



## Environmental Aspects of Using Fire Protection Systems with a Sustainable Development Approach

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**Abstract** Waste management is an increasingly important issue and challenge in our world today, which must be one of the foundations of sustainable development in such special areas too as the installation and maintenance of built-in fire alarm and extinguishing systems. These devices are now widespread, not only for the protection of ‘critical systems and facilities’, but also for protection of simpler facilities. In addition to the manufacture of these devices, their installation, maintenance and disposal also have many environmental aspects that need to be carefully considered in order to avoid unnecessary pollution. Hungarian experience shows that the handling of the various materials used in built-in fire protection systems is individually well regulated, but due to the wide range of regulations, it is difficult for the involved contractors and operators to apply it. Therefore, one of the keys to achieving effective waste management is the information of those involved. The systematisation and simplified communication of information on waste management and tasks can increase the efficiency of the contractors’ compliance, related to their special work. With this article we would like to contribute to sustainable development. The best first little step to inform the relevant professionals is to create a well-structured, easy-to-interpret table containing the most important related environmental protection tasks and information.

**Keywords:** Waste management, Fire alarm system, Built-in fire extinguishing systems, Hazardous waste, Electronic waste, Ionisation smoke detector

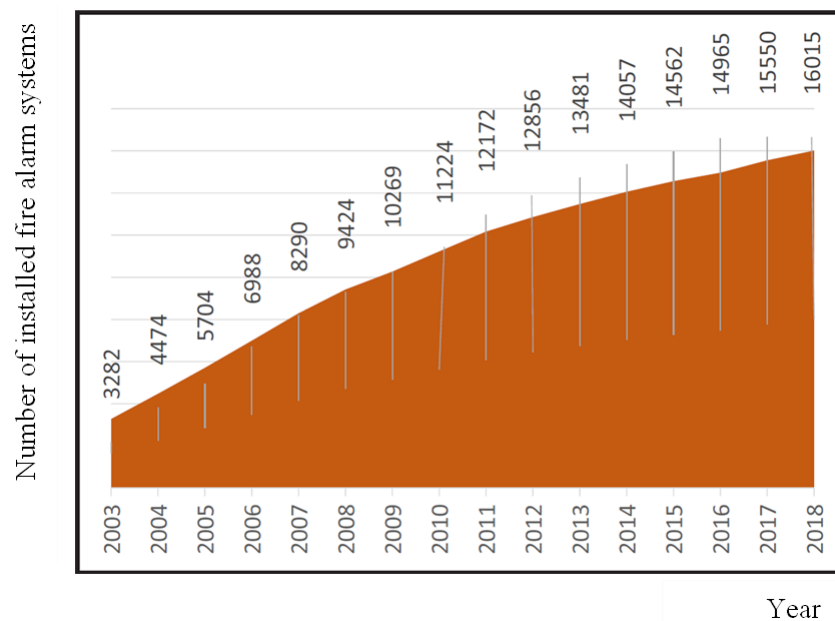
### 1. INTRODUCTION

The search for more effective ways of communicating and transferring information appears in almost every area of life. Communication planning has a key role not only in disaster management (Yamaguchi and Horie 2018), but also in environmental protection. One of the important issues is to know what regulations are relevant to the activities we carry out and the equipment and systems we work with.

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The aim of our research is to explore, examine and improve the efficiency of waste management tasks related to a special area: the built-in fire protection systems, not only in critical infrastructures (Identification, designation and protection of critical systems and facilities National Act. 2012), but also in buildings with other functions. Among the built-in fire protection systems, the subject of our research are the built-in fire alarm systems (Figure 1) and the built-in fire extinguishing systems, that have reached significant numbers in the world and in Hungary. As of 2018, more than 16,000 fire alarm systems devices were installed, but the amount of built-in extinguishing systems installed annually is also more than 2,000 (Defense Disaster Management 2011).



**Figure 1.** The number of fire alarm systems installed in Hungary between 2003 and 2018 (Defense Disaster Management 2019)

We should expect to see an increasing number of these devices and systems in the future, as not only the regulations but also numerous studies point to the benefits of their use and recommend their use (Rahman *et al.* 2021).

Considering the number of systems now in service, environmental questions arise in connection with their installation, operation and maintenance, affecting the manufacturer, the contractor and later, the user. We hardly found any scientific work, national or international papers that was focusing on this specific professional field from the aspect of waste management, except some publications dealing with issues concentrated on one sub-area, which will be used in this paper. The main objective of this paper is to examine the waste management aspects of built-in fire protection systems and to provide a clear and a simplified guide to those that are affected among the often voluminous and wide-ranging regulations.

It is assumed that the application of the wide range of requirements relating to fire protection equipment can be made more efficient by identifying their subject matter (linking the requirements to the groups of devices) and by organising them.

## 2. METHODS

### 2.1 Identification

First, we identify those system elements in relation to the affected system that have high environmental relevance. The risk factors as well as the harmful substances of these system components to the environment were examined, and then identified from a waste management aspect. The most expedient way to do this is to identify such materials by their so-called HAK codes (Waste Identification Code) in *Concerning the list of wastes Decr.* (2013).

With regards to the identified materials, we organise and summarise the regulations that impose specific tasks to be performed by those affected, in the form of a tabular guide. The knowledge of those professionals, working in these specially installed fire alarm and extinguishing systems, and those who come into contact with them is often incomplete or poor in terms of environmental protection. For this reason, we consider it to be important to highlight and systematise the tasks assigned to such professionals.

### 2.2 Legal and regulatory background

Most of the regulations apply to manufacturers who produce devices using different materials and technologies. Some of the materials used may be released into the environment during operation, for example when a poorly maintained gas extinguishing system is blown off. However, safety equipment contains significant amounts of materials (e.g. large quantities of plastic or radioactive materials) which must be properly disposed of after dismantling to avoid release to the environment. But there are also many materials in these devices that are easy and economically viable to recycle, so the primary aim is to recover as much of these as possible. We can see that these requirements also accompany built-in fire protection devices and equipment throughout the process from manufacture to disposal, often over several decades. There is a legitimate expectation that the life cycle of a product and its impact on the environment should be monitored in this field too. Manufacturers should place greater emphasis on this in the future.

