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Review and Analyze the Sources, Characteristics and Composition of Electronic Waste

[1,2]LY, NHT; [1]*GIAO, NT

[1]*College of Environment and Natural Resources, Can Tho University, 3-2 Street, Xuan Khanh Ward, Ninh Kieu District, Can Tho City, 900000, Vietnam*
[2]*Doctoral Student in Soil and Water Environment, College of Environment and Natural Resources, Can Tho University, 3-2 Street, Xuan Khanh Ward, Ninh Kieu District, Can Tho City, 900000, Vietnam*

**Corresponding Author Email: ntgiao@ctu.edu.vn*
**OCRID: https://orcid.org/0000-0001-5916-4710*
**Tel: +84907739582*

ABSTRACT: The objective of this paper was to review and analyze the sources, characteristics and composition of electronic wastes by collecting the studies related to the research problem from various databases. The results of the evaluation of articles show that electronic waste includes all old or expired electrical and electronic equipment that has been discarded by consumers. With an average growth rate of about 2.6 million tonnes per year, it is estimated that by 2030, the amount of e-waste generated will be up to 82 million tonnes. E-waste is classified into many different categories and contains many valuable materials that can be recovered and reused to overcome the shortage of raw materials, while limiting the adverse impacts of hazardous substances in e-waste on the environment and human health. The results of the research provide a general and valuable overview of the sources, characteristics and composition of electronic waste.

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The increasing demand for electricity and electrical and electronic equipment has contributed to a large increase in the amount of electronic waste (e-waste) in developing and developed countries. E-waste includes a wide range of electronic devices such as information and telecommunication equipments, household appliances, lighting equipments, automated dispensing equipments, medical equipments, monitoring and control equipments, entertainment and sports electronics, toys, mobile phones and computers (Shahabuddin *et al.*, 2023). E-waste is considered the fastest growing waste stream and generated about 2.6 million tonnes annually (Nithya *et al.*, 2021). Among different continents, Asia have the largest amount of e-waste (46.4%), followed by Americas (24.4%), Europe (22.4%), Africa (5.4%) and Oceania (1.3%) (Forti *et al.*, 2020). The study by Forti *et al.* (2020) also showed that Asia is the continent that generates the highest amount of e-waste but the amount of e-waste generated per capita in Asia is much less than that in Europe, Oceania and Americas. Unlike household waste, e-waste has the characteristics of being both hazardous and useful (Ilankoon *et al.*, 2018). E-waste is a mixture of plastics, metals and synthetic materials. The metallic and non-metallic components in e-waste have high recyclability such as copper, gold, silver, aluminum, iron,... (Debnath *et al.*, 2018). However, there are also many heavy metals such as lead, mercury, cadmium and persistent organic pollutants such as polychlorinated biphenyls, brominated flame retardants (He *et al.*, 2017; Rautela

**Corresponding Author Email: ntgiao@ctu.edu.vn*
**OCRID: https://orcid.org/0000-0001-5916-4710*
**Tel: +84907739582*

et al., 2021). Heavy metals are the main risks associated with e-waste pollution due to their toxicity, recalcitrance to biodegradation and rapid bioaccumulation found during the treatment and recycling of e-waste (Jiang *et al.*, 2019; Ali and Mahrukh, 2020). Therefore, if not properly treated, these toxic substances in e-waste will cause serious damage to the ecosystem, human health, and waste a large amount of valuable materials (Hai *et al.*, 2015). Forti *et al.* (2020) also showed that only 17.4% of the volume of e-waste is collected and recycled due to the complicated collection and recycling process. Therefore, the aim of the study is to review and analyze the sources, characteristics and composition of electronic waste.

MATERIAL AND METHODS

The study used secondary data obtained through a literature review of articles related to characteristics, sources, types and composition of electronic waste in scientific articles published in specialized journals. In this study, articles were collected from the databases included ScienceDirect, Springer Nature, Google Scholar. These databases were selected due to their representativeness and coverage in publishing and searching for research articles on e-waste. Many studies around the world have also used these database to systematically review and evaluate articles on e-waste (Maphosa and Maphosa, 2020; Andeobu *et al.*, 2021; Madkhali *et al.*, 2023).

