

NEGATIVE IMPACTS OF E-WASTE

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Abstract:The paper describes the negative effects of e-waste on the environment and human health. In addition to the obvious and ever-present problem of pollution due to inadequate disposal of e-waste, the negative impacts are multiplied if it is known that numerous rare metals have been used in the production of modern electronic devices. Even resources that are assumed to be always available (water, coal, oil, wood, etc.) are slowly but surely disappearing, so it is not necessary to explain in particular how big a risk it is to ensure an uninterrupted supply of rare and precious metals that make up the components of electronic devices. It is obvious that the way they are obtained - by exploiting the planet Earth - is unsustainable and destructive in many ways. It is also clear that the method of production and use of electrical devices and equipment and the method of their final disposal after use must be changed if the survival of the human species and plant and animal species on planet Earth is not to be threatened by uncontrolled technological progress.

Key words:e-waste, environment, health, negative, impact.

1. INTRODUCTION

Electrical and electronic waste, or e-waste, includes discarded waste electronic equipment and devices. Due to the accelerated technological development, this type of waste represents an increasing environmental problem and challenge. In 2014, the estimated amount of e-waste generated worldwide was 41.8 million tons. This amount included: 12,8 million tons of small components (vacuum cleaners, microwave ovens, toasters, electric shavers, video cameras, etc.) and 11,8 million tons of large components (washing machines, dishes washers, dryers, stoves, photovoltaic panels, etc.), followed by 7 million tons of HVAC equipment, 6,6 million tons of screens and monitors, and 3 million tons of smaller IT devices (mobile phones, calculators, desktop computers, printers, etc.) For the year 2022, 60,5 million tons of generated e-waste is predicted with a growth rate of 4-5% per year [1].

This trend will not slow down any time soon given the current trends in the design and manufacture of electrical equipment, which support the premature and artificial end of the life cycle of electrical devices and their premature rejection and replacement. The rapid development and change of design and specifications is certainly a sign of the incredibly accelerated development of this technology, but at the cost of human health and environmental pollution.

Numerous local communities damage the quality of their environment due to inadequate legislative restrictions and the lack of effective technological methods for the final treatment of e-waste. On the other hand, numerous first world countries recognized the problem of e-waste management, but as the cheapest and safest solution for their country, they chose to simply export e-waste to third world countries.

Inadequate management of e-waste represents one of the biggest problems from the aspect of environment and human health protection and is solely the result of the inadequate attitude of human society towards e-waste. These developments were not accompanied by an appropriate environmental protection policy.

On the other hand, an integral e-waste management system is the basis for the successful protection of the basic elements of the environment: water, soil, air, flora and fauna, landscapes, etc. Strict compliance and application of the adopted legislative framework for e-waste management

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provides conditions for the establishment and development of an integral waste management system [2], [3].

2. EU DIRECTIVES FOR E-WASTE MANAGEMENT

In the EU, two directives are in force that provide legislative frameworks and instructions for e-waste management: Waste Electrical and Electronic Equipment Directive (WEEE) [4] and Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS) [5], setting targets for the collection, recycling and recovery of all types of waste electronic and electrical products. The WEEE Directive classifies e-waste into numerous categories, the primary ones being: historical and non-historical e-waste.

Historic e-waste includes all electrical and electronic equipment on the market before 2005, while all electrical and electronic equipment put on the market after 2005 falls under non-historical e-waste. Apart from the production date, an important difference is that for e-waste before 2005, the owner is designated as the person responsible for its disposal and after 2005, the manufacturer or supplier must ensure safe collection, recycling and disposal [4].

In addition to these two categories, the WEEE Directive defines 10 categories of e-waste:

- 1st Class (large household appliances): refrigerators, freezers, refrigerated cabinets, washing machines, dish washers, clothes dryers, electric stoves, hotplates, built-in ovens and hobs, microwave ovens, heaters, TA ovens, electric radiators, electric fans, air conditioners, boilers...
- 2nd Class (small household appliances): vacuum cleaners, sewing, knitting and weaving devices, irons, toasters, fryers, grinders, coffee makers, electric knives, hair clippers, hair dryers, toothbrushes, shavers, massagers, watches, wristwatches and measuring devices...
- 3rd Class (IT and telecommunications equipment): centralized data processing, mainframe computers, small computers, personal computers, printing units, notebook computers, sticks, copiers, typewriters, pocket and desktop calculators, telefaxes, telephones, public, wireless, mobile, telephone secretaries...
- 4th Class (consumer leisure equipment): radios, TVs, video cameras, video recorders, Hi-Fi devices, audio amplifiers, musical instruments...
- 5th Class (lighting equipment): lighting fixtures for fluorescent lamps, flat and compact fluorescent tubes, high-pressure lamps, incandescent lamps...
- 6th Class (power and electronic tools): drills, saws, sewing machines, equipment for turning and grinding, polishing, turning, cutting, tools for riveting, soldering and similar use...
- 7th Class (toys for recreation and entertainment): electric vehicles, handheld video game consoles, electric sports equipment, slot machines for playing with metal money...
- 8th Class (medical auxiliary devices): radiotherapy equipment, cardiology devices, dialysis devices, pulmonary ventilators, nuclear medicine devices, laboratory equipment for diagnosis, analysis, cooling, examination devices...
- 9th Class (monitoring and monitoring instruments): smoke detectors, heating regulators, thermostats, measuring, weighing, calibration devices, other monitoring instruments...
- 10th Class (automatic machines): automatic machines for hot drinks, for bottles, cans, for solid products, ATMs...

The RoHS directive of the European Union is part of the global regulation regarding environmental protection, with the task of reducing the impact of electronic/electrical waste to the prescribed measure. The ROHS directive refers to the restriction of the use of hazardous substances in electrical and electronic products. It involves the use of 4 heavy metals (mercury, cadmium, lead, hexavalent chromium) and 2 products added to plastic to reduce flammability (PBB and PBDE).

The analysis of the requirements of the ROHS directive, as well as a recommendation for the establishment of a procedure for ensuring ROHS compliance represent a systematic responses to the fulfillment of a complex set of requirements required for manufacturers. Ensuring RoHS compliance acts preventively, because the use of environmentally hazardous substances is already taken into account when designing an electronic/electrical product [5].

3. E-WASTE GENERATION

Advances in technology lead to the generation of ever-increasing amounts of e-waste. Modern electronics quickly become outdated and discarded and the fastest and easiest solution is a simple replacement by purchasing a new device. Thus, modern electronic devices have a characteristic shortcut to obsolescence. Little progress has been made to align the design of electronic products with the need for recycling and disposal because that very important part of production has always been focused on profit, marketing and the users. A new design that allows easier disassembly, repair or upgrading of the product would significantly extend its life and ultimately reduce the amount of e-waste [3].

Generators of e-waste can be classified into 3 main groups: households and small businesses, large businesses and the state, and manufacturers of electrical and electronic equipment. Households most often get rid of their e-waste (devices, equipment and appliances) not because they are no longer functional, but because the technology is simply outdated. The Law on Waste Management [6] allows the disposal of e-waste together with all other household waste in bins and containers. The replacement of electronic equipment is done regularly in large companies and institutions, so an international company such as Microsoft for example, replaces all its computers with new ones every 3 years [7].

Technology can certainly make a large number of devices outdated and obsolete but aggressive marketing mostly helps with that. After it has been used for an average of only 1 year and a maximum of 2 years, the correct equipment is discarded and replaced with newer and more modern ones in order to keep up with the times. Poor manufacturing, design and poor use lead to faster disposal of electronic devices, and other causes are [8]:

- Physical failure - 24% of laptops are discarded already in the first 3 years of use due to failures of physical parts.
- Upgraded software - due to incompatibility with older hardware, new upgraded versions of software increase the amount of discarded electronic devices because the processors, memories and other features are not enough to support new operating systems, latest programs, applications, computer games, etc.
- Digital television - the transition from analog to digital television and the development of HD television as a side effect has an increased amount of e-waste from analog TV devices.
- Battery replacement - many smaller electronic devices have rechargeable batteries but often with a limited cycle and number of charges and when this cycle is completed, it is time to replace the battery but a large number of electronic equipment does not consider battery replacement so replacement is difficult and the user often decides to buy a brand new device.
- Mobile telephony - the incredible explosion in the use and development of mobile phones of all kinds cannot be ignored so all companies that manufacture phones and companies that provide mobile telephony services are constantly renewing their offer with the latest models encouraging users to change phones more often, even though they are not even close to the end of their lifespan.

