GREENLand

Funded by the European Union

DELIVERABLE D1.1

REPORT OF SCIENTIFIC ROADMAP

Project acronym:	GREENLand
Project full title:	TWINNING MICROPLASTIC - FREE ENVIRONMENT
Grant №:	101079267
Type of action:	HORIZON - CSA
Project start date:	01.01.2023.
Project end date:	31.12.2023.
Cordis link:	https://cordis.europa.eu/project/id/101079267

Abstract of deliverable:	The goal of the scientific roadmap is to stimulate the transformation of social and economic systems through accumulated scientific and technological knowledge. This will initiate the development of a national microplastics strategy based on scientific excellence, policy and industry willingness for an eco-friendly lifestyle that will address the issue of growing volume of microplastics in the environment. In the first part of the scientific roadmap (Prevention), an overview of EU and Serbian policies and regulations regarding plastics and microplastics will be presented. In the following, the results of international cooperation between Serbian scientists and researchers from other countries will be shown (review of international projects on microplastics with the participation of Serbian researchers). The Detection of microplastics, the second part of the scientific roadmap, will be based on a review of published results and papers in the field of microplastics by Serbian researchers. The last chapter will be devoted to Purification. Measures to reduce plastic waste will be proposed, as well as new ideas on improving sustainable solutions to reduce microplastic pollution in Serbia.

Deliverable information	
Title:	REPORT OF SCIENTIFIC ROADMAP
Deliverable number:	D1.1
WP number:	1
Lead beneficiary:	Educons University (short name: EDU)
Contributing partners:	Educons University
Authors:	Nataša Stojić, Mira Pucarević, Ljiljana Ćurčić, Dunja Prokić, Biljana Panin, Dragana Vidojević, Sebastian Primpke, Mark Healy, Liam Morrison
Type:	R – document, report
Dissemination level:	PUB - Public
Delivery date:	31.12.2023.
Version:	V1.0

CONTENTS

STRATEGIC OPTIONS FOR REDUCING MICROPLASTICS IN SERBIA

The issue of microplastics (MPs) in Serbia is a complex one and requires a multi-faceted approach. Within the scientific roadmap for solving this issue, the main emphasis is on the development of the PDP (prevention, detection and purification) framework for the national management of microplastics (environmental legislation and its implementation). The goal of the scientific roadmap is to stimulate the transformation of social and economic systems through accumulated scientific and technological knowledge. This will initiate the development of a national microplastics strategy based on scientific excellence, policy and industry willingness for an eco-friendly lifestyle that will address the issue of growing volume of microplastics in the environment.

In the first part of the scientific roadmap (**P**revention), an overview of EU and Serbian policies and regulations regarding plastics and microplastics will be presented. In the following, the results of international cooperation between Serbian scientists and researchers from other countries will be shown (review of international projects on microplastics with the participation of Serbian researchers).

The **D**etection of microplastics, the second part of the scientific roadmap, will be based on a review of published results and papers in the field of microplastics by Serbian researchers.

The last chapter will be devoted to **P**urification. Measures to reduce plastic waste will be proposed, as well as new ideas on improving sustainable solutions to reduce microplastic pollution in Serbia.

1. PREVENTION

Regulations which aim to ban, restrict, or introduce levies on certain types of plastic products have either been adopted or are under development (Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment; Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions EU policy framework on biobased, biodegradable and compostable plastics…). It is necessary to optimize the balance of several facets of plastics production, use and waste management in order to alleviate the growing plastics waste environmental issue [46]. The technological solutions and strategies adopted by policymakers and governments to reduce the generation of plastic wastes will ultimately reduce emissions of microplastics [33]. Decision-makers need consistent metrics and definitions to guide and prioritize actions at several levels, from sustainable product design and efficient regional infrastructure to suitable policies and enforcement [46]. Therefore, efficient metrics regulating plastic pollution must be identified to guide sound eco-design and waste management policies. An important issue is the assessment of sustainable polymers and their persistence in the environment [33].

Due to excellent functional properties of plastic materials (durability, malleability, lightweight and low cost), plastic use will likely increase, particularly in lower-income countries, as their economies grow. This makes the control and mitigation of plastic pollution more critical than ever. In the EU, addressing plastic pollution is a top political priority, and the following EU legislation and policies refer directly or indirectly to reducing microplastics in the environment.

The Commission is committed to fighting microplastics pollution, as stated in the European Green Deal [10] and the new Circular Economy Action Plan [3]. Within the Zero Pollution Action Plan [31], the Commission set the target of reducing microplastics pollution by 30% by 2030. The EU Commission is working to reduce microplastics pollution from different sources: plastic waste and litter, accidental and unintentional releases (e.g. plastic pellet loss, tyres degradation or release from clothing), as well as intentional uses in products. The EU Commission takes another major step to protect the environment by adopting measures that restrict microplastics intentionally added to products under the EU chemical legislation

REACH [15]. The new rules will prevent the release of about half a million tonnes of microplastics to the environment [53]. They will prohibit the sale of microplastics, as well as of products to which microplastics have been added on purpose.

