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Legislative approaches to the management of polymer waste from electronic equipment: International and national dimension

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Abstract. The relevance of the study is determined by the rapid growth of waste electrical and electronic equipment worldwide, which is projected to exceed 74 million tons by 2030, and the particular complexity of recycling the polymer fraction containing hazardous flame retardant additives. The aim of this work was to conduct a comprehensive analysis of legislative approaches to the management of polymer waste from electronic equipment at the international and national levels and the development of practical recommendations for their implementation in Ukraine. The methodological basis of the study was a combination of comparative legal and systemic-structural analyses, which made it possible to compare legislative approaches of six countries and regions. It has been established that the principle of extended producer responsibility is the dominant regulatory model in the world, successfully implemented in the EU, USA, China, Australia, and Brazil. The contradiction between the goals of polymer recycling and restrictions on the content of hazardous substances, in particular brominated flame retardants, in EU legislation has been analysed. It was found that only 0.4 out of 2.6 million tons of polymers from e-waste generated annually in Europe are sent for recycling. Practical recommendations have been developed for the implementation of Draft Law No. 2350 in Ukraine, taking into account the experience of other countries. The results of the study can be used by government authorities in the formation of national e-waste management policy, as well as by scientists for further research in the field of environmental law and circular economy. Furthermore, the main regulatory barriers to effective polymer fraction recycling have been identified, related to legislative restrictions on hazardous additive content in secondary raw materials and the absence of specific regulations for polymer materials in most national legislations. The practical value of the study lies in the potential use of the formulated recommendations by government authorities in developing secondary legislation for Draft Law No. 2557-IX and by enterprises in organising e-waste collection and recycling systems

Keywords: waste electrical and electronic equipment; environmental safety; regulatory framework; extended producer responsibility; circular economy; implementation in Ukraine

Introduction

The problem of waste electrical and electronic equipment (WEEE) disposal is one of the most pressing global environmental challenges of today, necessitating the development of effective legislative mechanisms. The growth of WEEE volumes is exponential, which is a direct consequence of technological progress, industrialisation, and urbanisation. The total volume of e-waste is projected to exceed 74 million tonnes by 2030. The

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key component of WEEE is the polymer fraction, which makes up approximately 25-30% of their weight and contains not only hard-to-decompose plastic, but also dangerous flame retardant oxides and other additives. Legislative initiatives in this area are aimed not only at eliminating environmental hazards, but also at promoting a circular economy by attracting secondary raw materials to production processes.

The issues of managing WEEE and polymer waste electronics are actively studied by the world scientific community. C. Chaine *et al*. (2022) in their paper on plastic recycling with WEEE found that approximately 2.6 million tonnes of polymer waste from electronic equipment are generated annually in Europe, but only 0.4 million tonnes go to processing enterprises. The researchers concluded that the main reasons for low processing rates are a mixture of different polymers and the presence of toxic additives, in particular brominated flame retardants.

The Organisation for Economic Cooperation and Development OECD (2024) has systematised the key principles of the extended producer responsibility policy. According to this publication, extended producer responsibility (EPR) is the most effective approach to e-waste management, as it imposes responsibility on manufacturers for the entire product lifecycle. The study highlighted the importance of adapting EPR systems to the local conditions of each country. M. Compagnoni (2022), in a systematic review of the literature on evaluating the effectiveness of the extended producer responsibility principle for e-waste, concluded that despite the widespread introduction of EPR in the world, the results of its application vary significantly depending on the country and implementation mechanisms.

M.K. Portugaise *et al*. (2023) conducted a comparative analysis of EPR systems in Japan and Canada. The researchers found significant differences between producers' physical liability (Japan) and financial liability (Canada). According to the researchers, physical responsibility encourages manufacturers to change product design to simplify further processing, while financial responsibility focuses companies mainly on cost savings. Chinese researchers K. Li *et al*. (2023) in a publication on the modernisation of recycling through EPR mechanisms, analysed four phases of the development of the recycling system in China after the introduction of the subsidy scheme in 2012. On the example of GEM Co. Ltd., the researchers demonstrated a successful closed-loop model of WEEE recycling with an increase in the added value of dismantled materials through technological innovations.