In recent decades, a significant legal background has been developed in all parts of the world regarding the waste management. In the United States of America, the Federal Regulatory Code<sup>1</sup> (Code of Federal Regulations 2022), the French Grenelle de l'environnement (1) and (2) laws (Baranyai 2020), while in the EU as a comprehensive *Waste and repealing certain EU Directive* (2008) are just a few examples, that deal with waste management.

The domestic legislation in Hungary is of course in accordance with the legislation of the European Union. In Hungary, the *National Waste Act* (2012)<sup>2</sup> deals about waste, and their identification is regulated in 'Decree No. 72/2013. VM of the Ministry of Rural Development on

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<sup>1</sup> CFR = Code of Federal Regulations

<sup>2</sup> Modified by *National Waste Act* (2017)

the waste list' (Concerning the list of wastes Decr. 2013). In relation to the hazard characteristics defined in the *National Waste Act* (2012) such as "Explosive", "Flammable", "Irritant" or "Dangerous for the environment (ecotoxic)", the decree (Defense Disaster Management 2019) Annex 2. contains the main groups (between 01-20), subgroups and the corresponding individual waste types of the waste list. The legislation (Concerning the list of wastes Decr. 2013) defines a total of 837 types of waste, most of which are related to thermal production processes and wastewater treatment (Figure 2).

Those waste categories that are considered dangerous according to the regulation (Concerning the list of wastes Decr. 2013), are marked separately. The regulation (Concerning the list of wastes Decr. 2013) specifies 408 dangerous waste types in total. Figure 3 shows the proportion of hazardous waste within each main waste group. Main group 13 (Oil waste and liquid fuel waste) and 14 (Organic solvent, coolant, and propellant waste) stand out, where the proportion of hazardous waste is 100%. Surprisingly though, all waste types include approx. 50% hazardous waste on average.

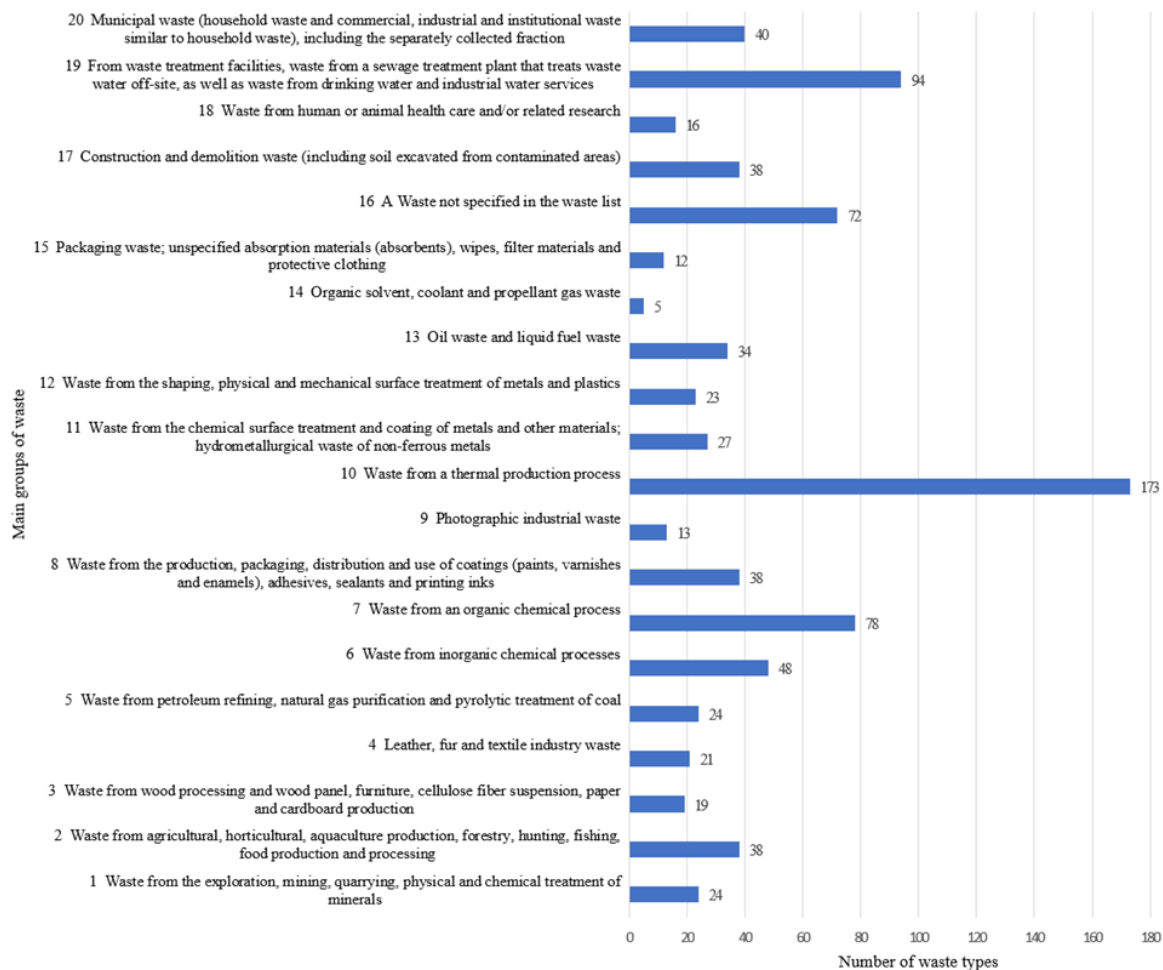
Several definitions exist to define waste. For instance, according to the *National Waste Act* (2012) 2. § (1) paragraph, Point 23, "*waste: any material or object that the owner gets rid of, intends to get rid of or is obliged to get rid of*". Those wastes, that have at least one of the hazard characteristics specified in the Decree of the Ministry of Rural Development (Defense Disaster Management 2019) Annex 1. are classified as dangerous.

Numerous laws and regulations deal with hazardous waste, including their material, type, danger, effect, *etc.* For example, special regulations apply to electronic waste (Waste electrical and electronic equipment EU Directive 2012) (Waste management activities that are connected to electric and electronic equipment Decr. 2014), batteries (Batteries and accumulators and waste batteries and accumulators and repealing EU Directive 2006) (Waste management activities that are connected to battery wastes and accumulator wastes Decr. (2012) as well as for the ozone-depleting and greenhouse gases (Fluorinated greenhouse gases and repealing EC Reg. 2014) (Conditions of activities with fluorinated greenhouse gases and ozone depleting substance Decr. 2015). The high number of waste types, as well as the amount and diversity of the regulations show that the question of waste management should be examined separately in each field of expertise.

