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## From wish to action – how does Croatia manage its hazardous waste?

### Abstract

The paper analyzes the hazardous waste management system in the Republic of Croatia with respect to the obligations arising from the EU *acquis communautaire* in the field of environmental protection. Besides analyzing the existing legislative regulations and strategic framework, assessments were made of the amounts of hazardous waste produced as by-products of the manufacturing and service processes.

The following data relating to hazardous waste producers were analyzed: air pollution emissions, water pollution emissions, soil pollution, pollution types, emissions of polluting substances, amounts of waste in the reporting year, temporary storage at the beginning and at the end of the year, waste management at the site of production, waste delivered to the waste collecting firm, waste caretakers, and data on hazardous waste export. For hazardous and special types of waste, changes in the amount of hazardous waste, collecting, storage, processing and recovery, hazardous waste care-taking and environmental protection management were analyzed.

Research results indicate three different factors underlying the functioning of hazardous waste management: effective prevention of hazardous waste production, recycling and incineration. All three factors are important for adjusting future activities to the EU guidelines for the period of 2014-2020.

Authors' recommendations could serve as guidelines for decision makers as well as a framework for the hazardous waste management strategy in Croatia.

**Keywords:** hazardous waste, hazardous waste management, environmental protection, system analysis, recycling, incineration, legislative regulations.

**JEL Classification:** Q5.

### Introduction

One of the features of modern, technologically developed communities is that sooner or later everything becomes waste. There is a whole range of materials that are difficult to recycle or are practically non-recyclable; their accumulation may directly or indirectly cause economic, environmental and health problems.

One of the first definitions of hazardous waste was put forward in the early 1980s in the USA and it included all substances hazardous to human health. It deals with waste possessing some of the characteristics that make it dangerous for commercial, industrial or other use, and its disposal (explosiveness, flammability, corrosiveness, toxicity, virulence, radioactivity, infectivity). In order to protect the public and the environment, most developed countries have introduced laws regulating emissions and the handling of hazardous waste in general.

In Annex IVB of the Basel Convention, disposal is defined as any activity that involves the manipulation of waste, and does not include the possibility of partial recovery of natural resources, recycling, direct or indirect reuse of waste. Waste management, according to the same source, includes reduction, collection, transportation, treatment and disposal of hazardous and other wastes, including taking care of landfills.

The most common definition of sustainable development (according to the Brundtland Commission) is “development which meets the needs of current generations without compromising the ability of future generations to meet their own needs.” Managing waste in a way that minimizes the toxic effect on the present and future generations is an integral part of sustainable development.

Due to the fact that hazardous waste is a threat to the environment and human health, special regulations have been introduced. These regulations encourage special management measures under which hazardous waste is stored separately from ordinary waste and is accordingly treated in a different manner.

Inadequate management of hazardous waste is manifested through waste disposal in a manner that endangers health, a low level of waste recycling, inadequate waste treatment or treatment of waste with inadequate technologies, insufficient monitoring of waste processing, and a large number of existing problems that have not been tackled yet.

In this paper, we present the current state and analyze the trends for the development of hazardous waste collection, treatment and disposal in Croatia.

The purpose of this research was to collect information on suspected, polluted, contaminated and remediated land (soil and groundwater) that has been impacted by past or ongoing pollution through industrial/agricultural activities, post-crisis events or accidents. A questionnaire was completed by counties and further by towns, municipalities and industries.

A pollutant release and transfer register is important to the authorities involved in decision making, since it provides the basis for prevention of environmental contamination. This allows agencies to identify the emission of pollutants, carry out monitoring, and thus implement the environmental protection policy, define priorities and implement the necessary actions towards integrated environmental protection, all in the function of sustainable development management. Many scientists now believe that waste treatment (e.g. thermal processes) resulting in generation of energy needed by humankind is the key element of sustainable waste management. The aim of waste management is to protect people and the environment and to conserve resources.

### 1. The legal framework of hazardous waste management

The EU economy should grow in a way that respects resource constraints and planetary boundaries, thus contributing to the global economic transformation. It should be competitive, inclusive and should provide a high standard of living with much less impact on the environment. All resources, from raw materials to energy, water, air, land and soil need to be managed sustainably.

The Waste Framework Directive requires that hazardous waste be registered, identified and separated from other types of waste. The Directive names features that make waste hazardous and these features are further specified in the Decision 2000/532/EZ.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is an international agreement signed by 172 signatory countries and put into effect in 1992. This agreement defines the legal protection of human health and environment from potential adverse effects of hazardous waste through control of cross-border transportation and disposal of hazardous waste. One of the intentions of the Basel Convention is to prevent the transfer of hazardous waste from developed countries to less developed countries.