D. Faibil *et al*. (2023) examined the factors of implementation of WEEE in developing countries, using the example of Ghana. Using the DEMATEL method, the researchers found that operational factors have a greater impact on the implementation of EPR than strategic ones. According to their findings, the extended deposit refund scheme is the most effective mechanism for encouraging electronics retailers to participate in the EPR system. Ukrainian researchers O. Yefremova *et al*. (2022) analysed the current state of polymer waste management in Ukraine. They stressed that recycled polymers can find new applications in various industries, especially in the light industry for the manufacture of shoe soles or fabrics with improved properties. N.W.M. Wong (2018) conducted a comparative analysis of e-waste management in Hong Kong and mainland China under the "one country, two systems" principle. The researcher found that despite different administrative approaches, both regions are moving towards harmonisation of EPR systems, although they face different implementation challenges. I. Ilankoon *et al*. (2018) in a comprehensive review of the international context of e-waste management systematised information on trade flows, regulatory mechanisms, environmental threats, and technologies for the recovery of valuable materials, emphasising the need to harmonise legislative approaches at the global level.

Despite significant scientific achievements in the field of WEEE management, the issues of legislative regulation of the polymer fraction of electronic waste remain rather neglected, especially in the context of contradictions between the goals of processing and restrictions on the content of hazardous substances. In addition, the issue of implementing European directives in Ukrainian legislation requires a detailed analysis, considering the specifics of the national waste management system. The purpose of the study was to comprehensively analyse and evaluate legislative approaches to the management of polymer waste of electronic equipment at the international and national levels. The main task was to identify the most effective models of legal regulation and develop practical recommendations for their implementation in Ukraine.

Materials and Methods

The study was based on a combination of several complementary methods of scientific cognition, which provides a comprehensive approach to the analysis of legislative mechanisms for managing polymer waste of electronic equipment. The comparative legal method was used to compare the legislative approaches of six countries and regions: the European Union, the United States of America, China, Australia, Brazil, and Ukraine. The comparison criteria were selected: the type of regulatory system (EPR, advanced processing fee, reverse logistics), the availability of specific standards for polymer materials, targets for collection and processing, mechanisms for financing the waste management system, and the state of implementation and efficiency of implementation. The system and structural analysis allowed considering the regulatory framework as a single system of interrelated elements, including international directives, national laws, and strategic documents.

This method has identified internal contradictions in EU legislation, in particular, the conflict between the WEEE and RoHS directives on the processing of polymers containing brominated flame retardants.

The method of analysing regulatory compatibility was used to substantiate the identified legal conflicts between the EU's environmental goals. In particular, the conflict between the desire for maximum processing of polymers and the establishment of strict limits on the content of hazardous substances (10 parts per million for decaBDE) was analysed, which actually makes it impossible to process a significant part of WEEE plastic waste. The selection of directives and scientific publications was carried out according to the following criteria: relevance (mainly 2019-2024 years of publication), topicality, representativeness of different regions of the world, availability of empirical data on the effectiveness of legislative mechanisms. Special attention was paid to publications that analyse the specifics of the WEEE polymer fraction and the problems of its processing. The material base of the study consisted of official texts of international directives, in particular Directive 2011/65/EU (2011), Directive 2012/19/EU (2012), and Directive (EU) No. 2024/884 (2024). National legislation was also analysed: Draft Law No. 2557-IX (2019), Law of Ukraine No. 2320-IX (2025), legislation of individual US states, regulations of China (Wong, 2018), Australia (Shooshtarian *et al*., 2021), and Brazil (Souza, 2023). Additional sources were reports from international organisations (Baldé *et al*., 2024), Eurostat statistics (2025), and scientific publications in specialised journals.

The logic of the study provided for the consistent implementation of such stages: collection and systematisation of the regulatory framework, comparative analysis of legislative approaches of different countries, identification of best practices and problematic aspects, formulation of recommendations for Ukraine. The geography of the study covered the EU and individual member states (Germany, Sweden), the United States with a detailed analysis of California legislation, countries in the Asia-Pacific region (China, Japan, Australia), and Latin America (Brazil). Such a wide geographical coverage was conditioned by the need to identify various regulatory models to form optimal recommendations for Ukraine. Limitations of the study were the lack of access to complete statistics on the volume of polymer processing with WEEE in all the countries under study, and the dynamic nature of legislation, which could change after the study was completed. In addition, the analysis mainly covered officially published regulations without a detailed review of their enforcement practices.

Results and Discussion

The European Union is one of the pioneers in the field of legislative regulation of WEEE. Its approach was based on two key directives that serve as the basis for the national legislation of member states. Directive No. 2012/19/EU (2012) – the directive on waste electrical and electronic equipment, first introduced in February 2003 and updated in 2012, sets out obligations for manufacturers of electrical and electronic equipment to collect and process their products after the end of their service life. The main purpose of the directive is to promote efficient use of resources, reduce the amount of electronic waste that ends up in landfills, encourage reuse and recycling. The directive covers all electrical and electronic equipment that depends on electric current or electromagnetic fields to perform its primary function, and applies to both consumer goods and professional use (Directive No. 2011/65/EU, 2011). Since 15 August 2018, the scope of the directive has been extended to all such equipment, with the exception of specially excluded categories (Directive No. 2012/19/EU, 2012).