### 3. RESULTS AND DISCUSSION

According to the general safety concept, we primarily use built-in fire alarm systems, and secondarily, built-in fire extinguishers as an active fire protection solution as reflected in the legislation on the establishment of the system (National Fire Protection Regulation Decr. 2014). Appendix 14 of the regulation defines 13+1 main uses based on the nature of use and risks (e.g., fire protection risk class, floor space, number of employees), and a total of 47 categories of purpose. In 44 cases fire alarm systems, and in 18 cases fire extinguishing systems are mandatory (

4).



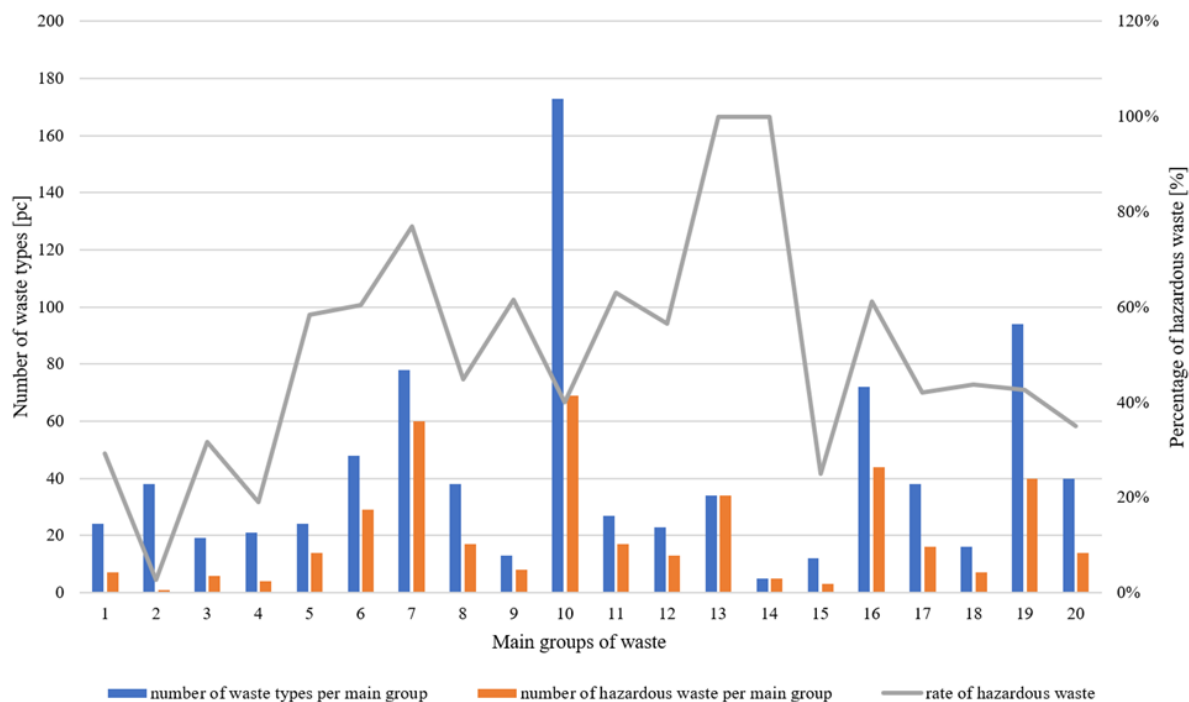
**Figure 2.** Distribution of waste types according to the main groups based on *Concerning the list of wastes Decr. (2013)*

The regulation has increased the number of these systems in recent centuries, as their installation has become mandatory in many cases. The elements used in fire protection systems as well as the internal parts and materials become waste when they are no longer needed. The most often causes are as follows:

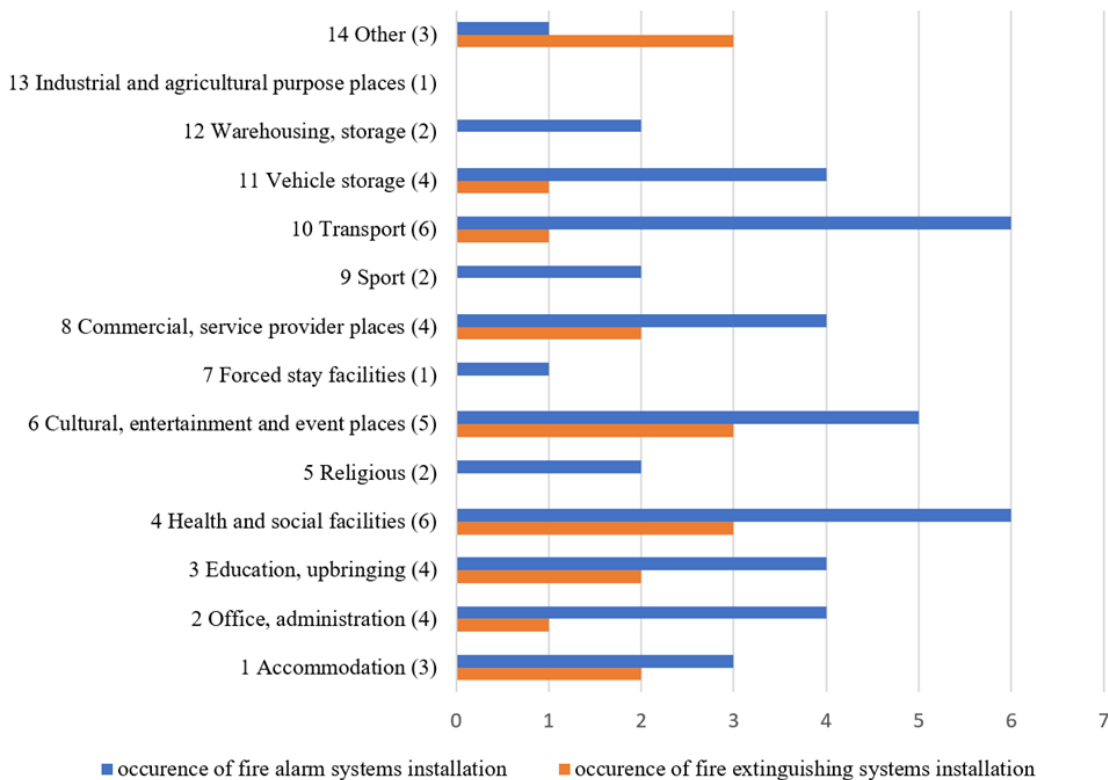
- unused residual materials generated during installation (e.g., wires).
- system components that failed during installation and/or operation.
- system elements and materials remaining during demolition following the end of the "lifetime" of the system or certain system elements, ageing, or termination for other reasons.