The following subsections examine EU legislation governing the discharge of microplastics in waste, water, air and food.

EU LEGAL REGULATIONS ON WASTE

The analysis of the EU waste legislation has shown that there is currently no single law in the EU that covers microplastics in a comprehensive manner. There are also no economic incentives for businesses to take measures to reduce the presence of microplastics in the environment.

The situation is similar in the Republic of Serbia. Based on the analysis of the waste legislation in the Republic of Serbia, it was concluded that Serbia did not have specific laws that directly addressed the issue of microplastics. However, there are several laws and regulations that indirectly address the problem.

Some microplastics are formed when larger plastics break down. These unintentionally formed microplastics fall outside of the scope of the new initiative, and are addressed by:

- *Plastics strategy* [13]*;*
- *Waste framework directive (WFD)* [23]*;*
- *Marine Strategy Framework Directive (MSFD)* [28]*;*

According to EU Plastic Strategy [13], around 25.8 million tons of plastic waste are generated in Europe every year. Less than 30% of such waste is collected for recycling. Landfilling and incineration rates of plastic waste remain as high as 31% and 39% respectively. While landfill has decreased over the past decade, incineration has grown. In the EU, the potential for recycling plastic waste remains largely unexploited. Reusing and recycling of end-of-life plastics is very low, particularly in comparison with other materials such as paper, glass or metals. It was estimated that plastics production and the incineration of plastic waste give

global rise of approximately 400 million tonnes of CO_2 a year. In total, it is estimated that between 75.000 and 300.000 tonnes of microplastics are released into the environment each year in the EU. While a large amount of microplastics result from the fragmentation of larger pieces of plastic waste, significant quantities also enter the environment directly, making it more challenging to track and prevent them. Finally, some alternative materials claiming biodegradability properties, such as 'oxo-degradable plastics', have been found to offer no proven environmental advantage over conventional plastics, while their rapid fragmentation into microplastics cause concerns. Therefore, the Commission has taken action with the intention of restricting the usage of oxo-plastics in the EU.

Part of the reason for the extensive degree of microplastic pollution that now exists is the chronic overproduction of virgin plastics and the unsustainable design of plastic products. Fundamentally, we need to phase down material and resource usage to sustainable levels worldwide and choose carefully which applications we use plastics for. Improving the design and composition of plastic products across sectors is a concrete and obvious way forward [36].

Most of the microplastics found in the environment are the result of the degradation of larger plastic products when exposed to solar irradiation, abrasion or erosion. The main sources of secondary microplastics identified to date include road transport, synthetic textiles, agriculture, plastic manufacturing, tourism, fishing and aquaculture and shipping, building and construction [36].

The WFD [23], amending Directive 2008/98/EC on waste, lays down basic waste management principles. It requires waste to be managed without endangering human health or harming the environment, and in particular without risk to water, air, soil, plants or animals, and without causing a nuisance through noise or odours. According to the EU waste hierarchy, waste prevention measures, followed by reuse, are the top priority when it comes to waste management and policy. Waste prevention is the most efficient way to improve resource efficiency and to reduce the environmental impact of waste. The WFD prescribes measures for preventing and reducing the generation of waste, in order to break the link between economic growth and the environmental impact associated with the generation of waste, and to make transition towards circular economy. The WFD obliges member states to reduce the generation of waste, in particular waste that is not suitable for reusing and recycling.

According to Reducing Marine Litter: action on single-use plastics and fishing gear [55] , the European Chemicals Agency is preparing restriction dossiers for microplastic particles intentionally added to preparations, such as cosmetics, and the use of oxo-degradable plastics. Besides, the problem of microplastics for marine litter, the Plastic Strategy identifies single-use plastics as a specific problem for the marine environment. The identification of the origin, pathway and type of marine debris can be difficult, as litter degrades and fragments over time. Some plastics enter the marine environment as 'macro plastics' and then degrade slowly into smaller fragments. Others enter directly in the form of microplastics, which are plastic particles with a diameter less than 5mm. Some of these microplastics are intentionally added to products (e.g. scrubbing agents in cosmetics, detergents, paints) or to serve as input for further processing (e.g. plastic resin pellets). Others originate from the abrasion of large plastic objects during manufacturing or use (e.g. tyre dust, textile fibres).