The WEEE directive sets specific requirements for manufacturers selling products on the EU market. In particular, manufacturers are required to register with national authorities and report on the volume of equipment placed on the market. In addition, manufacturers must organise and finance the collection, processing, recycling and recovery of WEEE, provide detailed information to processing companies about the composition of products, and mark products with the "crossed-out trash can" symbol, which informs consumers about the need for proper disposal (Directive No. 2012/19/EU, 2012). Notably, the directive does not contain specific requirements for processing the polymer fraction, setting only general collection targets for all categories of WEEE.

A key element of the directive is the extended producer responsibility system, which forces manufacturers to finance the entire recycling process. This encourages companies to engage in "ecodesign", i.e., develop products that are more durable, energy efficient, and easy to disassemble and recycle. The directive sets ambitious collection targets: EU member states must collect 45 tonnes of WEEE for every 100 tonnes of goods placed on the market. Since 2019, this figure has increased to 65 tonnes, or 85% of the formed WEEE (Brady Corporation, n.d.). To achieve these goals, member states create national producer compliance schemes, to which companies pay annual fees covering collection and processing costs. Directive No. 2011/65/EU (2011) on the restriction of hazardous substances (RoHS) – the RoHS directive is an integral complement to the WEEE directive, since its main purpose is to limit the use of certain hazardous substances in the manufacture of electrical and electronic equipment. This makes the recycling process safer for the environment and human health (Brady Corporation, n.d.). The RoHS directive restricts the content of lead, mercury, cadmium, hexavalent chromium, and some brominated flame

retardants, and certain phthalates. For most substances, a limit is set that does not exceed 0.1% of the weight of a homogeneous material, while for cadmium, this indicator is 0.01% (Directive No. 2011/65/EU, 2011). Compliance with RoHS requirements is a prerequisite for obtaining a CE marking confirming that the product meets EU standards.

Implementation at the national level and conflicting aspects. Implementation of the WEEE Directive No. 2012/19/EU (2012) differs significantly in different EU member states, which creates administrative challenges for international companies. However, this approach allows countries to adapt mechanisms to their conditions. For example, Germany, which introduced the e-waste act in 2005, achieved high collection and recycling rates of about 45% of equipment sold. Sweden is the leader, collecting about 60% of the WEEE generated in the country. Their success is an example of how an effective EPR system and convenient collection points for consumers can provide high performance (Ukraine will introduce new..., 2024). B. Mayanti & P. Helo (2024), in the study of the EPR system in Finland, demonstrated how reverse waste logistics contributes to the transition to a circular economy by slowing down and closing material cycles.

Despite its success, the EU's WEEE policy has internal contradictions, especially with regard to polymer waste management. This question is relevant because polymers from WEEE often contain brominated flame retardants (Paben, 2018). Although the WEEE directive requires selective treatment of plastics containing brominated flame retardants, proposed changes to EU legislation on persistent organic pollutants set a low limit on the content of one of these flame retardants (decaBDE) at 10 parts per million (Aldoori *et al*., 2023). M.A. Charitopoulou *et al*. (2021), in their review of plastic thermochemical recycling methods with WEEE, emphasised that the presence of brominated flame retardants is a major obstacle to efficient recycling, as these additives require special removal technologies during recycling. Statements by the European Confederation of Recycling Industries and the European Electronics Recyclers Association indicate that achieving such a low concentration level is technically impossible at the industrial level. P. Hennebert & M. Filella (2018) confirmed in their study that sorting WEEE plastics by bromine content is critical for compliance with EU regulatory requirements, but existing industrial technologies do not provide sufficient accuracy for such sorting. W.A. Stubbings *et al*. (2021) in a study of the mixed plastic WEEE recycling stream in the UK found that careful management of polymer types prior to extrusion can ensure compliance with EU requirements for low levels of persistent organic pollutants, but this requires significant investment in sorting technology. This means that instead of recycling, a significant portion of WEEE plastic waste, which contains brominated flame retardants, will be sent to incineration (Aldoori *et al*., 2023). This situation demonstrates a direct conflict between the EU's two main environmental goals: eliminating hazardous substances and promoting a circular economy.