To ensure wide coverage of articles in search engines, avoid biased research and find relevant research articles, some keywords in both Vietnamese and English languages were used including electronic waste (e-waste), overview of e-waste, sources of e-waste, composition of e-waste, e-waste generation, classification of e-waste, characterization of e-waste, hazardous metals from e-waste, precious metals from e-waste. The articles were searched for the period from 2000 to 2024. The titles and abstracts of all articles were screened to check their relevance to e-waste. After reviewing the titles and abstracts of the articles, documents with irrelevant content and duplicate articles were eliminated. A total of about 55 domestic and foreign research articles were selected for further evaluation and in-depth research. These articles were entered into Microsoft Excel software for synthesis and classification.

RESULTS AND DISCUSSION

Concept and sources of electronic waste: E-waste is any electrical and electronic equipment that is no longer useful to its owner (Shaikh, 2021). There is currently no comprehensive definition of e-waste. According to the Basel Action Network, discarded appliances using electricity, which include a wide range of e-products from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users (Puckett and Smith, 2002). While according to the Organization of Economic Cooperation and Development, any appliance using an electric power supply that has reached its end of-life is e-waste (Suja *et al.*, 2014). According to the Step Initiative (2014), e-waste refers to the reverse supply chain that collects products no longer desired by a given consumer and refurbishes for other consumers, recycles, or otherwise processes wastes. However, many studies have identified the need for a clear definition of e-waste due to the rapid change in technology that is reducing the lifespan of electronic products (Bigum *et al.*, 2013). Currently, the most widely accepted definition of e-waste is the European Union Waste Electronic and Electrical Equipment Directive - all components, sub-assemblies, and consumables, which are part of the product at the time of discarding (Directive, 2003). This Directive is also recognized as the most widely applied e-waste management law in the world today and defines the concept of e-waste.

Based on the definition of e-waste, the source of e-waste can be all items with electrical components or circuits with batteries or power sources in government organizations, commercial organizations, research organizations, households and manufacturing industries (Ankit *et al.*, 2021). These sectors are in the process of rapid development and contribute to the majority of e-waste generated when any device becomes obsolete. Important devices include large and small household appliances, information technology and telecommunications equipment, entertainment equipment, medical equipment from hospitals and the private sector, machinery, industrial equipment, etc. (Ari, 2015; Ankit *et al.*, 2021). Many studies show that household e-waste contributes quite a bit to e-waste generation, usually accounting for 20 – 21% (LeBel, 2012). At the same time, it is difficult to estimate the actual amount of household e-waste generated. Household e-waste is usually discarded household appliances such as televisions, washing machines, refrigerators, mobile phones, etc. (Ankit *et al.*, 2021). Meanwhile, e-waste from government agencies, organizations, industrial sectors, private sector, and hospitals generates the most waste. Of which, 79% of computers (PCs) are the most used and discarded devices (LeBel, 2012). In addition, Mundada *et al.* (2004) pointed out that about 1050 million tonnes of peripherals (IC chips, circuit boards, CRTs,...) are discarded each year. In addition, the import and export of e-waste is also a significant source of e-waste (Jain *et al.*, 2023). E-waste is exported to poor countries for dumping and mainly for the extraction of precious metals from the waste generated. Therefore, the import and export of e-waste has become an important component of e-waste recycling (Jain *et al.*, 2023).

The amount of e-waste is increasing, although it only accounts for a small proportion of the total amount of municipal solid waste. The first estimated amount of e-waste was in 1994 (7 million tonnes), after which the production of e-waste increased exponentially in the following years (Pascale *et al.*, 2018). **Figure 1** shows that the amount of e-waste generated was estimated at 33.8 million tonnes in 2010. With an average growth rate of about 2 – 2.6 million tonnes per year, the amount of e-waste increased to 44.4 million tonnes in 2014 and 55.5 million tonnes in 2020. In 2022, the amount of e-waste worldwide increased by 82% compared to 2010, reaching 62 million tonnes. It is estimated that by 2030, the amount of e-waste is expected to increase significantly, reaching 82 million tonnes (Forti *et al.*, 2020; Balde *et al.*, 2024). On the other hand, the compound annual growth rates of the global population and e-waste from 2015 to 2019 were calculated to be 0.9% and 2.9%, respectively. This shows that the amount of e-waste generated globally is increasing at a faster rate than the global population growth rate (Forti *et al.*, 2020).

