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USING SMART DIGITIZATION IN HAZARDOUS WASTE MANAGEMENT[1]

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Abstract

The global information society is growing at a fast pace. At the same time, the increase in purchasing power, urbanization and industrialization in many developing countries have led to an increase in the quantities of products placed on the market and respectively purchased, thus generating large volumes of toxic waste. Thus, digitization and connectivity are critical to help achieve the Sustainable Development Goals, the transition to an increasingly digitalized world also involves multiple risks due to irrational consumption of resources and mismanagement of waste. In our view, the problem of hazardous waste management is possible by implementing modern and smart digital technologies in waste management, and by implementing waste digitization will improve the health of planet Earth, will reduce the negative impact of pollutant emissions on the environment, will restore essential ecosystems to ensure our long-term sustainability. Thus, the use of waste as a resource is necessary to reduce the need to extract new resources. This study was developed within the State Program 20.80009.0807.22 Development of the mechanism for the formation of the circular economy in the Republic of Moldova.

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JEL Classification: Q53, Q54, Q57, Q58

Introduction

In recent years, toxic waste is that waste which is harmful to human health, to nature, that contains particularly dangerous substances. Thus, toxic materials can be produced by humans or can occur naturally in the environment. Toxic waste can cause damage to living things if these toxins are buried in the soil, in the water they drink or even if they interact with flood waters. Mercury, for example, remains in the environment and accumulates. Humans and animals can absorb this substance when they eat fish. Toxic waste must be handled with care. That's why many cities around the world have regulations when interacting with them. Toxic waste must be disposed of in facilities intended for this purpose. Toxic waste has become more abundant since the Industrial Revolution. In addition, most technological advances contain toxic chemicals. For example: products such as mobile phones, computers, televisions, batteries, pesticides and solar panels contain harmful chemicals. Disposal of these materials has become problematic because they cause serious health problems in the world.

In our view, the problem of hazardous waste management is possible by implementing modern and smart digital technologies in waste management, and by implementing waste digitization will improve the health of planet Earth, will reduce the negative impact of pollutant emissions on the environment, will restore essential ecosystems to ensure our long-term sustainability. In a short time, extreme events, such as storms, heat waves, floods and droughts with intensities that once occurred every 100 years, became the new reality of the planet. Thus, it is necessary, before it is too late, to take firm measures to implement smart technologies.

The degree of approach to the topic in the scientific literature. Currently, contemporary researchers are conceptually addressing the risk of waste that can be characterized and assessed through the following three components:

1. Degree of hazardousness of the waste (including: volume, concentration, extent, etc.);
2. The route of exposure by which the dangerous substance passes from the source to the receptor (comprising the geographical and hydrogeological location, etc.);

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3. Receptor status. Thus, it is important to know this data and information to assess the risk posed by the production, storage and warehousing of hazardous waste [10].

All these characteristics indicate that structurally the waste itself is very harmful and the amount of waste generated by the population is closely linked to consumption and production patterns. Thus, demographic changes, such as the increase in the number of single-person households, also affect the amount of waste they generate. In this study, the authors aim to reflect on the issue of toxic waste in the Republic of Moldova, which has a harmful impact on the environment and public health. Therefore, studying the literature, toxic waste, according to businessdictionary.com (2017), are all materials, liquid, solid or gaseous, that can cause damage by swallowing, inhalation or absorption through the skin.

In the Republic of Moldova, According to Law no. 209 of 29.07.2016 on waste, hazardous waste is any waste that has one or more of the hazardous properties specified in Annex no. 3 of the law. Therefore, according to art. 7 of Law no. 209 of 29.07.2016 on waste, the list of wastes, including hazardous waste, is prepared and updated periodically by the Ministry of Agriculture, Regional Development and Environment and is approved by the Government. Thus, in the case of a type of waste which falls, according to the List of wastes, under two different codes, depending on the possible presence of hazardous characteristics (codes marked with an asterisk), the classification as non-hazardous waste is done by producers and owners of such waste only on the basis of an analysis of origin, tests, analysis reports and other relevant documents [11].