The Landfill Directive stipulates that hazardous waste must be separated from other waste types and disposed of in specially regulated landfills for hazardous waste while municipal waste is disposed of in landfills for non-hazardous waste.

Siting of hazardous waste management facilities depends on various factors, some of which are regulated by law.

As regards hazardous substances in waste, Directive 96/59/EC (EU, 1996) requires that equipment with polychlorinated biphenyls (PCBs) in quantities greater than 5 dm<sup>3</sup> should be decontaminated or

disposed of in a proper warehouse by 2010. (9) Directive 2011/65/EU (EU, 2011a), abolishing Directive 2002/95/EC (EU, 2002b), prohibits heavy metals in all new electrical and electronic equipment (EEE) by 2019.

The Basel Convention, ratified by the EU and all the EU-27 countries, touches on the transboundary movements of hazardous wastes and their disposal. Convention recommendations are implemented in the EU through Regulation (EC) No1013/2006, known as the Waste Shipments Regulation (EZ, 2006), which also refers to the OECD system for the control of transboundary movements of wastes destined for recovery (OECD Decision C / 92/39 final, as amended by the Decision of the OECD C/2001/107 final).

Some multilateral environmental agreements pertaining to marine pollution by hazardous waste: Dumping Protocol for the Convention for the Protection of the Mediterranean Sea against Contamination (ratified by the EU and seven member states of the EU-27); Hazardous Waste Protocol for the Convention for the Protection of the Mediterranean Sea against Contamination (ratified by Malta); Dumping Protocol for the Convention on the Protection of the Black Sea against Pollution (ratified by Bulgaria and Romania), with Annex V of MARPOL 73/78 on prevention of pollution by garbage from ships (ratified in all EU-27 countries) and the Convention on the Prevention of Marine Pollution by Dumping of Wastes (ratified by most EU member states). There is also the International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (ratified by several EU member states but not yet put into effect).

Priority hazardous substances in surface waters are scheduled to be completely eliminated by 2028 in accordance with Directive 2008/105/EC.

On the international level, relevant multilateral environmental agreements are: Convention on Long-range Transboundary Air Pollution (UNECE, 1979) (and its protocols on heavy metals and persistent organic pollutants), Stockholm Convention on Persistent Organic Pollutants, Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Convention on the Transboundary Effects of Industrial Accidents, whose signatories are most of the EU countries. Several EU member states are also signatories to the International Convention on the Control of Harmful Anti-fouling Systems on Ships.

Directive 2008/105/EC also introduced environmental quality standards for all the 33 priority substances and eight other pollutants already regulated by the existing EU laws (referred to in Directive 76/464/

EEC (EU, 1976b) and Annex IX of the Water Framework Directive). Thirteen of the 33 priority substances are classified as dangerous (metals, organic pollutants, pesticides, etc.). The Directive requires the Commission to propose controls for termination or elimination of emissions, discharges and losses of these substances, and anticipates a term of 20 years to achieve cessation of contamination. As a result, 13 dangerous priority hazardous substances must be completely eliminated by 2028 at the latest.

The legal basis for hazardous waste management in Croatia for the period of 2007-2017 is the Waste Management Plan of the Republic of Croatia (OG 85/07), which relies on the Waste Management Strategy of the Republic of Croatia (OG 130/05), Sustainable Waste Management Law (OG 94/13), the existing legislation and EU directives. Special systems for different categories of waste, such as batteries and accumulators, dilapidated vehicles, waste oil and some types of non-hazardous waste have been established in Croatia. Hazardous waste for the treatment and rehabilitation of which Croatia has technological possibilities is exploited, while the waste that cannot be processed is exported to countries having appropriate technologies for this purpose. Further, technological and technical capacities for the collection, storage and processing of waste are continuously improved and developed in accordance with the possibilities and market trends.

All decisions concerning the export and transportation of hazardous waste, as well as its supervision are based on the regulations complying with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.

## 2. Methodology, materials and methods

This study was conducted in the Republic of Croatia, located in Eastern Europe, as shown in Figure 1. The country is divided into 21 counties. Croatia's population was 4,284,889 in 2011. The total area of the country is 56,594 km<sup>2</sup>, with a population density of 75.8/km<sup>2</sup> in 2011.



Source: <http://hr.wikipedia.org/wiki/Hrvatska>.

**Fig. 1. Location of Croatia**

Qualitative and quantitative studies were carried out for hazardous and special waste streams based on their origin (industrial, commercial, municipal, import, and export) and on the activities (collection, transportation, storage, treatment, reuse, and disposal). Further, quantitative research included a survey of hazardous waste generation, a survey of hazardous waste treatment facilities and capacities, and finally a survey of suspected, polluted and/or contaminated sites. Results of the project "Development of Hazardous Waste Management System, Including the Identification and Management of 'Hot Spot Sites' in Croatia were" used.