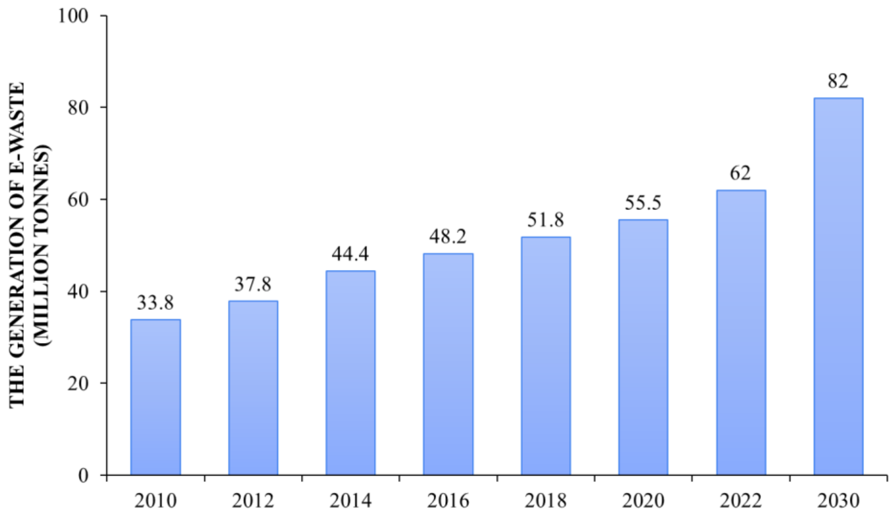

Fig. 1: Global electronic waste generation 2010 – 2022 and expected by 2030

For each type of e-waste, large-sized equipment, small-sized equipment, and heat exchange equipment all account for high proportions of 24.4%; 32.5%, and 20.1%, respectively (Forti *et al.*, 2020). The amount of e-waste generated can vary between regions of a country and between countries. Due to the definition of waste generated, the technology used, the consumption patterns of users, and the standard of living around the world (Andarani and Goto, 2014). In 2019, countries in the Asian region generated the most e-waste (24.9 million tonnes) with an annual e-waste growth rate of 4.4%, followed by the Americas (13.1 million tonnes) and Europe (12 million tonnes, while e-waste in Africa and Oceania was only about 2.9 million tonnes and 0.7 million tonnes (Forti *et al.*, 2020). Although Asia has the highest e-waste generation due to its largest population (more than 50% of the world's population), Europe is the region with the highest e-waste generation per capita compared to other regions in 2019 (Murthy and Ramakrishna, 2022). In addition, although Africa is the second most populous continent in the world, it has the lowest e-waste generation. This may be due to the growth of technology slow and have more limited access to energy than other continents (Andeobu *et al.*, 2021). Research by Balde *et al.* (2017) also shows that the amount of e-waste generated each year in Africa is partly due to the import of new and used electronic equipment from developed countries while only a small part of it is produced by some domestic assembly plants. On the other hand, in the collection and recycling of e-waste, Europe is the leading continent among the continents in the world. Europe collected approximately 5.1 million tonnes of e-waste, accounting for 43.6% of the e-waste generated in the same year 2016. Asia and the Americas also collected and recycled 2.9 million tonnes (13.6%) and 1.23 million tonnes (10.1%) of e-waste respectively in 2016. Oceania and Africa had the

lowest e-waste collection and recycling rates compared to the other continents (ITU, 2020).
Previous research has also shown that the majority of e-waste is generated in wealthy countries such as the United States or European Union member (Oliveira *et al.*, 2012). The United States is noted as the largest e-waste generator with a cumulative total of 3 million tonnes per year. China is next with 2.3 million tonnes per year and Brazil has the largest e-waste generation among emerging economies in the world (Oliveira *et al.*, 2012). However, in 2019, the leading e-waste generating countries worldwide have changed significantly. There are 10 countries with the highest e-waste generation worldwide, with the highest e-waste generation recorded in China, followed by the United States, and the remaining countries in decreasing order include India, Japan, Brazil, Russia, Indonesia, Germany, the United Kingdom, and France (Forti *et al.*, 2020). In addition, the amount of e-waste generated can vary between regions of a country due to the definition of waste generated, the technology used, consumption patterns, and changes in living standards globally (Andarani and Goto, 2014).