National dimension: Ukraine's policy in the field of WEEE. The legislation of Ukraine in the field of waste management is at the stage of reform aimed at harmonisation with European standards. The fundamental act is the Law of Ukraine No. 2320-IX (2025), which defines the general legal and organisational basis for activities in this area. This law establishes a hierarchy of waste management, which includes preventing its formation, reducing volumes, promoting reuse and recycling. However, a specialised regulatory act is required to manage a specific flow of WEEE. Such an act should be the Draft Law No. 2557-IX (2019). This document is developed considering the requirements of previous directives, which indicates Ukraine's strategic course towards European integration (Ukraine will introduce new..., 2024). The key provision of the draft law is the introduction of an extended manufacturer's responsibility system, which provides that manufacturers will be responsible for the entire life cycle of their products, including their disposal. It is important to note that Draft Law No. 2557-IX mainly copies the general targets for collecting WEEE from EU Directives and does not contain specific requirements for processing the polymer fraction, which is a potential legislative gap. Comparative analysis of global legislative models. Outside the European Union, there are different approaches to the regulation of WEEE, reflecting regional characteristics and priorities. Summary data on the regulatory framework of different countries are presented in Table 1.

Table 1. Comparative matrix of the regulatory framework of Ukraine and the world in the field of WEEE

Country/ Region	Main regulation	Year of adoption	Regulation model	Key features	Status
Ukraine	Draft Law No. 2557-IX	2019	EPR	Harmonisation with EU directives; introduction of EPR	Draft law included in the agenda of the Verkhovna Rada
EU	Directive 2012/19/EU (WEEE)	2012	EPR	Mandatory collection targets; financial responsibility of manufacturers; product labelling	In force, implemented in national legislation

Table 1. Continued

Country/ Region	Main regulation	Year of adoption	Regulation model	Key features	Status
USA	State legislation	since 2003	EPR and ARF	Fragmented approach; California uses ARF; most states use EPR	Current laws in 25 states and the District of Columbia
China	Administrative Measures for the Prevention and Control of Environmental Pollution by Electronic Waste; Collection and Treatment Decree on Wastes of Electric and Electronic Equipment	2007, 2011	EPR	Prohibition of solid waste imports; introduction of EPR in 2012	Current laws
Australia	National Television and Computer Recycling Scheme	2011	EPR	Funded by industry; state-level ban on electronic waste landfill (Victoria)	Current laws
Brazil	National Solid Waste Policy (PNRS)	2010	Reverse logistics	The "polluter pays" principle; the need for sectoral agreements for implementation	Current policy with sectoral agreements since 2019

Note: EPR – Extended Producer Responsibility; ARF – Advanced Recycling Fee

Source: compiled by the authors based on State E-Waste Legislation in the U.S (n.d.), Directive No. 2011/65/EU (2011; 2012), N.W.M. Wong (2018), Draft Law No. 2557-IX (2019), S. Shooshtarian *et al*. (2021), R.G. Souza (2023)

Unlike the EU, the United States does not have a single federal system for regulating e-waste. Instead, legislation is regulated at the state level, where only 25 states and the District of Columbia have relevant laws (State E-Waste Legislation in the U.S..., n.d.). This fragmented approach creates heterogeneity of regulation, which can lead to uneven standards and efficiency. There are two main models of WEEE legislation: extended manufacturer liability, which is used in 24 states, and extended ARF, first introduced in California in 2003. With the ARF model, consumers pay a fixed fee of USD 6 to USD 10 when purchasing an electronic device, and these funds are sent to a special state fund to reimburse recyclers (State E-Waste Legislation in the U.S, n.d.). Notably, US state-level legislation does not contain specific requirements for labelling plastics or restrictions on the use of individual polymer additives in WEEE.

Countries in Asia and the Pacific, which are major manufacturers and consumers of electronics, are also actively implementing legislation on WEEE. China, which has struggled with large volumes of imported waste, introduced a "National Sword" policy in 2018 and has imposed a complete ban on the import of solid waste, including metals and plastics, since 2021. In addition, in 2012, China adopted the EPR system, assigning manufacturers the responsibility for collecting and processing products (Wong, 2018). However, Chinese legislation does not contain specific rules directly related to polymer materials in electronic waste, in particular, requirements for labelling plastics or restrictions on the use of individual polymer additives. In Japan, the principle of EPR was introduced even earlier, namely from 1997 for packaging materials, and from 2001 for specific types of household appliances, which makes it one of the first leaders in the region (Kojima *et al*., 2009). Australia has been operating a "National Television and Computer Recycling Scheme" funded by industry since 2011. This scheme provides households and small businesses with free access to collection and recycling services. At the state level, in particular in Victoria, a complete ban on the disposal of electronic waste has been introduced from 2019, which significantly tightens the requirements for the management of WEEE and encourages the transition to a circular economy (Shooshtarian *et al*., 2021). Similar to the United States and China, Australian law does not provide for specific regulations regarding polymer additives in e-waste.