The rapid development of technology leads to a shorter lifespan of electronic products and generates more and more waste. Every year, depending on the quantity, each country uses hundreds of thousands, even hundreds of millions of electrical and electronic devices. In 2012, for example, 1,6 billion mobile phones were produced and by 2008, over a million home desktop computers were assembled [9]. Globally, there are about 8,5 billion mobile phone users, more than the total number of people on planet Earth [10].

4. NEGATIVE IMPACTS OF E-WASTE

E-devices have special characteristics, which make their production, use and disposal dangerous for the environment and human health. E-devices require special handling and storage due to their composition. At the end of their shortened lifespan, they become e-waste which has become a global problem mainly due to the following reasons: unsustainable design and profit-oriented marketing are the cause of increased generation of e-waste and due to product obsolescence, e-waste is generated in alarming amounts, e-devices contain a large number of rare and scarce materials and over a thousand different substances that are mostly toxic and create enormous pollution during disposal, which in most cases is inadequate and ineffective and inadequate handling of e-waste degrades the environment and endangers human health [2], [3].

Over a thousand different types of materials are used to make electronic devices and their components (semiconductors, chips, printed circuits, disk drives, etc.). The largest number of substances used are toxic, such as: chlorine-based solvents, bromine-based flame retardants, PVC, heavy metals (lead, mercury, arsenic, cadmium, hexavalent chromium), plastics and gases [11]. Over 1.450 tons of brominated carbon derivatives, which belong to the class of neurotoxins, better known as TBBPA, were used to produce 991 million mobile phones, which were sold in 2006 [12].

The effects of these substances on the human body are diverse and certainly harmful. Lead damages the central and peripheral systems, the cardiovascular and reproductive systems and the kidneys and is found in motherboards, screens and monitors, approximately 1,5-4 kg per monitor. Cadmium is fatal for the kidneys because it settles on them and it can be found in chips and as a plastic stabilizer. It is well known that mercury has a toxic effect on the body, brain, kidneys, and fetus. If it is disposed of inadequately and gets into the watercourse, it can get into the human body because it is very easily deposited in living organisms for human consumption (fish for example). It is estimated that around 22% of the world's consumption of mercury is realized in the electronic industry and mercury is an integral part of every thermostat, sensor, relay, battery, mobile device and LCD screen. Hexavalent chromium is used for: corrosion protection, as casing stiffener or even as a decoration and it is easily absorbed in cells and can damage human DNA [13].

The most common material of the modern era is certainly plastic and the average computer contains about 7 kg of it. PVC (polyvinyl chloride) plastic is most commonly used. By burning plastic, carbon-dioxide is released, the harmful effects of which on the environment are numerous and generally known and it is a well-known gas with the greenhouse effect. Bromine flame retardants are used to prevent fires in plastic housings, while barium is used as radiation protection in CRT monitors. Barium is a soft, silver-colored metal that can cause swelling of the brain, muscle weakness and damage to the heart, spleen, and liver with only brief exposure. Due to its non-magnetic nature and light weight, the metal beryllium is used in motherboards and it is carcinogenic and causes lung cancer. The main ingredient of printer toner is a highly carcinogenic pigment that most often gets into the body by inhalation, causing irritation of the respiratory tract. Phosphorus, which is also poisonous, is used to coat CRT monitors [13].

Very important elements in the production of electronic devices and exploitation of rare and precious resources include: huge amount of energy, materials and water. Raw materials for the production of e-devices are primarily obtained through excavation and mining, where a large area of land is exploited and a large amount of energy and fuel is consumed. The pollution and degradation of water, air and soil ecosystems in mining is also serious and extensive. For one ton of gold, palladium or platinum, 10,000 tons of carbon-dioxide are released into the atmosphere [14].

Tiny semiconductors, better known as chips or integrated circuits are used in almost every device today and have led to the third electronic or information revolution and require a huge amount of material and energy for production. Silicon is used for their production and 1 semiconductor can contain about 500-10,000 different chemical ingredients. The production of 1 microchip, weighing only 2 grams, generates 26 kg of waste materials, most of which are toxic [15]. Old TV sets with cathode ray tubes, CRTs, which have now mostly ended up in landfills, contain about 2-4 kg of lead per TV set. New LCD TV sets with a liquid crystal display as a component have mercury lamps to illuminate the screen. The amount of 1 gram of mercury per year is enough to pollute a lake of 1,6 hectares so much that the fish become inedible. One LCD TV set contains 1 microgram of mercury [16].