According to the statistical reports from the Republic of Moldova submitted to the National Bureau of Statistics, all toxic waste are containing harmful substances, including toxic products that have become unusable in the process of treatment or transportation and cannot be used according to their destination (for example: pesticides unusable and prohibited). Therefore, harmful substances (products, compounds) that are in the form of products or semi-finished products are not subject to evidence. Also, aren't subject to evidence the toxic industrial wastes that hit the natural sources of surface water together with the wastewater and the gases released into the atmosphere, which are reflected in the statistical reporting forms no. 1 - water management "Water use" and no. 1-air "Protection of the atmospheric air". Thus, according to the degree of action on the human body, harmful substances are divided into four categories: category I - extremely harmful substances; category II - very harmful substances: category III - moderately

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harmful substances; category IV – slightly harmful substances. The harmful categories of toxic waste, chemical content and physical characterization of industrial toxic waste are determined by laboratory analyzes in enterprises, scientific research institutions with the inclusion of specialists from institutions and subdivisions for environmental protection or specialists of territorial sanitary-epidemiological stations. When determining the chemical content of the waste, the percentage content of toxic substances in the dry mass shall be calculated.

Hazardous waste properties: HP1 "Explosive", HP2 "Oxidizing", HP3 "Flammable", HP4 "Irritant - skin irritation and eye damage", HP5 "Specific target organ toxicity (STOT) / aspiration toxicity", HP6 "Acute toxicity", HP7 "Carcinogenic", HP8 "Corrosive", HP9 "Infectious", HP10 "Reproductive toxicity", HP11 "Mutagenic", HP12 “Release of a gas with acute toxicity”, HP13 “Sensitizers”, HP14 “Ecotoxic”, HP15 “Wastes capable of developing one of the hazardous properties mentioned above, which the initial waste does not directly present”.

According to the National Bureau of Statistics (NBS), indicators of the methodology for completing the statistical report form no. 1-toxic waste are completed annually by the production units, factories, enterprises, industrial and agricultural units where toxic waste is accumulated, stored, used or neutralized (liquidated). In this report, toxic wastes of the companies are those wastes that contain substances that are particularly harmful to the health of citizens and to nature. All toxic wastes containing harmful substances, including toxic products that have become unusable in the storage or transportation process and that cannot be used according to their destination (for example, pesticides that have become unusable and prohibited) are subject to evidence [6].

The purpose of the research is to identify digital tools that would contribute to the reduction of waste, especially toxic waste, and would contribute to increasing the productivity of some companies through the process of reuse or recycling and would have an impact on the circular economy. Thus, the use of waste as a resource is necessary to reduce the need to extract new resources. In this context, the European Union has set out several main objectives for transforming waste into a resource. An important goal is set out in the EU Roadmap to an *Energy Efficient Europe.*

Hazardous waste management in EU law. Therefore, the main legislative instrument in the field of toxic waste is the Waste Framework Directive. It presents a hierarchy of waste management: it starts with prevention, followed by preparation for reuse, recycling and recovery and ends with disposal. The directive

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aims to prevent the generation of waste as much as possible, to use the waste generated as a resource and to reduce to a minimum the amount of waste that reaches landfills. Therefore, EU countries can take different approaches to achieve their waste targets. Some approaches seem to work better than others. For example, if well designed, landfill fees appear to be an effective way to reduce landfill waste. Increasing producer responsibility, which means that the manufacturer must receive the product back at the end of its life cycle, also seems to be an effective method.

Thus, through communication: "*Investing in a smart, innovative and sustainable industry. A renewed EU industrial policy strategy" - Brussels, 6.11.2017, COM (2017) 479 final/2*, it is aimed to strengthen the capacity of industry to adapt and innovate to the requirements, to facilitate investment in new digital technologies for a transition towards a more circular low-carbon economy. Stimulating the use of the technological base and adapting new business models will favor future viability and a better functioning of the single market [12].

With regard to the regulation of waste management at EU level, a set of legislative acts have been adopted. Therefore, the main waste directives are:

- Directive (EU) 2018/849 of 30 May 2018 amending Directive 2000/53/EC *on end-of-life vehicles;*
- Directive 2006/66/EC *on batteries and accumulators and waste batteries and accumulators;*
- Directive 2012/19/EU *on waste electrical and electronic equipment;*
- Directive (EU) 2018/850 of 30 May 2018 amending Directive 1999/31/EC *on landfill of waste;*
- Directive (EU) 2018/851 of 30 May 2018 amending Directive 2008/98/EC *on waste;*
- Directive (EU) 2018/852 of 30 May 2018 amending Directive 94/62/EC *on packaging and packaging waste.*

The revised legislative framework on waste entered into force in July 2018. Thus, after amending Directive 2008/98/EC, the main objective of the new Directive 2018/851, according to Article 1, is to establish "*measures to protect the environment and public health through preventing or reducing the generation of waste, the adverse effects of waste generation and management and reducing the overall effects of resource use and increasing the efficiency of their use, which are essential for the transition to a circular economy and to ensure the long-term competitiveness of the Union*." [1].