### 3.1 System Elements and Materials of Built-in Fire Alarm Systems in Terms of Waste Management

A typical fire alarm system consists of the following system elements: fire alarm control panel(s), automatic detectors, manual call points, output and input modules, alarm devices (sound and/or light indicators), fireproof and non-fireproof cabling, *etc.*



**Figure 3.** Rate of the hazardous waste per main waste group based on *Concerning the list of wastes Decr. (2013)*



Note: '( )' contains the number of "sub-orders"

**Figure 4.** Proportion of mandatorily installed fire alarm and fire extinguishing systems by purpose, based on the *National Fire Protection Regulation Decr. (2014)*

They also include batteries as a secondary power supply that play a significant role for operation of life protection systems as per the requirements in *National Fire Protection Regulation Decr.* (2014). The most important of these in terms of quantity and danger are listed below.

### 3.1.1 Electronic Waste

In almost all system elements of the fire alarm systems - with the exception of wires - printed circuit electronic components (for example Figure 5) can be found, which can be classified in the HAK (Waste Identification Codes) 1602 subgroup. The generation of the so-called 'e-waste' is occurring at the highest rate in the world (Eurostat 2020), given that the information technology is developing at such a huge extent (Bojár 2018). The danger of e-waste lies in the hazardous materials used in individual batteries, such as lead<sup>3</sup> and mercury, but their proper treatment can also be beneficial, as gold, silver, palladium and copper can also be extracted from them in large quantities. In terms of the e-waste, the solution therefore lies in proper collection and efficient recycling. This is also important, because the total mass of 'e-waste' generated in the world exceeded 57 million tons by 2011, and its estimated value reached 62.5 billion dollars by 2019 (Greendex 2021). Although, as the construction industry has a leading role in waste production - with 36.4% according to 2016 EU data (Eurostat 2022), households themselves are the biggest producers of electronic waste (with 52.7%, (Eurostat 2020)). In the EU, the recycling rate is still less than 40% (Eurostat 2020), but according to 2019 UN data (The Global E-waste Monitor 2020), only 17.4% of e-waste generated in the world is recycled. That is why it is important that all stakeholders know and comply with the waste management requirements that apply to them.



**Figure 5.** Electronic components on a printed circuit board (Kentec 2022)

### 3.1.2 Radioactive Waste

In relation to the fire alarm systems, the radioactive materials as dangerous materials must be highlighted, because smoke detectors that work on the basis of ionisation use small amounts of radioactive isotopes due to their operating principle (Mohai 2012). The most common radioactive material used in the smoke chamber (see in Figure 6) is Am-241. In recent decades, because of the health and environmental protection approach, these sensors are now very rarely used for new

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<sup>3</sup> An EU Directive was issued on the reduction of hazardous substances that can be used in e-waste (Restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) EU Directive 2011)

systems, but the regulations regarding their dismantling (transportation, destruction, *etc.*) make it difficult for those affected.



**Figure 6.** Am-241 radioactive isotope in an ionisation smoke detector (HomeHow 2021)

The relevant regulations distinguish between the use of low-activity substances (exemption level<sup>4</sup>) and certain activities, for which, according to the *Nuclear Energy National Act* (1996), a separate official permit is not necessary. For instance, such activity includes the use and installation of smoke detectors rely on ionisation principles. This "exemption" however, does not apply to manufacturing, repair, or any activity that involves the disassembly of the sensor.

They can only be transported in accordance to the ADR5 class 7 (Radioactive substances) as per the relevant domestic regulations (ADR 2021) (The transportation, forwarding and packaging of radioactive materials Decr. 2013).

### 3.1.3. Batteries

The so-called gel batteries are an improved version of the lead-acid batteries, where the electrolytes between the cells is "gelled" with the help of silica gel. This way, compared to the traditional lead-acid batteries, more advantageous properties and easier usage can be achieved (see in Figure 7).



**Figure 7.** 12V gel battery used in fire alarm system (Wholesale Batteries Direct. 2022)

<sup>4</sup> Exemption level: group of activities established in a separate law (Exemption activity concentration of radionuclides and on the establishment on their exemption activity level Decr. 1997) or all activities, where any substance or preparation containing radionuclides is exempt from the scope of *Radioactive materials and equipment generating ionising radiation Government Decr.* (1997)

<sup>5</sup> ADR (Accord Dangereuses Route): Agreement about the transportation of dangerous goods internationally on roads



Due to the lead content, gel batteries are considered as dangerous waste, although their recycling - primarily the technology of extracting lead and plastic - is well developed, and their obligation of collection is regulated by law (Waste management activities that are connected to battery wastes and accumulator wastes Decr. 2012). The 1.2 million tons per year (Waste and waste management 2022) generation of waste batteries and cells in the EU increases and poses significant environmental risk. Referring to the *National Fire Protection Regulation Decr. (2014)*, batteries in life protection equipment, including the fire alarm system must be replaced every four years, even if nothing is wrong with them - contributes significantly to the generation of waste.

#### **3.1.4. Plastic waste**

Most of the system components of built-in fire protection systems contain plastic, such as sensors, buzzers, and the plastic cover. Although plastics, as organic polymers, are practically non-biodegradable (their degradation time under the influence of light is estimated to be hundreds of years (Science Learning Hub 2022)), they are not classified as hazardous waste. The most environmentally friendly solution is to produce recycled plastic from the dismantled plastic components after collecting and cleaning them. In electronic devices, plastics may be found as individual parts, or in the casing of the devices. The dismantling, selection, and sorting after selective collection play an important role.