The problems of e-waste management in developing countries are systemic in nature. I.C. Nnorom & O. Osibanjo (2008), in their review of e-waste practices and legislation in these countries, identified a critical lack of effective regulatory mechanisms and infrastructure for safe recycling, leading to uncontrolled accumulation of hazardous waste. In Brazil, the largest producer of WEEE in Latin America, the main legislative act is the National Solid Waste Policy, adopted in 2010 (Souza, 2023). This policy is based on the "polluter pays" principle and the concept of reverse logistics. It assigns responsibility to manufacturers, importers, distributors, and retailers for waste collection and recycling. However, despite the adoption of the law, there was a significant gap between its provisions and practical implementation. Only in 2019, a sectoral agreement was signed between the government and the

electronic industry, which allowed the structure and implementation of the reverse logistics system (The World Bank, 2013). M. Ottoni *et al*. (2020) investigated a circular approach to valorising e-waste through urban mining in Rio de Janeiro, demonstrating the potential to recover valuable materials even in a limited infrastructure environment. This highlights that in developing countries, the adoption of the law is only the first step, and the real challenges lie in interagency and intersectoral cooperation and implementation.

A comparative analysis of the legislative approaches of different countries shows that, despite regional differences, the global trend tends to assign responsibility for the life cycle of electronic products to their manufacturers. The extended producer responsibility model is dominant in the world, which indicates its recognised effectiveness as a mechanism that encourages more responsible production and promotes the transition to a circular economy. The results are consistent with the findings of the OECD (2024), which defines EPR as the most effective approach to e-waste management at the global level. However, the study revealed significant differences in the implementation of this principle in different countries, which confirms the thesis about the need to adapt EPR systems to local conditions.

Comparing the EU harmonised model, which uses directives to establish common rules but allows for variability in implementation, the US fragmented approach demonstrates the advantages and disadvantages of both systems. S.H. Leclerc & M.G. Badami (2023), in an empirical study of the role of municipalities in EPR programmes, found that the effectiveness of such programmes largely depends on the level of cooperation between local authorities and producer responsibility organisations, which is an important conclusion for the development of the Ukrainian WEEE management model. M.K. Portugaise *et al*. (2023), in their study of Japan and Canada, came to similar conclusions about the differences between the physical and financial responsibility of manufacturers. The study expanded on these findings, showing that fragmentation of regulation at the US state level creates additional administrative barriers for manufacturers operating in the national market.

Of particular importance are the results of a study on the contradiction between the goals of polymer processing and restrictions on the content of hazardous substances in EU legislation. The revealed conflict between the WEEE and RoHS directives on brominated flame retardants confirms the concerns expressed by the European confederation of the processing industry, as reported by J. Paben (2018). The study showed that this contradiction is not exclusively a technical problem, but is of fundamental importance for the entire system of circular economy in the field of electronic waste. The study by C. Chaine *et al*. (2022) found that only 0.4 of the 2.6 million tonnes of polymer waste from electronic equipment in Europe goes for recycling. The analysis allowed explaining these low statistics not only for technical reasons related to the heterogeneity of polymers and the presence of toxic additives, but also for regulatory barriers, in particular, too strict limits on the content of hazardous substances in secondary raw materials. This is an important addition to the existing scientific discourse, which emphasises the need for a comprehensive approach to solving the problem.

The experience of developing countries, in particular Brazil and Africa, demonstrates the specific challenges of implementing WEEE legislation. D. Faibil *et al*. (2023) in a Ghana study found that operational factors have a greater impact on the implementation of EPR than strategic ones. The analysis of the Brazilian experience confirms this conclusion: despite the adoption of the National Solid Waste Policy in 2010, the practical implementation of the reverse logistics system took place only nine years after the signing of the sectoral agreement. This is important for Ukraine, which is at the initial stage of developing the WEEE management system. Results of the study by K. Li *et al*. (2023) on the modernisation of WEEE processing in China through EPR mechanisms demonstrated the possibility of combining environmental and economic goals. Success of GEM Co. Ltd. in creating a closed cycle, recycling with increased added value of dismantled materials is an example to follow. However, the study showed that the Chinese experience has limited applicability for Ukraine due to the lack of specific regulations on polymer additives in China, which is a critical gap in legislation.