Following the above, the revised legislative framework on waste under Directive 2018/851, in order to move to an European circular economy with a high

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degree of resource efficiency, Member States shall take the necessary measures **to achieve the following objectives:**

Directive 2018/851, according to art.11 par. 2

- separate collection of hazardous household waste (until the end of 2022), biological waste (until the end of 2023), textiles (until the end of 2025).
- By 1 January 2025, Member States shall organize the separate collection of ***hazardous waste*** fractions from households, in order to ensure treatment and to ensure that they do not contaminate other municipal waste streams.

Directive 2018/852, according to art.6 par. 5.

- *recycling of packaging waste by 31 December 2025 at the latest,* at least 65% of the weight of all and at least 70% of the weight of packaging waste will be recycled by 31 December 2030;
- *recycling targets for certain packaging materials, by 31 December 2025 at the latest*, for the recycling of the following specific materials contained in packaging waste: Paper and cardboard: 75%, Ferrous metals: 70%, Glass: 70%, Aluminum: 50%, Plastic: 50%, Wood: 25%.
- *recycling targets for certain packaging materials, no later than December 31, 2030*: Paper and cardboard: 85%, Ferrous metals: 80%, Aluminum: 60%, Glass: 75%, Plastic: 55%, Wood: 30%.

During 2018, several actions related to the circular economy were carried out. Thus, the European Commission has published the so-called ***circular economy package***. The first important action is to adopt a European strategy on plastics:

Communication: A European Strategy for Plastics in a Circular Economy Brussels, 16.1.2018, COM (2018) 28 final - this strategy lays the foundations for a new plastics economy, in which *the design and production of plastic materials and plastic products fully meet the needs of reuse, repair and recycling and where more sustainable materials are developed and promoted.*

This Strategy proposes concrete actions to turn the vision for a more circular economy of plastics into reality. In this context, the strategy proposes a set of measures at EU level, as by 2030 all plastic packaging should be recyclable, thus contributing to the transition to a more circular economy. The strategy provides for actions to:

1. Improving the economic aspects and the quality of plastics recycling;
2. Reduction of plastic waste and waste disposal in the public domain;
3. Orientation of investments and innovation towards circular solutions;
4. Capitalizing on global action.

According to this objective, the strategy contributes ”*to achieving the priority set by the Commission on an energy union with a modern, low-carbon and energy-*

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efficient and resource-efficient economy, and will make a tangible contribution to achieving the objectives of sustainable development for 2030 and compliance with the Paris Agreement". This approach covers the entire value chain, which will encourage growth, job creation and innovation. Also, such an approach can reaffirm European leadership in global solutions and help us make the transition to a circular, low-carbon economy, while providing citizens with a cleaner and safer environment.

Another COMMUNICATION on the implementation of the circular economy package: options for addressing the interface between chemicals, products and waste laws. Strasbourg, 16.1.2018 COM (2018) 32 final. The proposed framework aims to facilitate recycling and increase the use of secondary raw materials by limiting unnecessary constraints and facilitating the cross-border movement of secondary raw materials, so as to ensure that they can be easily traded across the EU. Another objective of the Communication is to replace chemicals of concern and, where this is not possible, to reduce their presence and improve their traceability [2].

In 2018, the European Commission adopted other ambitious initiatives in the context of the Circular Economy Action Plan: *the EU Directive on reducing the environmental impact of certain plastics. Brussels, 28.5.2018 COM (2018) 340 final.* The European Commission proposes on 28 May 2018 for adoption a new directive that aims to reduce the impact of certain plastics on the environment by implementing the EU Strategy for Plastics, addressing the gaps identified in existing legislation. The Directive proposes main actions for specific disposable plastic articles, taking into account consumer behavior as well as consumer needs and opportunities for businesses. When alternatives are clearly available - both single-use and multi-use - restrictions are proposed. Other measures include appropriate labeling, raising awareness, voluntary action and establishing extended producer responsibility schemes that would cover the costs of waste cleaning [1].