As a country in the Asian region, Vietnam is also experiencing a sharp increase in the consumption of electrical and electronic equipment due to increased demand for products in recent years. E-waste in Vietnam often originates from the disposal of electrical and electronic equipment in households, industrial processes in the electronics industry, imports of discarded electronic equipment from other countries, and e-waste dismantling and recycling sites (Tran and Salhofer, 2016; Poudel *et al.*, 2023). In 2019, the amount of e-waste generated in Vietnam was 257,000 tonnes, equivalent to 2.7 kg per capita (Forti *et al.*, 2020). It is estimated that the number of discarded devices in 2025 will be approximately 17.2 million devices (including televisions, refrigerators, washing machines, personal computers, and air conditioners), equivalent to 567,000 tonnes (Nguyen *et al.*, 2019). In addition, if the sources of e-waste from illegal import and export activities are included, the amount of e-waste predicted to be generated in Vietnam will be much higher. Therefore, it is important to pay attention to the potential for e-waste generation in Vietnam (Yoshida *et al.*, 2016).

Classification of electronic waste: There are many methods to classify e-waste, such as based on product type, size, processing method and technology or e-waste can be classified based on physical and chemical composition (Halim and Suharyanti, 2020). According to the study of Lee *et al.* (2024), e-waste is usually classified into four groups and presented in Table 1.

Table 1: Main types of e-waste

Categories	Examples
White goods	Air conditioners, heaters, carpet sweepers, clocks, clothes dryers, electric cookers, electric hot plates, electric kettle, electric knives, electric radiators, electric stoves, freezers, grinder-mixture-blenders, irons, microwave, refrigerators, toasters, vacuum cleaners, and washing machines
ICT devices	Calculating devices, communication satellite, copying machines, desktops, laptops, mobile phones, monitoring and control instruments, monitors, network cables, notebooks, pocket calculators, printers and scanners, routers, telephones, and wi-fi modems
Consumer equipment	Automatic dispensers, camcorders, digital cameras, electrical and electronic tools, electric shavers, fax machines, hi-fi equipment, leisure and sporting equipment, medical devices, musical equipment, personal stereos, photocopiers, radios, toys, TVs, and smoke detectors
Lighting equipment	Electric lamps, fluorescent tubes (straight and compact), halogen bulbs, high intensity discharge lamps, LED bulbs, and sodium bulbs
Equipment components/accessories	Batteries, printed circuit boards (PCBs), plastic casings, cathode-ray tubes (CRTs), activated glass, and lead capacitors

Source: Lee *et al. (2024)*

On the other hand, according to Directives 2002/96/EC, 2012/19/EU and 2018/849/EU (Directive, 2012; Directive, 2018), e-waste was initially classified into ten categories including: large household appliances; small household appliances; IT and telecommunications equipment; consumer equipment and photovoltaic panels; lighting equipment; electrical and electronic tools (with the exception of large-scale stationary industrial tools); toys, leisure and sports equipment; medical devices (with the exception of all implanted and infected products); monitoring and control instruments and automatic dispensers. After two amendments, all e-waste was reviewed and grouped from ten categories into six main categories under the new directive including temperature exchange equipment; screen and monitors; lamps; large equipment; small equipment and small IT and telecommunication equipment are presented in Table 2.

