrine disruptors and carcinogenic [2], [3]. They are present in printed circuit boards and incorporated in polymers which are used for casing. This means we are almost constantly in contact with BFRs. The two most common BFRs are Polybrominated Biphenyls (PBB) and Polybrominated Diphenyl Ethers (PBDE).

Another important heavy metal is Lead (Pb). It was widely used in old solders and is still present in some batteries and electronic components. Lead is extremely toxic for humans and can lead to neurological disorders, especially for children [4], reproductive system, immune system, nervous system and kidneys disorders [5], [6]. It is also restricted by the EU regulations [7].

Phtalastes are also widely used in electronic devices as plasticizers. They are used to increase the flexibility of polymers. We find them in cable insulation, plastic parts and housings and many other plastic components not directly linked to electronics. Phtalates exist under mutiple forms. Most of them are known for their high endocrine disruption properties [11].

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TABLE I
Common Toxic Chemicals in Electronics and EU Limits

Substance	Max (%)	Main Uses
Lead (Pb)	0.1	Solders, batteries
Mercury (Hg)	0.1	Switches, sensors
Cadmium (Cd)	0.01	Ni-Cd batteries
Hexavalent Cr	0.1	Metal plating
PBB	0.1	Flame retardants
PBDE	0.1	Flame retardants
DEHP	0.1	Cable plasticizers
BBP/DBP/DIBP	0.1	Plasticizers

Note: PBB = Polybrominated Biphenyls; PBDE = Polybrominated Diphenyl Ethers; DEHP = Di(2-ethylhexyl) phthalate; BBP = Benzyl butyl phthalate; DBP = Dibutyl phthalate; DIBP = Diisobutyl phthalate. Limits from EU RoHS Directive [7].

Cadmium (Cd) is another heavy metal used in batteries (Ni-Cd), electroplating and coatings. We find cadmium in some semiconductors as well. As electronic devices users we are exposed to cadmium through inhalation of dust particles or via direct contact with casings or other cadmium plated components. [10]. The exposure to cadmium can cause disorder in the immune system, reproductive system and nervous system [10].

Mercury (Hg) is another heavy metal used in some switches, sensors, lamps and batteries. Although its use has been greatly reduced in the last decades, we can still find mercury in some electronic devices. Mercury is highly toxic and can affect the nervous system, digestive system and immune system [12].

Hexavalent chromium (Cr VI) is used for corrosion-resistant coatings and metal plating. We find this toxic chemical on printed circuit board to protect the copper traces. Hexavalent chromium is known to be carcinogenic and can cause respiratory problems. It can also affect the skin and cause allergic reactions. The two main exposure pathways are inhalation and dermal contact. [13]

Other toxic chemicals can be found in electronic devices but are less common. The discussed chemicals are the most widespread and the most regulated by the European Union.

III. Exposure Pathways

How are we exposed to these toxic chemicals when handling electronic devices ? The main exposure pathways are inhalation, ingestion and dermal contact [14]. The inhalation of dust particles is a common way to be exposed to toxic chemicals. The dust particles can come from the handling of the electronic devices or from the degradation of the devices over time or from the unboxing of new devices. The ingestion of toxic chemicals can happen when we eat or drink without

washing our hands after handling electronic devices. The dermal contact is also a common way to be exposed to toxic chemicals. We are in contact with electronic devices all day long.

The respective effect on health of each chemicals depends on the exposure pathway. The age and the health condition of the person exposed are also important factors. Children are more vulnerable to toxic chemicals as their organs are still developing.

IV. EU Regulatory Framework

Since the toxic chemicals used electronic devices are harmful for humans and the environment, we could expect strong regulations to limit their use and exposure. As the use of these toxic chemicals is widespread and confer important specific properties to electronic devices, it is difficult to completely ban them. However, the European Union has implemented regulations to limit their use.

The most important regulation is the Restriction of Hazardous Substances Directive (RoHS) [7]. It restricts the use of certain hazardous substances in electrical and electronic equipment. The maximum concentration limits for the most common toxic chemicals in electronics are listed in Table I. The RoHS is a good step to limit the use of toxic chemicals in electronic devices. However, we could wonder if the regulations are sufficient to protect us since the regulation only limits the concentration of toxic chemicals. As we can read in RoHS directive, exemptions are possible for certain device categories purchased before 2019.

Are the regulations well enforced ? According to an impact assesment report from the European Commission from 2017 [15], 23-28% of the electronic devices placed on the EU market were non-compliant with RoHS directive. This can be explained by the complexity of the supply chain and the lack of control. The enforcement of the regulation is uneven across the EU member states as well. Each member state is responsible for the enforcement of the regulation within its territory.[14] The reports about non-compliant devices are mainly about electronic devices imported from China.[14] Some companies should benefit from exemptions but the exemption system seems to unclear and difficult to enforce as well according to the evaluation report from 2023 [14].

The RoHS directive is not only about the toxicity for humans but also for the environment. The recycling of electronic devices and the correct management of e-waste is an important aspect to consider as well. It is important to regulate the use of toxic chemicals in electronic devices but also to ensure that the devices are recycled properly to avoid environmental contamination. The protection of the environment is an indirect protection for humans as well. Most of the sources used in this review deal with ingestion of toxic chemicals via contaminated food or water as well.

V. Conclusion

This review has highlighted the presence of toxic chemicals in everyday electronic devices and their potential health risks. We could ask ourselves if the current regulations are sufficient to protect us from these toxic chemicals. Even if those chemicals are toxic, they are still widely used in electronic devices due to their specific properties. It is important to continue researching and monitoring the presence of these toxic chemicals in electronic devices. We can expect it to lead to new regulations which will then lead to the development of safer alternatives.

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