Thus, on 4 March 2019, the European Commission presented a *comprehensive report on the implementation of the Circular Economy Action Plan* to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.

The report also highlights the importance of adopting the first EU policy framework - *the Strategy for Plastics in a Circular Economy*, which states that by 2030, all plastic packaging placed on the EU market must be reusable or recyclable, and by 2025, 10 million tons of recycled plastics will be included in new products.

The Report sets out adapted sets of measures, which are in the final stages of the legislative process on single-use plastic articles and fishing gear, such as:

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- measures to reduce the consumption of food containers and beverage cups, plastic, as well as the specific marking and labeling of certain products;
- the target of including 30% of recycled plastics in beverage bottles from 2030 and 25% for PET bottles from 2025, as well as the target of separate collection of 90% of plastic bottles by 2029, as well as the introduction of design requirements for connecting caps to bottles;
- measures aimed at reducing plastic waste from ships, such as the establishment of a flat fee for waste from ships, etc.

The Commission proposes that EU countries, in order to accelerate the transition to a circular economy, need to invest in innovation and provide support for adapting the industrial base. Over the period 2016-2020, the Commission has stepped up efforts in both directions, providing public funding for the transition totaling more than € 10 billion.

The new action plan for the circular economy, adopted on 11 March 2020 by the European Commission, is part of the main blocs of the European Green Pact, a new European agenda for sustainable growth and an EU growth strategy to achieve climate neutrality by 2050.

Communication An action plan on the circular economy for a cleaner and more competitive economy. Strasbourg, 11.3.2020 COM (2020) 98 final. The document proposes initiatives throughout the life cycle of products, aiming at their design, promoting the processes of the circular economy, encouraging sustainable consumption and aiming at ensuring that the resources used in the EU economy are preserved for as long as possible. At the same time, in order to promote a longer duration of products, the Commission proposes a series of actions focused on the sectors that use the most resources and where the potential for circularity is high. Thus, the Commission introduces concrete measures on:

- electronic products and ICT - "Initiative for circularity in the field of electronics" to have products with a longer life and to improve waste collection and treatment;
- batteries and vehicles - a new regulatory framework for batteries in order to improve the durability and boost the potential for battery circularity (this legislative proposal will be based on the evaluation of the Batteries Directive and the work of the Battery Alliance);
- packaging - new mandatory requirements on what is allowed on the EU market, including the reduction of (excessive) packaging;
- plastics - new mandatory requirements for the content of recycled materials, special attention being paid to both micro-plastics and plastics of biological and biodegradable origin;

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- textiles - a new EU Strategy for textiles in order to strengthen competitiveness and innovation in this sector and stimulate the EU market for the reuse of textiles;
- constructions and buildings - a comprehensive Strategy for a sustainably built environment that promotes the principles of circularity in the case of buildings;
- food - a new legislative initiative on reuse, in order to replace disposable packaging, single-use crockery and cutlery with reusable products in food services.

At both European and national level, this provision pays attention to the avoidance of waste production as a whole and its transformation into high-quality secondary resources that benefit from a functioning secondary raw materials market. Thus, the Commission will examine the possibility of establishing a harmonized model at EU level for the separate collection and labeling of waste. According to Eurostat, the amount of waste generated annually by EU economic activities amounts to 2.5 billion tonnes, which means 5 tonnes per capita. There is currently no comprehensive set of legal and policy requirements to ensure that all products placed on the EU market are increasingly sustainable and meet the circularity criteria, and the Commission's New Circular Economy Action Plan (CEAP) European Parliament, presented on 11 March 2020, aims to do just that [14].

The process of toxic waste management in the Republic of Moldova. The toxic waste management process takes place through the collection, transport, recovery and disposal of waste, including the supervision of these operations and the subsequent maintenance of disposal sites, including the actions taken by a trader or broker. Some of this waste can be recycled (solvents, oil). Others must be stored in places specially designed for hazardous waste. Therefore, the extraction of less material and the use of existing resources could help to avoid some of the impact created along the chain. In this context, unused waste is also a potential loss.