N.W.M. Wong (2018), in a comparative analysis of Hong Kong and mainland China, found a tendency to harmonise EPR systems despite different administrative approaches. The current study extends this conclusion to a global level: despite significant differences in specific mechanisms, countries on different continents are moving towards similar regulatory models based on the principle of producer responsibility. Ukrainian researchers O. Yefremova *et al*. (2022) highlighted the potential of using recycled polymers in various industries. The analysis showed that the implementation of this potential in Ukraine will depend on the ability of Draft Law No. 2557-IX to take into consideration both the positive experience of the EU in the field of EPR and its problematic aspects related to the regulation of hazardous substances in polymers.

An important area of further development of the legislation is the introduction of specific requirements for marking polymer components of electronic equipment, which will help to increase the efficiency of their sorting and processing. The EU experience shows that this approach can significantly improve the circulation of materials in the field of e-waste management. To improve the Ukrainian policy in the field of WEEE, considering international experience, it is recommended first of all to speed up the adoption and implementation of

Draft Law No. 2557-IX (2019), having developed a clear mechanism for financing the EPR system and identifying responsible bodies. It is also important to ensure cooperation between all stakeholders, as the creation of platforms for dialogue between the government, manufacturers, distributors, and public organisations is critical for successful implementation, as evidenced by the experience of Brazil. Moreover, it is necessary to consider the world experience when studying the successful models of Germany and Sweden in creating efficient collection and processing systems, and factoring the challenges associated with regulatory contradictions that have arisen in the EU. In addition, it is advisable to promote scientific research, which in Ukraine should be aimed at analysing the technical and economic feasibility of processing polymers with WEEE in the conditions of new, more stringent environmental standards. These recommendations are based on a comprehensive analysis of international experience and consider the specifics of the Ukrainian legal framework. However, limited financial and technical resources should be considered for the introduction of advanced processing technologies. Thus, the analysis revealed a key gap in global legislation: none of the countries studied, except for the European Union, has specific rules for regulating polymer materials in electronic waste. The absence of such standards is the main regulatory barrier that makes it impossible to efficiently process the WEEE polymer fraction at the industrial level.

Conclusions

The analysis of legislative approaches to the management of polymer waste of electronic equipment at the international and national levels indicates the dominance of the principle of extended manufacturer responsibility as the most effective regulatory model. This approach has been successfully implemented in the European Union, the United States, China, Australia, and Brazil, although with different implementation mechanisms that reflect regional characteristics and priorities. The European Union is a leader in this area, having implemented comprehensive WEEE and RoHS directives, although it faces new challenges related to the recycling of plastics containing hazardous substances. The revealed contradiction between the goals of maximum polymer processing and strict restrictions on the content of brominated flame retardants demonstrates the need for an integrated approach to the development of an environmental policy that considers the technological capabilities of the processing industry.

The US experience shows that the lack of unified federal regulation can lead to fragmentation and uneven standards. While Asian and Latin American countries are actively implementing EPR systems, adapting them to their own conditions. The study also found that none of the countries analysed, except the EU, has specific regulations on polymer materials in the composition of e-waste, which is a significant gap in global legislation. Ukraine, following the global trend, is taking significant steps in developing the Draft Law No. 2557-IX, which meets European standards. This is an important step in the development of a advanced and efficient e-waste management system that can protect the environment and promote sustainable development. However, for successful implementation, it is necessary to draw on both the positive experience of other countries and the challenges they face. Further research should be directed to a detailed analysis of the technical and economic feasibility of processing polymers with WEEE in Ukrainian conditions, development of proposals for specific norms for the polymer fraction in Ukrainian legislation, and the investigation of the possibilities of harmonisation of Ukrainian standards considering the identified contradictions in EU legislation.

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References

[1] Aldoori, H., *et al*. (2023). Recycling of plastics from e-waste via photodegradation in a low-pressure reactor: The case of decabromodiphenyl ether dispersed in poly(acrylonitrile-butadiene-styrene) and poly(carbonate). *Molecules*, 28(6), article number 2491. doi: 10.3390/molecules28062491.

[2] Baldé, C.P., *et al*. (2024). *The global e-waste monitor 2024*. Geneva: Global E-waste Monitor 2024.

[3] Brady Corporation. (n.d.). *WEEE compliance: Guide to the WEEE directive*. Retrieved from https://www.bradyid.com/resources/weee-compliance-guide.