Table 2: Classification of e-waste

No.	Category	Examples
1	Temperature exchange equipment	Air conditioners, freezers, refrigerators, heat pump
2	Screen and monitors	Televisions, monitors
3	Lamps	LED lamps, fluorescent lamps, high intensity discharge lamps
4	Large equipment	Washing machines, large printing machines, dishwashing machines
5	Small equipment	Vacuum equipment, radio, toasters, toys, medical devices, video cameras, electronic tools
6	Small IT and telecommunication equipment	Telephones, printers, personal computers, pocket calculators

Source: Miner *et al. (2020)*

In addition, electronic waste is also classified according to its origin and usage such as large household appliances, information and communication technology equipment, consumer electronics, small household appliances, electrical and electronic tools, lighting equipment, toys, entertainment and sports equipment, medical equipment, monitoring equipment, control and automatic distribution... (Singh and Amin, 2018). However, many countries in the world only focus on managing some typical types of household electrical and electronic waste such as televisions, computers, telephones, refrigerators, washing machines, air conditioners (Hong *et al.*, 2015; Ismail and Hanafiah, 2021; Velasquez-Rodriguez *et al.*, 2021). The average percentage of each type of e-waste can vary depending on many factors such as socio-economic conditions, consumer behavior, population, and the dependence of businesses and households on electrical and electronic equipment (Balde *et al.*, 2017). For each type of waste, small appliances accounted for the majority of e-waste generated worldwide in 2019 with 17.4 million tonnes. This was followed by large appliances with 13.1 million tonnes and heat exchangers with 10.8 million tonnes. Finally, the equipment group containing displays, small IT and telecommunications equipment, and lamps accounted for the smallest proportions at 6.7 million tonnes, 4.7 million tonnes, and 0.9 million tonnes, respectively (Forti *et al.*, 2020). On the other hand, heat exchangers are the fastest-growing group of equipment in recent years with an average annual growth rate of 7%. This is followed by large appliances at 5%, and lamps and small appliances at 4%. However, small IT and telecommunications equipment has a rather slow growth rate (Forti *et al.*, 2020). Particularly for European countries, large household appliances have the highest generation of e-waste, accounting for 42.1%. This is followed by IT and telecommunications equipment (33.9%). The remaining equipment accounts for a relatively small proportion of e-waste. In addition, for developing countries, e-waste is mainly televisions, computers, and mobile phones (Kalia *et al.*, 2021; Shahabuddin *et al.*, 2023).

In Vietnam, e-waste has not received due attention because the infrastructure for recycling and treating this type of waste is limited as well as the distinction between hazardous waste and e-waste is unclear (Danh, 2022). Therefore, the classification of e-waste in Vietnam is classified according to their usage. In addition, the group of household electronic devices and office equipment such as personal computers, fax machines,... accounts for the highest disposal rate among the types of e-waste in Vietnam. Research by Brindhadevi *et al.* (2023) showed that Hanoi residents discarded more than 161,000 televisions, 97,000 personal computers, 178,000 refrigerators, 136,000 washing machines and 97,000 air conditioners in 2020. In addition, electrical equipment containing electronic components or unused electronic components due to damage (breakage) are listed in the List of hazardous waste issued with Circular No. 36/2015/TT-BTNMT on Hazardous Waste Management with hazardous waste code 16 01 13 and the hazard threshold is denoted as ** (this is hazardous waste in all cases, there is no need to apply the hazardous waste threshold but always identify it as hazardous waste). For Circular No. 02/2022/TT-BTNMT, discarded electrical and electronic equipment is more clearly defined and presented in Table 3.

Table 3 indicates that the electronic equipment and components in the list of hazardous waste, controlled industrial waste and common industrial solid waste issued with Circular No. 02/2022/TT-BTNMT are all denoted as NH, which means hazardous waste in all cases. However, this Circular only classifies some types of electrical and electronic equipment. Therefore, some studies in Vietnam choose the classification of electronic waste according to the European Union Directive to collect data on electronic waste generation, and at the same time be able to evaluate, analyze and compare with studies on electronic waste in the world.