A questionnaire method was used and collected data were calculated as the mean and percentage. Qualitative research was also done and data were descriptively analyzed. Data on waste collection, treatment or landfilling had to be filled in the questionnaires sent to entrepreneurs – hazardous waste producing companies licensed for the collection and disposal of hazardous waste and to the counties in charge of hazardous waste management monitoring. Based on the collected data and information, qualitative and quantitative analyses of hazardous and special waste streams as per geographical distribution and activities (NACE codes) were conducted. The analyzed sample included 137 companies spatially representing 17 counties (out of 21).

Statistical analysis was planned so as to include the analysis of the nonlinear relationship of the response variable (waste stored,  $Y$ ) with the processes and materials used as predictor variables ( $X$ , waste produced) based on the nonlinear relationship:

$$Y = g(X; \theta) + \varepsilon, \quad (1)$$

where  $Y \in R$  is the response variable,  $X \in R_k$  is the predictor variable,  $k \in N$ ,  $\theta \in R_p$  is the unknown regression parameter,  $p \in N$ , and  $\varepsilon$  is a random error. In line with the results of many experiments, predictor  $X$  is costly or impossible to measure, and it was therefore planned to apply a proxy  $Z$  of  $X$ , which is measured, instead.

For this analysis, it would be necessary to observe the severity of raw materials,  $Y$ , among the 600 entities in the relation of certain characteristics,  $X$ , nature (solid, liquid or gas), quantity ( $t/year$ ), hazardous or non-hazardous. The actual exposure of the entities to raw materials  $X$ , however, may vary randomly from the  $Z$  values measured via questionnaires. In that case,  $X$  can be expressed as  $Z$  plus a random error.

The questionnaire for hazardous waste generation was to be applied to companies, potential hazardous waste generators, which do not report according to legal requirements.

Most of the counties have similar information regarding hazardous waste issues:

List of companies and individuals who have presented plans for interventions (schools, hospitals, factories, auto workshops, auto mechanics, print shops, municipal companies, banks, homes for the elderly, INA oil industry, etc.).

Waste management plans submitted by waste producers that annually produce more than 150 tons of non-hazardous waste and/or more than 200 kg of hazardous waste.

Data from the Environmental Pollution Registry on the types and quantities of produced, collected, processed and exported hazardous waste.

Processing and waste handling are key issues that arise at the time of hazardous waste generation up to its safe long-term storage. Ideally, waste can be stabilized, detoxified or disabled by an appropriate treatment.

Hazardous waste is transported in trucks, railway wagons, tugboats and boats. Truck transportation is most common. At the same time, small truck transportation is most dangerous. Carriers of hazardous waste should be given special training and special

equipment such as gloves, masks and coveralls. Such trucks have special registration plates, designated markings, are equipped for safe transportation of hazardous waste and should not be used to transport other products.

### 3. Results and discussion

Data analyses of general descriptions of companies, services and production according to the nature of operation showed a high percentage of engagement in collection of hazardous as well as non-hazardous waste. Less than 50% of all companies carry out the treatment, recovery and disposal of non-HW and HW.

Half of the companies that responded provided NACE codes for activities other than HW management. The majority of companies deal with both hazardous and non-hazardous waste. Some of them, whose main activity is related to oil and oil derivatives, reported no activities related to non-hazardous waste. The companies that perform different operations with hazardous and non-hazardous waste usually carry out more activities related to non-hazardous waste. Figure 2 presents the nature of operation according to non-hazardous waste vs. hazardous waste.