[4] Chaine, C., Hursthouse, A.S., McLean, B., McLellan, I., McMahon, B., McNulty, J., Miller, J., & Viza, E. (2022). Recycling plastics from WEEE: A review of the environmental and human health challenges associated with brominated flame retardants. *International Journal of Environmental Research and Public Health*, 19(2), article number 766. doi: 10.3390/ijerph19020766.

[5] Charitopoulou, M.A., Kalogiannis, K.G., Lappas, A.A., & Achilias, D.S. (2021). Novel trends in the thermochemical recycling of plastics from WEEE containing brominated flame retardants. *Environmental Science and Pollution Research*, 28(42), 59190-59213. doi: 10.1007/s11356-020-09932-5.

[6] Compagnoni, M. (2022). Is extended producer responsibility living up to expectations? A systematic literature review focusing on electronic waste. *Journal of Cleaner Production*, 367, article number 133101. doi: 10.1016/j.jclepro.2022.133101.
[7] Directive (EU) No. 2024/884 of the European Parliament and of the Council "Amending Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE)". (2024, March). Retrieved from https://eur-lex.europa.eu/eli/dir/2024/884/oj.
[8] Directive No. 2011/65/EU of the European Parliament and of the Council "On the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment". (2011, June). Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:174:0088:0110:EN:PDF.
[9] Directive No. 2012/19/EU of the European Parliament and of the Council "On Waste Electrical and Electronic Equipment (WEEE)". (2012, July). Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02012L0019-20180704.
[10] Draft Law No. 2557-IX "On Waste Electrical and Electronic Equipment". (2019, October). Retrieved from http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=67234.
[11] Eurostat. (2025). *Waste statistics – electrical and electronic equipment*. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment.
[12] Faibil, D., Asante, R., Agyemang, M., Addaney, M., & Baah, C. (2023). Extended producer responsibility in developing economies: Assessment of promoting factors through retail electronic firms for sustainable e-waste management. *Waste Management & Research*, 41(2), 389-402. doi: 10.1177/0734242X221105433.
[13] Hennebert, P., & Filella, M. (2018). WEEE plastic sorting for bromine essential to enforce EU regulation. *Waste Management*, 71, 390-399. doi: 10.1016/j.wasman.2017.09.031.
[14] Ilankoon, I.M.S.K., Ghorbani, Y., Chong, M.N., Herath, G., Moyo, T., & Petersen, J. (2018). E-waste in the international context – a review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. *Waste Management*, 82, 258-275. doi: 10.1016/j.wasman.2018.10.018.
[15] Kojima, M., Yoshida, A., & Sasaki, S. (2009). Difficulties in applying extended producer responsibility policies in developing countries: Case studies in e-waste recycling in China and Thailand. In *The 3rd expert meeting in solid waste management in Asia and Pacific Islands* (pp. 263-269). Cham: Springer. doi: 10.1007/s10163-009-0240-x.
[16] Law of Ukraine No. 2320-IX "On Waste Management". (2025). Retrieved from https://zakon.rada.gov.ua/laws/show/2320-20#Text.
[17] Leclerc, S.H., & Badami, M.G. (2023). Extended producer responsibility: An empirical investigation into municipalities' contributions to and perspectives on e-waste management. *Environmental Science & Policy*, 145, 108-120. doi: 10.1002/eet.2059.
[18] Li, K., Qin, Y., Zhu, D., & Zhang, S. (2023). Upgrading waste electrical and electronic equipment recycling through extended producer responsibility: A case study. *Circular Economy*, 2(1), article number 100025. doi: 10.1016/j.cec.2023.100025.
[19] Mayanti, B., & Helo, P. (2024). Circular economy through waste reverse logistics under extended producer responsibility in Finland. *Waste Management & Research*, 42(1), 59-73. doi: 10.1177/0734242X231168801.
[20] Nnorom, I.C., & Osibanjo, O. (2008). Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. *Resources, Conservation and Recycling*, 52(6), 843-858. doi: 10.1016/j.resconrec.2008.01.004.
[21] OECD. (2024). *Extended producer responsibility: Basic facts and key principles*. Paris: OECD Publishing. doi: 10.1787/67587b0b-en.
[22] Ottoni, M., Dias, P., & Xavier, L.H. (2020). A circular approach to the e-waste valorization through urban mining in Rio de Janeiro, Brazil. *Journal of Cleaner Production*, 261, article number 121140. doi: 10.1016/j.jclepro.2020.120990.
[23] Paben, J. (2018). *Industry groups: EU regulation would end e-plastics recycling. Resource recycling*. Retrieved from https://lnk.ua/fU4A99Cor.
[24] Portugaise, M.K., Jóhannsdóttir, L., & Murakami, S. (2023). Extended producer responsibility's effect on producers' electronic waste management practices in Japan and Canada: Drivers, barriers, and potential of the urban mine. *Discover Sustainability*, 4, article number 8. doi: 10.1007/s43621-023-00124-y.
[25] Shooshtarian, S., Maqsood, T., & Wong, P.S.P. (2021). Extended producer responsibility in the Australian construction industry. *Sustainability*, 13(2), article number 620. doi: 10.3390/su13020620.
[26] Souza, R.G. (2023). E-waste situation and current practices in Brazil. In *Handbook of electronic waste management. International best practices and case studies* (pp. 377-396). São Paulo: Elsevier. doi: 10.1016/B978-0-12-817030-4.00009-7.
[27] State E-Waste Legislation in the U.S. (n.d.). Retrieved from https://eridirect.com/sustainability/us-legislation/.