Table 3: Symbols of electrical and electronic equipment in Circular 02/2022/TT-BTNMT

Waste code	Category	EC Code	Basel Code (A)	Basel Code (Y)	Properties of hazardous	Sign classification
16 01 06	Fluorescent lamps and waste activated glass	20 01 21	A1030	Y29	Đ, ĐS	NH
16 01 07	Disposal equipment containing CFCs	20 01 23		Y45	Đ, ĐS	NH
16 01 12	Waste batteries	20 01 33	A1160 A1170	Y26 Y29 Y31	Đ, ĐS, AM	NH
16 01 13	Waste electronic equipment or electrical equipment (other than those listed in codes 16 01 06, 16 01 07, 16 01 12) containing electronic components (with the exception of the circuit boards do not contain components with hazardous elements exceeding the threshold)	20 01 35	A1180 A2011	Y26 Y29 Y31	Đ, ĐS	NH

Note: AM: Corrosive; Đ: Toxic; ĐS: Ecotoxic; NH: Hazardous

Composition of electronic waste: The composition of e-waste is very diverse and contains more than 1000 different substances, so it is difficult to determine the general material composition of e-waste (Mohan and Chaithanya, 2015). Each type of e-waste has different functions and materials used, and the composition of e-waste often depends a lot on factors such as the type of electronic device, model, manufacturer, date of manufacture and age of the device (Mmereki *et al.*, 2016). Therefore, the components in e-waste will cause different impacts on the environment and human health if not strictly managed and treated.

Many studies in the world have concluded that there are five types of materials present in e-waste including: ferrous metals, non-ferrous metals, glass, plastic and other materials (Nahar *et al.*, 2017). Technological developments have produced electronic products that are more efficient and less resource-intensive, but more complex due to the heterogeneity of their components and materials. The heterogeneity of materials is governed by their application as well as their structure such as the type, thickness, plastic layers, solder joints and adhesives used (Khaliq *et al.*, 2014). However, almost all e-waste contains some amount of valuable metals, mainly copper (Cu). In addition, e-waste from small IT and telecommunications equipment, personal computers, and desktop computers (PCs) will contain more precious metals than household appliances (Mmereki *et al.*, 2016). For example, a mobile phone can contain more than 40 elements with base metals such as Cu, tin (Sn), lithium (Li), cobalt (Co), indium (In), antimony (Sb) and precious metals such as silver (Ag), gold (Au), palladium (Pd)… (Mmereki *et al.*, 2016). These metals are often classified into precious metals and toxic metals. Precious metals include gold, silver, aluminum, iron, copper, platinum,… however, more than 50% of these metals are not recovered (Forti *et al.*, 2020). Meanwhile, toxic metals in e-waste are often mercury, cadmium, lead, chromium (Nahar *et al.*, 2017; Forti *et al.*, 2020).

Research by Yken *et al.* (2021) also pointed out that e-waste can contain valuable as well as potentially toxic materials including metals such as base metals, precious metals and rare earth elements (61%), plastics (20%), ceramics (2%), glass (5%), wood (3%), rubber (1%) and pollutants (5%). Therefore, the efficient and environmentally friendly recovery of precious metals from e-waste not only reduces the huge amount of waste but also ensures its conversion into a useful resource (Ankit *et al.*, 2021). For each type of device, many studies have shown that different electronic products contain different amounts of base metals and precious metals. Among them, large-sized electrical and electronic devices contain less potential pollutants than small-sized electrical and electronic devices. Refrigerators and washing machines typically contain steel and less environmental pollutants than personal computers and mobile phones (which contain high amounts of heavy metals and flame retardants) (Ankit *et al.*, 2021). A comparison of mobile phones, televisions, and personal computers shows that mobile phones contain more diverse and complex materials than televisions and personal computers. At the same time, televisions are the type of device that contains fewer materials than the other two types of devices (Islam *et al.*, 2024). The work of Islam and co-workers (2024) are consistent with the results of Mmereki *et al.* (2016) in stating that almost all e-waste contains some amount of Cu. For mobile phones, the amount of Cu in this device is 15%. While, those of televisions and personal computers have Cu percentages of 3% and 4.33%, respectively. In general, mobile phones and personal computers contain more precious metals than household appliances (televisions). However, it can be seen that e-waste from a large number of post-consumer products is one of the most complex types of waste today.