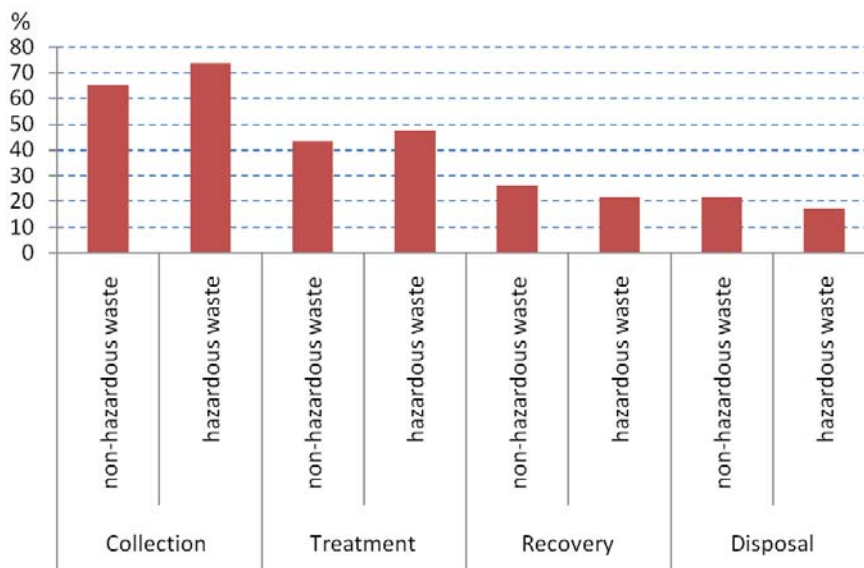


Fig. 2. Nature of operation

The results include estimates of hazardous waste streams and trends in Croatia and the ways of its treatment and disposal. Estimates indicate that significant amounts (up to 30%) of hazardous waste streams are not reported. The analysis shows that 95% of collected waste is treated and recovered, while 3% is exported. Submitted information on the procedures indicates that most of the waste is treated in accordance with the procedures involving incineration of waste on land, followed by the procedures involving recycling and reclamation of metals and metal compounds, procedures involving recycling

and reclamation of organic substances not used as solvents as well as procedures related to regeneration of acids or alkalis.

According to available data, generated hazardous waste is collected by specialized companies. In addition to the information provided, it should be noted that some companies thought that contracting a specialized company and reporting to the State Bureau of Statistics would suffice. These companies were not aware of the reporting obligations they had in relation to the Registry.

The amount of produced hazardous waste is much bigger than that of non-hazardous waste. Companies engaged in different operations with hazardous and non-hazardous waste usually perform more activities related to non-hazardous waste. Some types of waste

are collected solely on demand (asbestos), and most companies schedule collection of waste oils from services and industry. Companies mostly collect on demand from industries. Scheduled collection also refers to industry, but with lower significance (Figure 3).

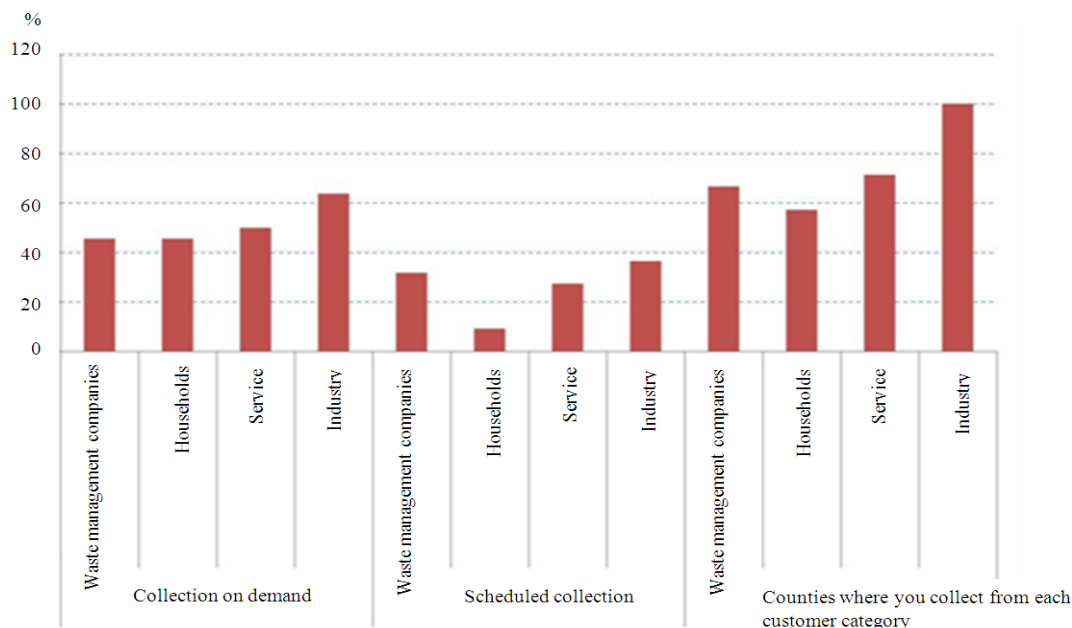


Fig. 3. Collection

Approximately 30% of companies apply validation through sampling, but 15% of companies with own laboratories and 10% with a reception area for validation and sampling ensure better performance. (Figure 4).

More than 45% of companies use chemical-physical treatment of organic hazardous waste and more than 40% pay for hazardous waste disposal. More than 30% of companies did well regarding the chemical-physical treatment of inorganic hazardous waste and even more than 20% charge an entry fee when picking up hazardous waste. Some companies highlight the fact that entrance fee is charged for all types of waste, except for special waste regulated by the Ordinance on Waste. Those who pay for hazardous

waste have exposed the following types of waste: lead-acid batteries, waste oil, waste vehicles and other fuels. Waste lubricating oil is mentioned as the component recovered for reuse. About 20% of companies reported to the Croatian Environmental Agency components recovered for reuse and 14% reported material recovered for recycling.