Waste is traditionally seen as a source of pollution. But well-managed waste can be a valuable source of materials, especially when raw materials start to run out. The best option is to stop the production of waste. And when that's not possible, other good options are reuse and recycling.

Recycling of waste is not possible without selective collection at source, this being an essential condition for maximizing the recovery of waste. Waste recycling generates additional revenue for companies, especially when it comes to waste paper, cardboard, plastic, metal, wood, rare metals, glass, etc. Essential aspects in generating benefits and opportunities:

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Figure. 1. Toxic/harmful waste management process
Source: elaborated by the authors.

- Appropriate selection at source.
- Efficient collection and storage system (compactors reduce the volume of waste collected and allow to reduce transport costs).
- Collaboration with authorized organizations for waste transport and recycling.
- The use of high-performance recycling technologies.
- Knowledge of waste properties and values [9].

From toxic products can be recycled mostly from the products of various industries: ***packaging, glass, metal, batteries, tires and plastics, used oil, paper and cardboard; electrical and electronic equipment, wood; construction and demolition waste.***

- *Metals* are materials that can be recycled in a proportion of 90-95% if they are collected selectively. Certain metals, such as aluminum, can be recycled

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indefinitely. By recycling metals, energy consumption is reduced by 70% compared to the production of a completely new element.

- *Recycling paper and cardboard*. Almost any kind of paper and cardboard can be recycled. Recycling technology can remove inks, clips, staples, glue to which books are attached, but not oil. Therefore, oil and food-stained papers and cardboard cannot be recycled. In addition, waxed, plasticized or plastic-coated paper (glossy magazine covers), napkins or other used sanitary paper products cannot be recycled. Milk and juice boxes are recycled separately. Cardboard can be recycled several times, but not indefinitely. That is why it is good to avoid the packaging as much as possible, even if they are made of paper.

- *Glass recycling.* Glass can be recycled by melting indefinitely, without losing its properties. Also, the costs of recycling are lower than those of producing glass from raw materials, thus saving energy. Only glass of the same color can be produced from colored glass. Therefore, colorless glass is more valuable, as it can be reused for many purposes. Heat-resistant glass, such as Jena vessels, is not recycled with ordinary glass because it affects the melting process [16].

Thus, it is important that the waste is recycled, it is necessary that it is correctly identified and then sorted and put by the consumer in a separate container with the concrete specification of the waste.

Electrical and electronic equipment that constitutes toxic waste according to the provisions of art. 50 of Law no. 209/2016 on waste, including all components, subassemblies and consumables are an integral part of the equipment when it becomes harmful waste. Thus, waste electrical and electronic equipment contains various metals such as iron and aluminum, but also other metals such as copper and even precious metals such as silver and gold. Some of them also contain materials that are hazardous or harmful to the environment. Therefore, it is useful to collect the given waste separately, both in terms of recycling and environmental protection.

The categories of electrical and electronic equipment regulated by the *Regulation on WEEE approved by Government Decision no. 212 of 07.03.2018*, are:

1. Large household appliances
2. Small household appliances
3. Computer and electronic communications equipment
4. Consumer electrical appliances and photovoltaic panels
5. Lighting equipment
6. Electrical and electronic tools (excluding large industrial fixed tools)

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7. Toys, leisure equipment and sports equipment
8. Medical devices (except for all implanted and infected products)
9. Supervisory and control tools
10. Vending machines.

Therefore, of the total flow of solid waste, e-Waste represents only 2%, instead it accounts for 70% of the volume of hazardous waste that reaches the landfill. Due to its properties, this waste is included in Annex VIII of the Basel Convention, under the heading for hazardous waste. For example, the cathode ray tube of a TV can pollute about 50 m2 for 30 years, consisting of materials such as aluminum, lead, zinc, nickel, manganese, barium or cobalt. Refrigerators contain chlorofluorocarbons (CFCs), which are responsible for damaging the ozone layer and reducing the Earth's ability to protect itself from the sun's harmful rays. The phones contain heavy metals and rare metals. If this equipment were incinerated, it could release 36 tonnes of mercury and 16 tonnes of cadmium annually. Being so dangerous, this waste should not end up in landfills, but should be collected separately and recycled accordingly [8].