[28] Stubbings, W.A., Abdallah, M.A.-E., Misiuta, K., Onwuamaegbu, U., Holland, J., Smith, L., Parkinson, C., McKinlay, R., & Harrad, S. (2021). Assessment of brominated flame retardants in a small mixed waste electronic and electrical equipment (WEEE) plastic recycling stream in the UK. *Science of the Total Environment*, 780, article number 146543. doi: 10.1016/j.scitotenv.2021.146543.
[29] The World Bank. (2013). *Sustainable e-waste management, key for future protection of Brazil's environment*. Retrieved from https://lnk.ua/374R1cEdR.
[30] Ukraine will introduce new approaches to the management of waste electrical and electronic equipment. (2024). Retrieved from https://ecolog-ua.com/news/ukrayina-zaprovadyt-novi-pidhody-do-upravlinnya-vidhodamy-elektrychnogo-ta-elektronnogo.
[31] Wong, N.W.M. (2018). Electronic waste governance under "one country, two systems": Hong Kong and Mainland China. *International Journal of Environmental Research and Public Health*, 15(11), article number 2347. doi: 10.3390/ijerph15112347.
[32] Yefremova, O., Ivanishena, T., Ishchuk, T., Trukhina, O., & Yefremova, Yu. (2022). The current state of polymer waste management. *Herald of Khmelnytskyi National University. Technical Sciences*, 313(5), 26-31. doi: 10.31891/2307-5732-2022-313-5-26-31.

Законодавчі підходи до поводження з полімерними відходами електронного обладнання: міжнародний та національний вимір

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Анотація. Актуальність дослідження зумовлена стрімким зростанням обсягів відходів електричного та електронного обладнання у світі, які за прогнозами перевищать 74 мільйони тон до 2030 року, та особливою складністю переробки полімерної фракції, що містить небезпечні вогнезахисні добавки. Метою роботи був всебічний аналіз законодавчих підходів до поводження з полімерними відходами електронного обладнання на міжнародному та національному рівнях та розробка практичних рекомендацій для їх імплементації в Україні. Методологічну основу дослідження становила комбінація порівняльно-правового та системно-структурного аналізів, що дозволила зіставити законодавчі підходи шести країн та регіонів. Встановлено, що принцип розширеної відповідальності виробника є домінуючою моделлю регулювання у світі, яка успішно впроваджена в ЄС, США, Китаї, Австралії та Бразилії. Проаналізовано суперечність між цілями переробки полімерів та обмеженнями щодо вмісту небезпечних речовин, зокрема бромованих антипіренів, у законодавстві ЄС. Виявлено, що лише 0,4 з 2,6 мільйонів тон полімерів з електронних відходів, що утворюються щорічно в Європі, надходять на переробку. Розроблено практичні рекомендації щодо імплементації законопроєкту № 2350 в Україні з урахуванням досвіду інших країн. Результати дослідження можуть бути використані органами державної влади при формуванні національної політики управління електронними відходами, а також науковцями для подальших досліджень у сфері екологічного права та циркулярної економіки. Окрім того, визначено основні регуляторні бар'єри для ефективної переробки полімерної фракції, пов'язані із законодавчими обмеженнями вмісту небезпечних добавок у вторинній сировині та відсутністю специфічних норм щодо полімерних матеріалів у більшості національних законодавств. Практична цінність дослідження полягає у можливості використання сформульованих рекомендацій органами державної влади при розробці підзаконних актів до законопроєкту № 2557-IX та підприємствами при організації систем збору та переробки електронних відходів

Ключові слова: відходи електричного та електронного обладнання; екологічна безпека; нормативно-правова база; розширена відповідальність виробника; циркулярна економіка; імплементація в Україні