Thirteen percent of companies used cement kilns for incinerating hazardous waste and none of them used landfills. Packages containing residues of hazardous substances or contaminated with hazardous substances, absorbents, filter materials, solid wastes containing dangerous substances and calcium hydroxide were deposited in storages of disposal capacity from 1500tpa up to 40000tpa.

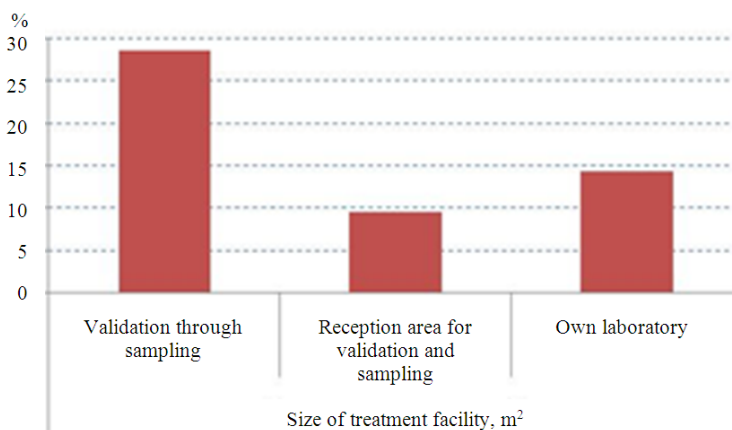


Fig. 4. Types of treatment

More than 90% of companies offered training courses in environmental management for employees. There was a person responsible for environmental protection in more than 80% of companies. From 50 to 80% of companies have an envi-

ronmental protection department, a quality manual, an environmental protection manual, and measure and report emissions to the environment and experienced an environmental audit (see Figure 5).

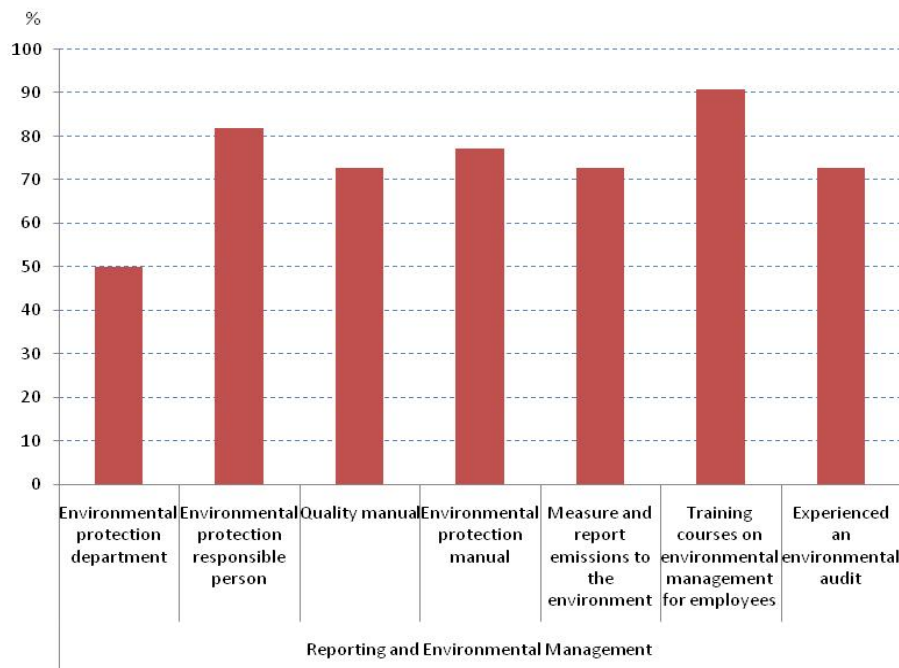


Fig. 5. Reporting and environmental management

In general, hazardous waste producers temporarily stored their waste in a designated space, within appropriate containers, until they delivered it to authorized hazardous waste collectors.

Manufacturing companies are faced with economic difficulties leading to discontinuation of production and outsourcing of some activities. The majority of contacted companies do not have a person responsible for environmental protection and there is a general lack of awareness of hazardous waste generation and reporting obligations. Further, companies often do not perform all activities according to the registration. There are significant differences among licensed companies in size, capacity and efficiency (in terms of tons of waste per worker). Small and medium sized companies depend heavily on remuneration provided by the Eco Fund. The main activity of big companies with a license is not related to waste; they treat waste they generate and their consumers' waste. There is limited specialization and only a few companies cover the whole of Croatia. These usually have established environmental procedures and provide training. There is some overlapping in reporting obligations (to the Croatian Environmental Agency and the Ministry of Environmental and Nature Protection, Ministry of Economy, Ministry of Labour and Pension System and Ministry of Entrepreneurship and Crafts).