Waste digitization - a cleaner future for the Republic of Moldova. Digitization is an useful and a current process in all EU countries. This smart system allows both the citizen and local public administrations to have concrete, measurable data on the volume of waste and the degree of selective collection, by placing containers with large volume, correctly dimensioned to the number of inhabitants, allowing access only to the tenants. Thanks to these platforms located in special areas, the blocks will be much tidier and cleaner. Through this solution, each town hall in the locality will be able to monitor the total volume of waste and the degree of selective collection for each family, thus being able to calculate the sanitation tax on the quantities actually stored.

For a more efficient waste management, in 2018 it was approved by the Government of the Republic of Moldova - The Concept of the Automated Information System "Waste Management". The document provides for the accumulation of information on waste in an electronic register, which ensures the record of the circuit of waste produced and collected, including data on export, import, reuse and disposal of waste. The information for completing the register shall be provided by the authorized economic operators in the field of waste management. The digitization of information aims to improve the activity of operators in the sector. The waste management database can be accessed by public authorities, entrepreneurs and individuals. This system facilitates the exchange of

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information between profile public authorities, but also with the European Environment Agency. The creation of the information resource facilitates the implementation of the European Classifier on the List of Waste, including Hazardous Waste, which allows the collection and processing of waste record data according to codes established in the EU [4].

Figure 2. Digitization of waste through smart sensors IoT (Internet of Things)
Source: [18]

For any locality, waste management is an important part of the construction of the city of the future, but very often it is neglected in digitization projects. Existing "simple" solutions are already obsolete - cities are growing rapidly and generating more and more waste, and the built infrastructure does not allow the integration of smart solutions in processes. Many localities have difficulty disposing of garbage on time, while others need solutions to improve service productivity. Some waste containers fill up faster than others, some areas are harder to reach for garbage trucks, and some companies need specific collection and transportation services. There are good examples for solving these problems and for implementing them in various localities.

An example is the smart IoT (Internet of Things) sensors, which allow the city administration to optimize the distribution of containers. Monitoring the level of filling and the type of waste is an easy task with the help of smart sensors. They can be installed in any type of garbage containers and are resistant to daily use.

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Smart sensors provide real-time monitoring of containers and are an important step in eliminating problems with spilled containers.

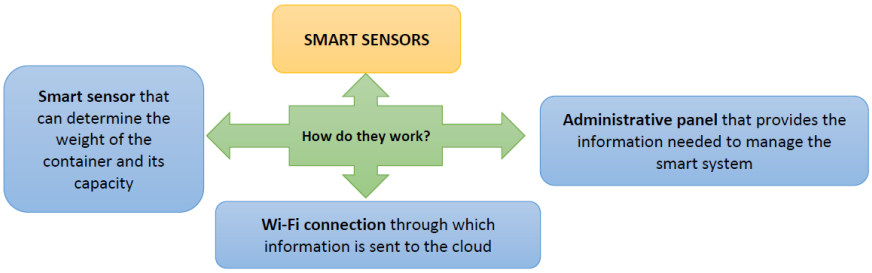

Figure 3. Functionality of smart waste sensors
Source: elaborated by the authors.

Real-time information collection allows the creation of detailed reports. Reliable and current statistics are available at any time and the city administration can use them to make informed decisions about how to optimize the system: areas that need more containers or more frequent collection, optimization of the collection schedule, redistribution of available resources and others. Each garbage truck, container and landfill is an important part of the waste management ecosystem. That is why their optimal use is very essential for the productivity of the whole process. Cloud technologies, IoT sensors and an intuitive management platform help create the optimal route daily for each truck that directs it exactly to where and when it is needed, depending on the optimal route between containers and landfill. This creates premises for reducing the price and improving the efficiency of the system. Modern cloud technologies and real-time data work together, enabling remote waste management [18]. This would be a good example to implement for localities in the Republic of Moldova.

Conclusions and recommendations.

The research results present a number of important and general aspects regarding the mechanism of toxic waste management through digitization.

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Therefore, it is important to note that despite a large share of the number of toxic wastes recorded annually globally and nationally, the impact of this waste is high on the environment and health, and for non-essential reasons it is not practiced selective collection and delivery of this waste to authorized recyclers. Which is why every citizen continues to keep toxic waste in the home, office, specially designed spaces for an indefinite period, including the disposal with other waste.