Printed circuit boards (PCBs) also contain many valuable metals such as gold, copper, and other hazardous materials such as lead,... (Gautam *et al.*, 2022). Research by Hong *et al.* (2020) also shows that PCBs are complex materials and can contain up to 63 different elements. PCBs are also an important component of all electronic products, accounting for nearly 6% of the total weight of components removed from e-waste (Barragan *et al.*, 2020). Therefore, recycling of metallic and non-metallic components from PCBs requires appropriate and environmentally friendly processing and recycling techniques. In addition, the content of base metals and precious metals in e-waste is higher than that of their respective primary ores. Research by Kumar *et al.* (2017) show that gold in PCBs is nearly 130 times higher than that of their ores. Many studies have also shown that waste printed circuit boards are a source of secondary metals including many metals from copper to zinc and precious metals such as gold and silver (Yaashikaa *et al.*, 2022).

In addition to valuable metals, toxic substances in e-waste have been noted by many authors around the world. Some of the toxic substances that can be mentioned include halogenated groups such as Phthalates in the form of Butyl benzyl phthalate (BBP), Dibutyl Phthalate (DBP), Di-2-ethylhexyl phthalate (DEHP), Polychlorinated biphenyls (PCB), Polybromated diphenyl ethers (PBDEs); heavy metals such as cadmium, mercury, chromium, beryllium, barium, copper, lead, nickel, zinc, selenium, ... and other radioactive substances. Among them, heavy metals such as lead, mercury, chromium and cadmium are common components of e-waste (Ghimire and Ariya, 2020). Many studies have noted that these hazardous substances are hazardous in nature. The recovery of toxic elements such as Cr, Hg, Ni and Pb from e-waste has been noted in the study of Kuntawee *et al.* (2020), and these metals are widely used in electronic devices for various purposes. For example, lead is found in batteries, CRT monitors, cables, wires, and also in cathode ray tubes, circuit boards and solders (Desye *et al.*, 2023). Cr is found in anti-corrosion coatings, tapes, floppy disks, dyes, and pigments. The concentrations of Cr and lead in e-waste are often high, such as in mobile phone circuit boards where Cr and Pb concentrations exceed 1000 ppm (Maragkos *et al.*, 2013). As for mercury, it can be found in LEDs, lamp parts, switches, batteries, telephones, computers, etc. Various industries have used mercury as a catalyst for chemical reactions or in the production of chemicals due to its unique properties (Aubrac *et al.*, 2022). Arsenic is also found in circuit boards, semiconductors, displays, while Ni is found in rechargeable Ni-Cd batteries, electron guns in CRTs (Ankit *et al.*, 2021). In addition, persistent organic pollutants (POPs), especially PCBs, are widely used in industrial and commercial applications such as solvent liquids for capacitors and transformers, adhesives in plastics, and old fluorescent lighting equipment. PCBs are toxic to fish, mammals, and humans, and can cause hepatotoxicity, reproductive effects, and neurotoxicity (Zhu *et al.*, 2022). In addition, damaged electrical and electronic equipment can be developed into new adsorbents for the treatment of heavy metal-containing waste derived from PCB waste (Xu *et al.*, 2014).

Conclusion: The results of research on articles related to the sources, characteristic and composition of electronic waste reveal that the amount of electronic waste is increasing along with the needs of people. The sources of electronic waste include all items in the government, commercial, institutional, research, household and manufacturing sectors that have electrical components or circuits with batteries or power sources. Countries in the Asian region generate the most electronic waste, followed by the Americas and Europe. In addition, Africa and Oceania have the lowest annual electronic waste generation compared to the remaining continents. Currently, electronic waste is classified into many categories depending on different purposes. However, according to the European Union directive, electronic waste is grouped into six main categories including temperature exchange equipment, screen and monitors, lamps, large equipment, small equipment and small IT and telecommunication equipment. In addition, e-waste contains not only valuable metals but also hazardous components that can have negative impacts on the environment and human health if not managed properly. If e-waste is properly recycled, it can provide opportunities to recover copper, gold, silver and other valuable metals. Furthermore, the concentration of metals in e-waste is significantly higher than in the natural ores from which these metals are mined. Understanding the sources and composition of e-waste can help to find effective solutions for the treatment and management of e-waste.

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