### **3.2. System components and materials of built-in fire extinguishing systems in terms of waste management**

The categories and types of built-in extinguishing systems have a wide palette (see Figure 8), thus accounting "waste" in them is also a complex task. Some of the built-in fire extinguishing systems require a detecting and extinguishing control component to enable their automatic operation (e.g., gas fire suppression systems), which is basically a smaller fire alarm system, therefore this category of fire extinguishers is classified to those detailed in point 3.1.

#### **3.2.1. Fire extinguishing materials**

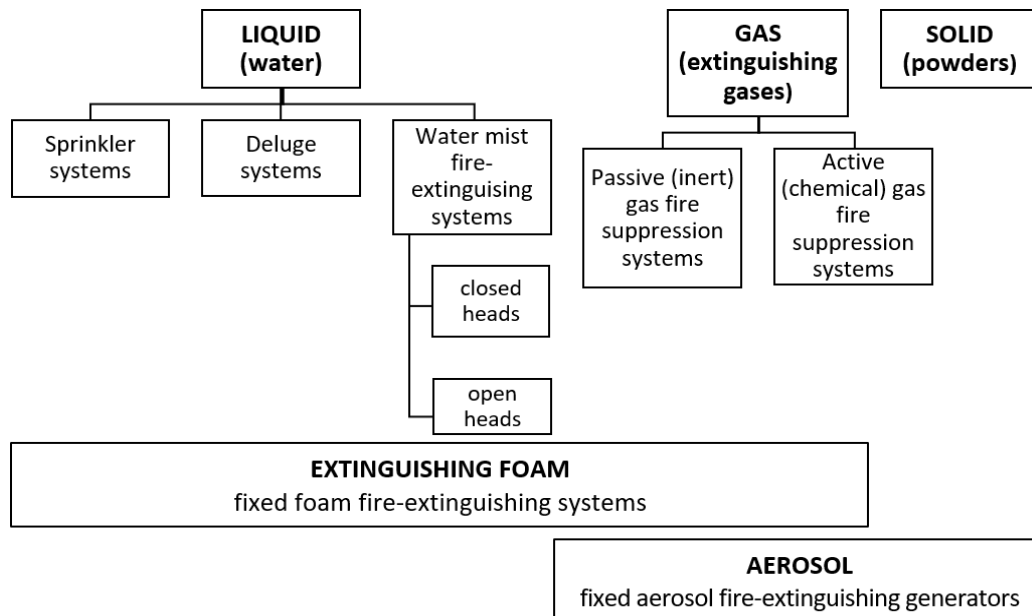
Examining the extinguishing materials used in fire protection systems, water and some inert extinguishing gases are the most favourable from the aspect of waste management, since these cannot be considered as waste materials. Water as an extinguishing agent can only be considered as waste (which in this case is necessary to be collected when appropriate), when it is mixed with some sort of hazardous substance, or when waste is generated during extinguishing due to water damage. Some of the inert gases, like Nitrogen or Argon, pose no danger to humans or the environment. However, there are some extinguishing materials that require greater attention. (Extinguishing powders are not discussed in this article, given that their use in built-in fire extinguishers is rare in Hungary.)

Extinguishing gases: Among extinguishing gases, HFC<sup>6</sup> gases are widely used as well as carbon dioxide and Novec1230. Halon's (primarily H1301) ozone-damaging effect must be noted,

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<sup>6</sup> Hydrofluorocarbon

although it may also be utilised in critical applications as per the legislation (Substances that deplete the ozone layer EC Reg. 2009), which can be applied under strict conditions and only in small quantities.



**Figure 8.** Main types of extinguishing systems grouped according to their state of composition, Source: Created by the Author

Regarding HFC (or commonly known as F-gases), attention should be paid on the greenhouse emissions that have an adverse effect on global warming. Due to the tightening process commencing with the EU's "*F-gas regulation*" (2006), these gases are subject to strict registration obligations (see "*Climate Gas Database*" (2022)). Activities with these gases require closed technology, regular leak detection and additional training for maintenance personnel (Conditions of activities with fluorinated greenhouse gases and ozone depleting substance Decr. (2015)).

The greenhouse effect of the carbon dioxide extinguisher is known since the Report of the Framework Convention on Climate Change produced by the United Nations. The 1997 Kyoto Convention was primarily aimed at reducing the release of such gases into the atmosphere (Tóth 2007). Nowadays, carbon dioxide is used for firefighting, but because of its physiological effects (Bánhidi and Kajtár 2000) with the availability of halogen substitute gases, the use of CO<sub>2</sub> has decreased, and is typically limited to the protection of spaces inaccessible to humans.

Aerosols: The extinguisher that forms a solid and then a colloidal dispersed system (aerosol) during firefighting (Karácsony 2012) appeared decades ago, for example in Russian space technology (TSZVSZ Hungarian Fire Protection Association 2009). The latest types of extinguishers, that contain mainly potassium salts (e.g. FirePro products) already have a "Green Label" certificate<sup>7</sup>.

<sup>7</sup> Certificate issued by the GEN (Global Eco-labelling Network), which purpose is to acknowledge and certify environmental achievements.

Extinguishing foams: In terms of foam usage in fire protection, air foams were considered instead of chemical foams. Foam concentrates, which are the basis of extinguishing foams, can be protein-based or synthetic. An environmentally problematic question is related to protein-based foaming materials as they consist of heavy metals (Hg, Cr, Ca, Co, Ni, Pb, Sn, *etc.*) and release aluminium salt to the environment. The surface-active substances that form the basis of synthetic foams represent a large environmental burden (Nagy and Kuti 2015) (Zólyomi 2008), as the hydrocarbon-based surfactants are stable compounds that have a very long decomposition time.



**Figure 9.** Aerosol fire extinguishing generator (Jordan Ayman Behnia Company 2022)



**Figure 10.** Fire extinguishing foam generating concentrate (FOAMTEC 2022)

Firefighting foams are clearly polluting, therefore, it is key to prevent their release into the environment. After their tests, rehearsals *etc.*, its removal and clearance should be ensured in advance.

### 3.2.2. Metal waste

Besides plastics, metals form a large part of the active fire protection systems, since extinguishing agents, whether it is liquid or gaseous, are usually stored in tanks, pressure vessels, or they are transported to the protected space through a pipe network. Tanks, bottles, and pipelines are mostly made of steel (Figure 11).