Therefore, in the study, the concept of toxic waste at national level reflected in normative and legislative acts, the process of hazardous waste management at EU and Moldovan level were identified, in order to identify the most efficient mechanisms that would boost the toxic waste market in the Republic of Moldova by increasing the rates of selective collection and reducing the quantities arriving at landfills. Analyzing the statistical data provided by the NBS and the Environment Agency, we elucidated the main causes underlying the decision-making behavior of waste owners and generators at the national level. For consumers:

✓ To limit the use of dangerous products through rational and responsible consumption;

✓ To try ecological alternatives to ordinary detergents;

✓ Products in good condition, but which they no longer use, must be reused (sale, donation);

✓ Defective products can be repaired and then reused;

✓ Waste is thrown in specially arranged places;

✓ Sort the waste and send it for recycling;

✓ Replace regular batteries with accumulators/rechargeable batteries;

✓ To return to the pharmacy the expired or no longer necessary medicines;

✓ Use water-based paint, not solvent-based;

✓ Waste management services are paid in the same way as any service or goods, etc.

All these activities lead to changing consumer behavior and more efficient management of hazardous waste. Therefore, local public authorities must also participate in the decision-making process by:

- Working groups;
- Public consultation meetings;
- Endorsement of draft decisions;

➢ To provide expertise and consultancy, through:

- Elaboration of project proposals;

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- Participating in the process of conceptualizing the model of hazardous waste management as well as municipal waste;
- Organizing study visits and exchange of experiences.
- And to provide communication and information services with citizens.

Thus, for the efficient management of toxic/hazardous waste, we come up with the following recommendations:

- Harmonization of the normative and legislative framework related to the Waste Law according to the European legislation;
- Population: rational consumption, collected and separated waste, paid services;
- LPA: integration in the regional waste management system, sorting / incineration stations, regional landfills;
- CSOs: pro-activism in decision-making and policy monitoring [7].

The study highlights the lack of facilities, and in these conditions, the awareness of the proper management of hazardous waste is not well perceived by the plants / factories generating hazardous waste. Thus, hazardous waste management is a complex subject consisting of several components. There is no perfect model that can be applied in any situation, but the EU has firm principles on which to base its approach to waste management that also can be applied in the Republic of Moldova, and a key tool would be digitization.

References

[1] European Commission. A European strategy on plastics in a circular economy Brussels, 16.1.2018, COM (2018) 28 final. [online], [accessed 25.10.2021], available on: https://eur-lex.europa.eu/legal-content/RO/TXT/DOC/?uri=CELEX:52018DC0028&from=EN

[2] European Commission. On the implementation of the circular economy package: options to address the interface between chemical, product and waste legislation, 16.1.2018, COM (2018) 32 final. [online], [accessed 25.10.2021], available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1552489350375&uri=CELEX:52018DC0032

[3] Iordanca–Rodica Iordanov, Irina Punga, 2020|AO ECOCONTACT. MANAGEMENTUL DEȘEURILOR MEDICALE GENERATE DE COVID–19. 111 p. Chișinău Republica Moldova. Disponibil pe: https://www.ecocontact.md/wp-content/uploads/2020/04/MANAGEMENTUL-DE%C8%98EURILOR-MEDICALE-GENERATE-DE-COVID.pdf

Annals of Spiru Haret University.
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ISSN:2393-1795 ISSN-L:2068-6900

[4] Ministry of Agriculture and Food Industry. An information management system for waste will be created in Moldova. [online], [accessed 1.11.2021], available on: https://www.madrm.gov.md/ro/content/%C3%AEn-moldova-va-fi-creat-un-sistem-informa%C8%9Bional-de-management-al-de%C8%99eurilor

[5] Ministry of Agriculture and Food Industry. Hazardous waste management. [online], [accessed 24.09.2021], available on: http://www.mediu.gov.md/ro/content/i2-gestionarea-de%C8%99eurilor-periculoase

[6] National Bureau of Statistics, METHODICAL INDICATIONS REGARDING THE COMPLETION OF THE STATISTICAL REPORT FORM no. 1 toxic waste (annually) «FORMATION, USE AND NEUTRALIZATION OF TOXIC WASTE» [online], [accessed 24.09.2021], available on: https://statistica.gov.md/public/files/Formulare_statistice_2010/Mediul_inconjurator/Instructiuni_1_deseuri_toxice.pdf