An additional problem is that the sources of some of the minerals, such as tantalum, tungsten and other rare metals, are unknown and unreliable. One should not ignore the negative impacts on poor countries that are most often exploited for the sake of extracting these resources. These areas are most often Asia, Africa and South America. Concern about this fact is shown only by organizations dealing with the protection of environment, human and children's rights in third world countries, where companies that extract these rare metals are most active [17].

5. CONCLUSION

When, after all of the above, after the exposed risks to human health and the environment, and taking into account the lack of these minerals and the degradation created by their exploitation, it is very irresponsible to dispose of old electronic devices in a landfill, neglecting repair, restoration of materials or recycling. Manufacturers of these devices must reduce the use of scarce raw materials and consider sustainable design. They need a device that can be used multiple times and easily recycled. Also, the less e-waste that ends up in a landfill means that more raw materials will be recycled from discarded electronic devices. The amount of electronic waste in the landfills of developing countries is growing rapidly as they themselves join the global information society. At the moment, electronic devices are disposed of in a very small percentage in an adequate way and there is a small number of legal frameworks that would regulate this. This situation creates a danger for the population and the environment. While the environmental protection industry has grown into a multi-billion dollar global industry over the past decades, its impact is largely unnoticed in developing countries. In addition to missed business opportunities, this is also a risk if one takes into account the fact that these countries have the largest amount of e-waste, mostly due to exports. E-waste contains highly toxic substances such as: lead, mercury and arsenic, but also very rare and valuable components such as copper and gold. When electronic devices reach the true end of their life cycle, when they can no longer be used, they must be properly dismantled, recycled and disposed of. Once again, it is important to resort to recycling and final disposal only at the very end of the life cycle, after repair, restoration, replacement of worn and broken parts in electronics and after recovering as much valuable raw materials as possible from an electronic device. Therefore, it is necessary to look at the entire life cycle of electronic products in order to understand the true value and burden they carry. It is time for consumers, users, researchers, manufacturers as well as national and international regulatory bodies to redirect part of their passion for new modern electronic devices towards responsible management of their old devices.

6. REFERENCES

- [1] Baldé, C.P., Wang, F., Kuehr, R., Huisman, J., *The global e-waste monitor – 2014*, United Nations University, Bonn, Germany, 2015.
- [2] Нешић Б., *Генератори отпада и загађивачи јужне и југоисточне Србије*, Центар за развој грађанског друштва „Protecta”, Ниш, Србија, 2010.

- [3] Нешић Б., *Управљање комуналним отпадом и потенцијали за рециклажу јужне и југоисточне Србије*, Центар за развој грађанског друштва „Protecta”, Ниш, Србија, 2010.
- [4] *Directive 2012/19/EU of the European Parliament and of the Council of 4th July 2012 on waste electrical and electronic equipment (WEEE)*, Official Journal of the European Union, L197, Volume 55, 2012.
- [5] *Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)*, Official Journal of the European Union, L174, Volume 54, 2011.
- [6] *Закон о управљању отпадом*, „Службени гласник РС”, бр. 36/2009, 88/2010, 14/2016, 95/2018, 35/2023.
- [7] <https://www.statista.com/statistics/273475/number-of-employees-at-the-microsoft-corporation-since-2005/>, December 2024.
- [8] Electronics TakeBack Coalition (ETBC), *Quickly Obsolete* (<http://bit.ly/hc2Tu7>), 2010.
- [9] <http://www.itu.int/pub/D-IND-ICTOI-2009>, December 2024.
- [10] <https://www.gsmainelligence.com/>, December 2024.
- [11] Widmer R. et al., *Global perspectives on e-waste*, Environmental Impact Assessment Review 25, 2005.
- [12] *Toxic Tech: Not in our Backyard*, Greenpeace (<http://bit.ly/bypCx8>), 2008.
- [13] Crowe, M. et al., *Waste from electrical and electronic equipment*, European Environment Agency, Copenhagen, Denmark, 2003.
- [14] <https://ehp.niehs.nih.gov/15-09699/>, December 2024.
- [15] Grossman E., *High tech trash: digital devices, hidden toxics, and human health*. Washington, D.C: Island Press, 2006.
- [16] Electronic TakeBack Coalition (ETBC), *E-waste: the exploding global electronic waste crisis* (Available at: [http:// bit.ly/enA1j4](http://bit.ly/enA1j4)), 2009.
- [17] European Commission, *Critical raw materials for the EU* (Available at <http://bit.ly/aXAc91>), 2010.