County-level administrative departments have no data on suspected, polluted, contaminated and remediated land (soil and groundwater) impacted by past or ongoing pollution through industrial/agricultural activities and disposal activities, post-crisis events or accidents. They only keep records of the municipal waste disposal sites. Hence, in order to fill the questionnaire, they have to pay to the Regional Office for Cadaster (SGA) for concrete information. According to the existing regulations, counties are not required to keep records of sites contaminated with hazardous waste, since hazardous waste is under state jurisdiction.

### 5. Hazardous waste management in Croatia vs. hazardous waste management in the EU

Hazardous waste management implies implementation of the prescribed measures for waste collection, transportation, storage, treatment and disposal; it also includes supervision of all activities and taking care of all amenities, including facilities after the completion of management. Hazardous waste disposal is done taking into account the geological, hydrological, topographical and climatic conditions and the distance from settlements.

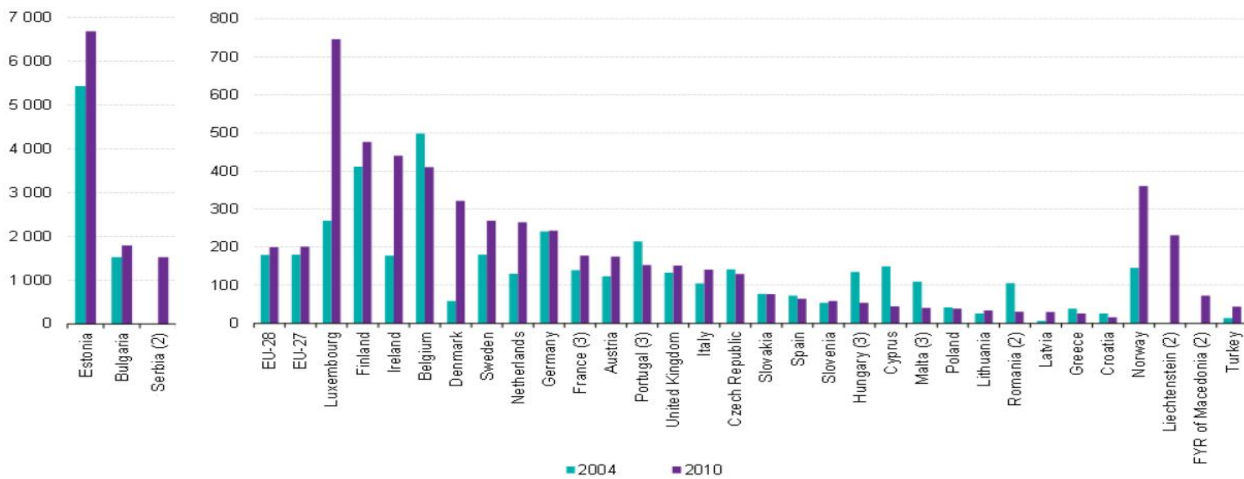
The EU-27 member states, along with Croatia, Norway and Turkey, generated a total of ca 2.6 billion tons of waste in 2008, or roughly 5.4 tons per

person, about 3.7% of which was hazardous (Eurostat Waste Data Centre, 2011; data reported according to the Waste Statistics Regulation).

Hazardous waste is disposed of in landfills for hazardous waste where it is incinerated and physically or chemically processed. As regards treatment, a significant proportion of hazardous waste is recycled or burned as fuel. As regards total waste, disposal still dominated (50%) over recycling (45%) in 2008 in the EU-27, Croatia, the Former Yugoslav Republic of Macedonia, Norway

and Turkey together, whereas 5% was sent to incineration. International Standard Industrial Classification of all Economic Activities enables connecting waste generation and economic activities, which makes it easier to create indicators for measuring the quantity of hazardous waste.

Figure 6 represents the amount of hazardous waste generated in the EU-27 per member state, expressed in kg per inhabitant and year. Hazardous waste covers all economic sectors and households, including waste from waste treatment (secondary waste).



Source: Eurostat (Last update: 06-12-2013).

Notes: (1) Two parts of the figure have different scales for y-axes. (2) 2004 not available. (3) 2004 estimate.