In terms of the possibilities of reuse, metals are ideal in the widely used "circular economic model" (Waste and repealing certain Directives 2008) since they can be recycled multiple times. When it is used as a secondary raw material, it greatly reduces the environmental burden.



**Figure 11.** Sprinkler tube and sprinkler head (Teknik Muayene 2022)

### 3.3. Summary Table

By preparing the Summary Table (Table 1), our aim was to prepare a comprehensive, easy-to-use "help", that provides relevant guidance in waste management issues affecting this special field for both the contractors and those involved in the operational phase (*e.g.* operators, maintainers) during their daily work. The table refers to the current legislation and provides consistent answers to the most important practical questions related to the previously discussed waste in the fire protection systems. The aid effectively supports the work of those involved in waste management, who are required to have legal background knowledge. The table also provides precise guidance on how waste from built-in fire protection systems can be categorised. The table summarises aspects related to the following questions:

- Is it considered to be hazardous waste?
- Should it be collected separately from municipal waste?
- Are there any regulations regarding its storage?
- Is it recyclable?
- Is its disposal regulated?
- Should recycling or destruction or long-term storage be documented?
- Does a specialist contractor or a licence necessary for its delivery?
- Should a separate authority or body be involved?

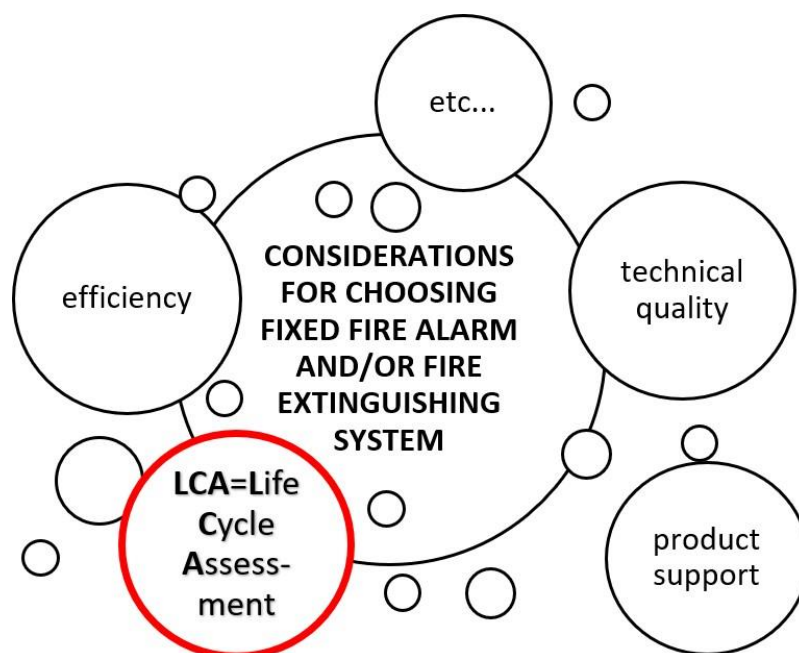
## 4. CONCLUSION

Environmental protection and waste management issues related to built-in fire protection systems primarily affect contractors and operators, as was shown in Table 1. It is in the interest of the manufacturer and the designer to deal with these aspects. In today's competitive market, environmental aspects are becoming more and more important.

**Table 1.** Key information about wastes generated from fixed fire alarm and fire extinguishing systems

	Metal waste	Plastic waste	Electronic waste	Radioactive waste	Greenhouse extinguishing gases
Is it considered hazardous waste?	<b>Yes</b> if the HAK code: 17 04 09* <sup>[1]</sup> , 17 04 10* <sup>[1]</sup> , 17 09 03* <sup>[1]</sup> <b>No</b> if the HAK code: 17 04 01 <sup>[1]</sup> , 17 04 07 <sup>[1]</sup> , 17 04 11 <sup>[1]</sup>	<b>Yes</b> if the HAK code: 17 02 04* <sup>[1]</sup> <b>No</b> if the HAK code: 17 02 03 <sup>[1]</sup> , <sup>[2]</sup> or 20 01 39 <sup>[1]</sup>	<b>Yes</b> if the HAK code: 20 01 35* <sup>[1]</sup> or 06 04 04* <sup>[1]</sup> <b>No</b> if the HAK code: 16 02 <sup>[1]</sup> → construction and demolition waste registration sheet	<b>Yes</b> e.g. Americium (Am-241) <sup>[3]</sup>	<b>Yes</b> if the HAK code: 14 06 01* <sup>[1]</sup> chlorofluorocarbons <sup>[1]</sup> , HCFC, HFC and 6 05 04* the foils
Should it be collected separately from municipal waste?	<b>Yes</b> Selectively collection	<b>Yes</b> if the HAK code: 17 02 04* <sup>[1]</sup> must be classified as a separate hazardous substance → In addition, selective collection	<b>Yes</b> <sup>[4], [5]</sup> FKF Residential selective waste collection yard	<b>Yes</b> Obligation to maintain and report on the Waste Register <sup>[53]</sup>	<b>Yes</b> <sup>[6]</sup> Collection back
Are there any regulations regarding its storage?	<b>Yes</b> <sup>[7]</sup> In the case of materials subject to a metal trade permit	<b>Yes</b> Selective collection and storage	<b>Yes</b> <sup>[4]</sup> FKF Residential selective waste collection yard	<b>Yes</b> <sup>[8], [9]</sup> Registration, control, data provision.	<b>Yes</b> <sup>[6]</sup>
Is it recyclable?	<b>Yes</b> <sup>[10]</sup> R4 code – recycling and recovery of metals and metal compounds	<b>Yes</b> Mechanically, chemically, thermally, biologically	<b>Yes</b> <sup>[4], [10]</sup>	<b>No</b> A job subject to a license <sup>[9]</sup>	<b>Part:</b> halon, HCFC, HFC, recovery with a closed system process, then regeneration or disposal (incineration)
Is its disposal regulated?	<b>Yes</b> Recycling	<b>Yes</b> Sorting, grinding, washing, drying, production of polymer granules	<b>Yes</b> <sup>[13]</sup> Disposal obligation, but only towards the manufacturer	<b>Not regulated</b> There is no destruction	<b>Yes</b> <sup>[11]</sup> Performed by trained personnel
Should recycling or destruction or long-term storage be documented?	<b>Yes</b> <sup>[4]</sup> Documentation from collection to recycling	<b>No need to document</b>	<b>Yes</b> <sup>[12]</sup> HAK code Manual and mechanical pretreatment. Coordinating Organizations → The manufacturer's obligation to take back, accept, collect and handle	<b>Yes</b> <sup>[9]</sup> Radiation protection risk above 1·10 <sup>1</sup> kBq Am-241 activity	<b>Yes</b> <sup>[5]</sup> Data service
Do you need a specialist company or a license to transport it?	<b>No</b> <sup>[7]</sup>	<b>Yes</b> if the HAK code: 17 02 04* <sup>[1]</sup> → A waste management permit is required	<b>No</b> <sup>[4]</sup>	<b>Yes</b> <sup>[13], [14]</sup> Decree „A“ and „B“ annex, ADR and RID regulation, COTIF, ADN	<b>Yes</b> <sup>[14], [15], [16]</sup> Decree „A“ table: List of dangerous goods and Annex "B"
Should a separate authority or body be involved?	<b>Yes</b> <sup>[17]</sup>	<b>Yes</b> Environmental authority	<b>Yes</b> Waste Management Authority → Environmental authority	<b>Yes</b> <sup>[9]</sup> Atomic Energy Supervisory Body	<b>Yes</b> Environmental authority