[7] POPA V., POPA N. Analysis of the european framework on the circular economy. In: Journal of Social Sciences, categoria C, Vol. IV, (1), 2021, p.21-28, ISSN 2587-3490, [online], [accessed 15.10.2021], available on: https://jss.utm.md/wp-content/uploads/sites/21/2021/03/JSS-1-2021_21-28.pdf

[8] Prisecaru, M., Despre reciclarea deșeurilor electrice si electronice. Responsabilitate socială, [online], [accessed 26.10.2021], available on: http://www.responsabilitatesociala.ro/editoriale/despre-reciclarea-deseurilorelectrice-sielectronice.html

[9] Sectoral Operational Program "Increasing Economic Competitiveness" - co-financed by the European Regional Development Fund "Investing for your future". Waste resources. INCREASING THE EFFICIENCY OF THE USE OF WASTE THAT CAN PRODUCE ENERGY IN THE LOGISTICS SECTOR, 2014 ODIMM, [online], [accessed 22.10.2021], available on: https://www.odimm.md/ro/compartimente-eco/reciclarea-deseurilor/item/resurse-din-deseuri?category_id=74

[10] Studiul privind Planul pentru gestiunea deșeurilor periculoase în România, Raport Final Agenția de Cooperare Internațională a Japoniei. Volumul 1. Raport Principal: Strategia şi Planul de Acțiune. Capitolul 4 Colectarea şi Transportul Deșeurilor Periculoase, disponibil pe: https://openjicareport.jica.go.jp/pdf/11737715_06.pdf

[11] Study on the General Plan for Hazardous Waste Management in Romania. Final Report Japan International Cooperation Agency. Volume 1. Main Report: Strategy and Action Plan Chapter 3 Waste Prevention and Recycling. [online], [accessed 22.10.2021], available on: https://openjicareport.jica.go.jp/pdf/11737715_05.pdf

[12] LAW No. 209 of 29-07-2016 on waste, Published: 23-12-2016 in the Official Gazette no. 459-471 art. 916, [online], [accessed 24.09.2021], available on: https://www.legis.md/cautare/getResults?doc_id=105806&lang=ro#, art 22

[13] European Commission. Brussels, 13.9.2017 COM (2017) 479 final Investing in a smart, innovative and sustainable Industry. A renewed EU Industrial Policy Strategy. [online], [accessed 20.10.2021], available on: https://ec.europa.eu/transparency/regdoc/rep/1/2017/RO/COM-2017-479-F2-RO-MAIN-PART-1.PDF

[14] Hotărârea Guvernului Nr. 696 din 11-07-2018. Publicat: 10-08-2018 în Monitorul Oficial Nr. 295-308 art. 835
[15] European Commission. COM (2020) 98 final, Bruxelles, 11.3.2020, A new Circular Economy Action Plan For a cleaner and more competitive Europe. [online], [accessed 20.03.2021], available on: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN, https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0011.02/DOC_1&format=PDF
[16] European Commission. Brussels, Directive (EU) 2018/849 of 30 May 2018 amending Directive 2000/53/EC on end-of-life vehicles; Directive 2006/66 / EC on batteries and accumulators and waste batteries and accumulators; Directive 2012/19 / EU on waste electrical and electronic equipment; Directive (EU) 2018/850 of 30 May 2018 amending Directive 1999/31/EC on landfill of waste; Directive (EU) 2018/851 of 30 May 2018 amending Directive 2008/98/EC on waste; Directive (EU) 2018/852 of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste. [online], [accessed 20.10.2021], available on: https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/?uri=OJ:L:2018:150:FULL&from=EN
[17] Waste recycling, ODIMM, [online], [accessed 22.10.2021], available on: https://www.odimm.md/ro/compartimente-eco/reciclarea-deseurilor
[18] WASTE LAW Draft, 2009, [online], [accessed 24.10.2021], available on: http://www.justice.gov.md/file/Centrul%20de%20armonizare%20a%20legislatiei/Baza%20de%20date/Materiale%202009/Acte/PL%20deseuri/Proiect%20Lege%20deseuri.pdf
[19] INTELLIGENT WASTE MANAGEMENT? [online], [accessed 2.11.2021], available on: https://telelink-city.com/gestionarea-inteligenta-a-deseurilor-ro/?lang=ro