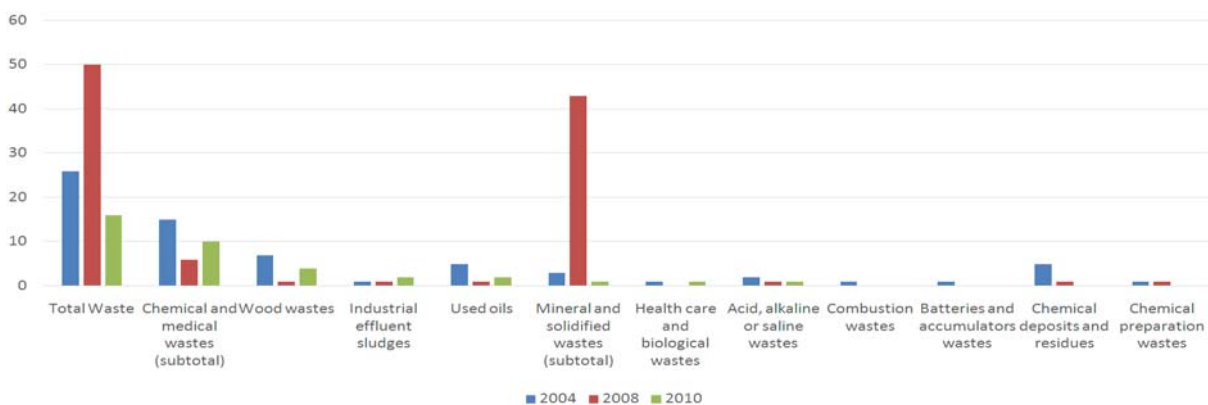
**Fig. 6. Hazardous waste generation by economic activity (kg per capita)**

Figure 6 shows the amount of all types of hazardous waste generated per capita in 2004 and 2010. Large amounts for Estonia (6.7 tons per capita) are due to oil shale while for Bulgaria (1.8 tons per capita) they are a result of copper ore extraction. Large amounts for Serbia (1.6 tons per capita) are also related to mining and quarrying. Apart from these special cases, the generation of hazardous waste in the EU member states and countries that are not members, given in Figure 6, show the 2010 trends, which vary from small amounts of hazardous waste, like 16 kg per capita in Croatia and 26 kg per capita in Greece, to

large amounts, such as 477 kg per capita in Finland and 747 kg per capita in Luxembourg.

Taking into account the possibility of transboundary pollution, it is clear that a global response is necessary in the fight against possible disasters, caused by inappropriate treatment of hazardous waste.

The increasing scale of environmental pollution has created new governance challenges. According to the Eurostat data, the production of hazardous waste in Croatia was significantly lower in 2010 than in 2004 (Figure 7).



Source: Eurostat (Last update: 06-12-2013).

**Fig. 7. Generation of hazardous waste in Croatia (unit kilograms per capita)**

Hazardous waste landfills are sometimes placed on locations that are practical but not adequate, which then leads to potential threats to groundwater, to leakage of toxic substances into rivers and lakes, or to the risk of skin contact if, for example, children play in the area.

Hazardous waste management often requires a risk assessment in case of a disaster due to improper handling. Further, it is necessary to predict all the possible answers if a risk event should occur. This is a potential danger not only for people but also for other living creatures and the whole ecosystem. Identification of species that the risk event may jeopardize and the ways in which this could happen is by far more complex than the risk assessment for human health only.

Hazardous waste can be characterized on the basis of the risk it poses as high-risk waste, intermediate risk waste or low risk waste.

Accidents with hazardous waste must be immediately reported to the state regulatory agencies and local institutions responsible for security. Prompt accident reports, among other things, contain information on the quantity of released hazardous substances and detailed information about the type of threats. Hazardous waste poses a serious risk to the ecosystem and to human health if it is not treated securely and in accordance with regulations.

**5.1. Ecological aspects of hazardous waste management in Croatia.** Pursuant to Article 41 of the Waste Act, it is necessary to procure a permit issued by the Ministry of Environmental and Nature Protection for implementation of activities related to the disposal and/or recovery of hazardous waste. These activities include collection and storage of hazardous waste. Handling of hazardous waste in Croatia is based on the obtained licenses and can be implemented in the following ways: incineration, incorporation of brick products, regeneration of solvents and acid neutralization, solidification and stabilization, sterilization and disinfection, electrolysis and dilution. Permits for handling particular categories of waste, which are subject to special rules, are issued according to the defined criteria. In the area of hazardous waste management, the Croatian Environment Agency (CEA) is responsible for providing reliable information and data on waste. In this area, the agency's activities are:

- ◆ to collect and compare data on hazardous waste in accordance with the Waste Act and its by-laws;
- ◆ to maintain the management information system;
- ◆ to prepare and develop indicators of hazardous waste;

- ◆ to prepare reports on hazardous waste management;
- ◆ to participate in the preparation and implementation of projects in the field of hazardous waste;
- ◆ to improve the quality, quantity, availability and comparability of hazardous waste data.