\* Hazardous waste



**Figure 12.** Position of LCA among the criteria of selecting the fixed fire alarm and extinguishing systems. Source: Created by the Author

By time, manufacturers can gain a more advantageous market position by developing and manufacturing systems and devices that have a less ecological footprint compared to others. That is why it is important that the so-called life cycle analysis (LCA<sup>8</sup>) is a way to reduce the global environmental burden caused by the discussed field.

Of course, it is valid for all personnel in a specialised field, that knowledge and skills are required to become a professional. From developing the skills of the profession's know-hows, via familiarising with the relevant legislation as well as the knowledge of practical issues regarding waste management. Therefore, we highlight that waste management issues shall be integrated into those people's training and further education system, who are involved at some levels of the process. By publishing the present paper, we are intended to provide help on making such training more effective. In the course of our work, we primarily examined the situation in Hungary, but for our objectives stated, we consider it important to examine this in other countries as well.

## REFERENCES

ADR. (2021). International Carriage of Dangerous Goods by Road Decree, 39/2021 ITM § 1

<sup>8</sup> LCA=Life Cycle Assessment

- Agreement on the International Transport of Dangerous Goods by Road Decr. (2021). 387/2021 § 5 <https://op.europa.eu/en/publication-detail/-/publication/55bd93c4-f686-11eb-9037-01aa75ed71a1/language-hu>
- Bánhidi, L., Kajtár, L. (2000). Comfort theory. Bp 2000, Egyetemi Kiadó, 436.
- Baranyai, G. (2020). Report on the research establishing the general legal regulation of sustainable development (professional report). University of Public Service, Faculty of Water Sciences, Department of Water and Environmental Policy.
- Batteries and accumulators and waste batteries and accumulators and repealing EU Directive. (2006). 2006/66/EC <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32006L0066> (date of download: 20.10.2022.)
- Bojár, G. (2018). Fourth industrial revolution or third IT revolution? The power of information for thousands of years. Hungarian Science 179, Akadémiai Kiadó, 37–46., doi: 10.1556/2065.179.1.4.2018
- Climate Gas Database. (2022.) National Climate Protection Authority. <https://nemzetiklimavedelmihatosag.kormany.hu/> (date of download: 03.12.2022.)
- Code of Federal Regulations. (2022). U.S. Government Publishing Office. <https://www.govinfo.gov/app/collection/cfr/2022/> (date of download: 05.12.2022)
- Community trading system of greenhouse gases and the implementation of the effort sharing decision National Act. (2012). CCXVII § 4 <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC127546/> (date of download: 06.12.2022)
- Community trade system of greenhouse gases Decr. (2012). 410/2012 Gov. Reg. § 1-3 <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC128804/> (date of download: 06.12.2022)
- Concerning the list of wastes Decr. (2013). 72/2013 VM § 7 <sup>[1]</sup>
- Conditions of activities with fluorinated greenhouse gases and ozone depleting substance Decr. (2015). 14/2015. Gov. Reg. § 3 <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC144130/> (date of download: 19.10.2022.)
- Defense Disaster Management. (201 1). Built-in fire extinguishing system between 2005 and 2010. *Defense Disaster Management Review*, 18 (4), 11-14.
- Defense Disaster Management. (2019). Nearly two million fire detectors since 2000. *Defense Disaster Management Review*, 26 (4) 19-20.
- Detailed rules for the management of construction and demolition waste Decr. (2004). 45/2004 BM-KvVM § 3
- Environmental protection product fee National Act. (2011). LXXXV § 2 <https://leap.unep.org/en/countries/hu/national-legislation/act-no-lxxxv-2011-environmental-protection-fee> (date of download: 06.12.2022)
- Eurostat. (2020). E-waste in the EU: fact and figures (infographic). Eurostat European Environment Agency Society. <https://www.europarl.europa.eu/news/en/headlines/society/20201208STO93325/e-waste-in-the-eu-facts-and-figures-infographic> (date of download 30.11.2022.)