In order to establish a system of hazardous waste management in small and medium-size enterprises, one should start from technical and technological capacities for the collection, storage and treatment of hazardous wastes, developed in accordance with the supply and demand of the market. Individual economic entities have been granted permits for the collection, transport and temporary storage of hazardous waste. In addition, there are several smaller specialized facilities in Croatia that were built for the recovery and treatment of hazardous waste. In certain industrial facilities, it is possible to recover and treat certain types of hazardous waste.

Environmental Health Department of the Croatian National Institute of Public Health promotes activities related to the management of medical waste and informs the public about the health and environmental protection aspects of hazardous waste.

The decision-making process and regulatory framework for monitoring export and transportation of hazardous waste in Croatia is fully compliant with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Croatia has established special systems for the collection of special categories of waste such as batteries and accumulators, end-of-life-vehicles, waste oil and some categories of non-hazardous waste.

Import of hazardous waste is prohibited. Transportation of hazardous waste in the Croatian territory may be carried out by a person registered to perform such activities, provided that person has a decision prescribed by the Waste Act (OG No. 178/04, 111/06, 60/08 and 87/09).

Given that there are no landfills designated for hazardous waste in Croatia and the possibilities of energy recovery or incineration are limited, most of Croatian hazardous waste destined for disposal is exported to other countries.

**5.2. Technological aspects of hazardous waste disposal.** On the technical level, engineers as well as businesses and regulatory institutions have discarded many ideas of hazardous waste treatment as being unverified and unreliable. Scientists and engineers in the field of entrepreneurship have modified their knowledge of chemical production processes within the framework of geology and hydrogeology, thus improving the necessary equipment



and techniques for recovery and improvement of hazardous waste disposal.

Many technologies tested in pilot projects were proven to be efficient on a large scale and industry encourages such technological research with the aim to achieve a common technological foundation.

Technological progress has provided new possibilities of solving the problem of environmental pollution from the technological, financial and timing aspects. Owing to the application of new technologies, laws and regulations, the process of hazardous waste management has been significantly changed in the last 20 years. The most important technologies for hazardous waste management include: pollution prevention, recycling and reuse, waste minimization, chemical treatment and detoxification, destruction, stabilization and land disposal. The least attractive among them is the possibility of land disposal from the viewpoint of the responsibility for long-term exposure to hazards and impact on the environment.

### Conclusions

Inadequate hazardous waste management in Croatia may be linked to waste disposal with inadequate health care, with the lack of recycling where possible, with avoidance of waste recovery and with the lack of supervision of hazardous waste transfer.

The lack of awareness and capacities to report have been identified as relevant challenges. These can be tackled by targeted awareness raising campaigns for hazardous waste and reporting obligations. It is recommended that these activities be targeted at companies that produce similar types of hazardous waste, e.g. those engaged in water transport. Further training is also needed for the hazardous waste management system while the roles of different stakeholders and institutions (counties, Eco Fund, statistics) need elaboration.

Research results indicate three different factors underlying the functioning of hazardous waste management: effective prevention of hazardous waste production, recycling and incineration. All three factors are important for directing future activities according to the European guidelines for the period of 2014-2020.

Reporting procedures among the counties and the central level should be strengthened.

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Given the large number of municipalities and cities in Croatia, the establishment of an integrated system of hazardous waste disposal sites and hotspots is considered almost indispensable on the county level. A formal record, which should be kept on the county level, would summarize all the data collected from municipalities/cities. This would enable the counties to manage their polluted sites and hotspots. Furthermore, it would provide a basis for monitoring, inspection and identification of the needs for collection, storage and treatment of hazardous waste within each county. Keeping records on the municipality/city level is simply too demanding for annual comparisons of hazardous waste amounts and the status of identified hotspots and dump sites.

Regulations should be changed in such a way that newly identified suspected sites have to be reported to the Croatian Environment Agency.

Research devoted to the development of the hazardous waste management system in Croatia resulted in a clear picture of hazardous waste generation at the national level.

Generation of hazardous waste should be reduced and if this is not possible, hazardous waste should be managed so that it is sorted and separated, i.e. treated at the place of generation and transported safely to the place of final treatment and/or landfill. The methods by which hazardous waste will be treated must be the least hazardous to human health and environment, and the public should be informed about the risks to public health and environment in cases when hazardous waste is being improperly treated, stored, transported, disposed of, or otherwise poorly managed. In treating hazardous waste, possibilities provided by new technologies should be used as well as the ICT solutions wherever convenient.

The hazardous waste management plan should be continuously improved. Data analysis done in this research provides a base for a potential increase of the ability of relevant central and local authorities to carry out annual inventories of waste generation as well as to improve the data collection system and develop or upgrade certain segments of the Waste Management Information System. In this way, reporting obligations can be easily fulfilled on a national, international or EU level.

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