- Eurostat. (2022). Waste management in the EU: trends and statistics (infographic). Eurostat European Environment Agency Society.  
[https://www.europarl.europa.eu/pdfs/news/expert/2018/4/story/20180328STO00751/20180328STO00751\\_hu.pdf](https://www.europarl.europa.eu/pdfs/news/expert/2018/4/story/20180328STO00751/20180328STO00751_hu.pdf) (date of download: 30.11.2022.)
- Exemption activity concentration of radionuclides and on the establishment on their exemption activity level Decr. (1997). 23/1997 NM
- Fluorinated greenhouse gases and repealing EC Reg. (2014). 517/2014/EU  
<https://www.eea.europa.eu/policy-documents/regulation-eu-no-517-2014> (date of download: 20.10.2022.)
- FOAMTEC. (2022). Fomtec P 6% is a fluorine free protein foam concentrate.  
<https://www.fomtec.com/products/p-6/> (date of download: 03.12.2022)
- F-gas EC Reg. (2006). 842/2006/EC <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32006R0842> (date of download: 02.12.2022.)
- Greendex. (2021). This year electronic waste's mass will be more than the Great Wall of China. <https://greendex.hu/iden-a-kinai-nagy-falnal-is-nagyobb-tomegu-lesz-az-elektronikus-hulladek/> (date of download: 30.12.2022)
- HomeHow. (2021). Best Smoke Alarms, Ionisation Smoke Detector.  
<https://www.homehow.co.uk/reviews/best-smoke-alarms> (date of download: 05.12.2022.)
- Identification, designation and protection of critical systems and facilities National Act. (2012). CLXVI § 1/j
- Jordan Ayman Behnia Company. (2022). Aerosol fire extinguishing system.  
<https://behniafire.com/en/product/aerosol-fire-extinguishing-system/> (date of download: 03.12.2022)
- Karácsony, J. (2012). Why is the sky blue?. Firka. Physics, publication of the Transylvanian Hungarian Technical Science Society, 21(5), 181-186  
<https://emt.ro/sites/default/files/archivum/2017-12/firka5-2011-2012.pdf> (date of download: 30.11.2022.)
- Kentec. (2022). Kentec Expansion Cards 4 Way Conventional Detection Zone Module  
<https://kentec.co.uk/product/expansion-cards-4-way-conventional-detection-zone-module/> (date of download: 05.12.2022.)
- Listing of disposal and utilisation operations related to waste management Decr. (2016). 43/2016 FM § 1.
- Metal trading activities Decr. (2013). 443/2013 Gov. Reg. § 27
- Metal Trade National Act. (2013). CXL § 4-5
- mod. National Waste Act. (2017). CXCVI § 2
- Mohai, Á. (2012). Design of fire protection equipment: I. Fire detectors. Szent István University. ISBN 978-963-269-305-7
- Nagy, Zs., Kuti, R. (2015). The effects of fire-fighting foams on the environment. *Military Engineer*, 10 (3), 156-164,



- National Fire Protection Regulation Decr. (2014). 54/2014 BM § 154
- National Waste Act. (2012). CLXXXV § 10
- Nuclear Energy National Act. (1996). CXVI § 12-15. [https://www.oecd-neo.org/law/legislation/hungary1996\\_aea.pdf](https://www.oecd-neo.org/law/legislation/hungary1996_aea.pdf) (date of download: 05.12.2022)
- Radioactive emissions into air and water Decr. (2001). 15/2001 KöM § 6
- Radioactive materials and equipment generating ionising radiation Government Decr. (1997). 124/1997
- Rahman, Md Z., Atun F., Martinez J. (2021). Earthquake and Fire Hazard Risk Perception: A Study on the Emerging Rangpur City of Bangladesh. *IDRiM Journal*, 11 (1), 1-21. <https://doi.org/10.5595/001c.28382>
- Registration and control of radioactive materials Decree. (2010). 11/2010 KHEM § 7
- Restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) EU Directive. (2011). 2011/65/EU
- Registration of waste management activities Decree. (2012). 439/2012 Gov. Reg. § 7-10
- Rules for the qualification of those performing activities related to fluorinated greenhouse gases Decr. (2016). 60/2016 NFM § 11
- Safety requirements for radioactive waste storage facilities Decree. (2014). 155/2014 Gov. Reg. § 60-63
- Science Learning Hub. (2022). Measuring biodegradability. <https://www.sciencelearn.org.nz/resources/1543-measuring-biodegradability> (date of download: 03.12.2022.)
- Substances damaging the ozone layer Decree. (2003). 94/2003 Gov. Reg. § 2
- Substances that deplete the ozone layer EC Reg. (2009). 1005/2009/EC, Annex VI
- Teknik Muayene. (2022). Checking fire protection equipment. <http://www.teknikmuayene.com.tr/yangin-tesisatlarinin-kontrolleri> (date of download: 02.12.2022)
- The Global E-waste Monitor. (2020). World Health Organization. [https://ewastemonitor.info/wp-content/uploads/2020/11/GEM\\_2020\\_def\\_july1\\_low.pdf](https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf) (date of download: 02.12.2022.)
- The transportation, forwarding and packaging of radioactive materials Decree. (2013). 51/2013 NFM § 1/A.
- Tóth, R. (2007). The situation of extinguishing gases in the light of environmental regulations. *Defense Disaster Management Review*, 2007 (1), 42-44.
- TSZVSZ Hungarian Fire Protection Association. (2009). Aerosol fire extinguishing technology and related standards. <http://www.vedelem.hu/files/UserFiles/File/konf2009/siofok/aeroszol.pdf> (date of download: 03.12.2022)
- Waste and repealing certain Directives (2008). 2008/98/EC. Official Journal of the European Union. L312 3-30

- Waste and waste management. (2022). Chemistry and environmental protection.  
<https://sites.google.com/site/kemiakornyezetvedelem/home/hulladek-es-hulladekkezeles>  
(date of download: 10.04.2022.)
- Waste electrical and electronic equipment (WEEE) EU Directive. (2012). 2012/19/EU
- Waste management activities that are connected to electric and electronic equipment Decree.  
(2014). 197/2014 Gov. Reg. § 3
- Waste management activities that are connected to battery wastes and accumulator wastes  
Decree. (2012). 445/2012 Gov. Reg.  
<https://www.fao.org/faolex/results/details/en/c/LEX-FAOC123472/> (date of download:  
19.10.2022.)
- Wholesale Batteries Direct. (2022). 12V/8Ah fire alarm battery.  
<https://www.wholesalebatteriesdirect.com/fire-alarm-control-panel-batteries/52062-12-volt-8-ah-fire-alarm-battery-replaces-12v-7ah-fire-lite-bat1270.html> (date of download:  
05.12.2022.)
- Yamaguchi, H., Horie, N. (2018). Communication-design for Disaster Risks through  
Shopping at a Large-scale Shopping Center: Transition from Disaster Prevention to  
Disaster Mitigation. *IDRiM Journal*, 8 (1), 22-45.
- Zólyomi, G. (2008). Environmental protection effects of firefighting methods. *Military  
Engineer*, 3 (1) 70-87.