In order to support the EU's transition to the circular economy, *Council Directive 1999/31/EC* [16] on the landfill waste also introduces restrictions on landfilling of all waste that is suitable for recycling or other material or energy recovery from 2030; limits the share of landfilled municipal waste to 10% by 2035; introduces rules on calculating the attainment of municipal waste targets and requires EU countries to put in place an effective quality control and traceability system for the landfilled municipal waste; requires the European Commission, with the European Environment Agency, to draw up early warning reports 3 years before each deadline in order to identify shortcomings in attaining the targets and to recommend action to be taken; allows EU countries to use economic instruments and other measures to encourage applying the waste hierarchy.

Directive 94/62/EC on packaging and packaging waste [32] prescribes that at least 65% of all packaging waste must be recycled by 31 December 2025. The recycling target for plastic is 50%. By 31 December 2030, at least 70% of all packaging waste must be recycled. This includes 55% of plastic. The revised Packaging Directive introduced more ambitious overall recycling targets for packaging (65 % in 2025 and 70 % in 2030), and higher material-specific targets (such as 55% in 2030 for plastic).

European Parliament and Council Directive (EU) 2015/720 [20] amending Directive 94/62/EC as regards reducing the consumption of lightweight plastic carrier bags prescribes

that Member States shall take measures to achieve a sustained reduction in the consumption of lightweight plastic carrier bags on their territory. Those measures may include the use of national reduction targets, maintaining or introducing economic instruments.

The European Green Deal [10] stipulates that the Commission will develop requirements to ensure that all packaging in the EU market is reusable or recyclable in an economically viable manner by 2030, will develop a regulatory framework for biodegradable and bio-based plastics, and will implement measures on single-use plastics.

The Zero Pollution Action Plan [31] aims at reducing plastic litter at sea by 50%, and microplastics released into the environment by 30% by 2030.

According to the *EU Strategy for Sustainable and Circular Textiles* [12], the Commission plans to address different lifecycle stages at which synthetic fibres are shed into the environment by a set of prevention and reduction measures. In addition to product design, measures will target manufacturing processes, pre-washing at industrial manufacturing plants, labelling and the promotion of innovative materials. Further options include washing machine filters, which can cut the volume released from laundering by up to 80%, development of mild detergents, caretaking and washing guidelines, end-of-life textile waste treatment, and regulations for improved wastewater and sewage sludge treatment.

THE EU LEGISLATION REGARDING MICROPLASTICS IN WATER

Proposal for a Directive amending the Water Framework Directive, the Groundwater Directive and the Environmental Quality Standards Directive - The Water Framework Directive (WFD) , jointly with the Environmental Quality Standards (EQSD) and Groundwater (GWD) Directives, provides the framework for the sustainable management of Europe’s surface water and groundwater bodies. It identifies microplastics as a persisting pollutant and requires member states to include microplastics in the surface and groundwater watch lists and to monitor as soon as the Commission establishes appropriate monitoring methods (an agreed EU measuring and monitoring method for microplastics should be in place by 2025).

The Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC) [28] - This directive aims at achieving good environmental status of the marine environment by 2020. The MSFD represents the first instance, worldwide, where MPs in the marine environment have been included in a legislative proposal. The directive calls for all of the EU's marine regions and sub-regions to achieve or maintain "Good Environmental Status" (GES) by 2020. GES is defined by means of 11 qualitative "descriptors." The relevant criteria and indicators applicable to those descriptors are defined in the Commission Decision 2010/477/EU. Microplastics are considered specifically in descriptor 10 of the MSFD [10.1.3: "Trends in the amount, distribution, and where possible, composition of micro-particles (in particular micro-plastics)"]. The descriptor establishes baseline quantities, properties, and potential impacts of MPs.

The Restriction of Hazardous Substances (RoHS) Directive (Directive 2011/65/EU) [29] - This directive restricts the use of certain hazardous substances in electrical and electronic equipment (EEE) in order to protect human health and the environment. It includes restrictions on the use of certain types of plastics, including those containing microplastics.

The Single-Use Plastics (SUP) Directive (Directive (EU) 2019/904) [25] - This directive aims at reducing the impact of certain single-use plastic products on the environment. Microplastics do not fall directly within this directive's scope, yet all EU producers are encouraged to strictly limit microplastics in their formulations. The restrictions on entering the market introduced in this directive also cover products made from oxo-degradable plastic (plastic materials that include additives which, through oxidation, lead to the fragmentation of the plastic material into micro-fragments or to chemical decomposition), which does not biodegrade correctly (thereby contributing to microplastic pollution), is not compostable, negatively affects the recycling of conventional plastic, and fails to deliver a proven environmental benefit.

EU Action Plan: "Towards Zero Pollution for Air, Water and Soil" [31] is a key deliverable of the European Green Deal. The main objective of this action plan is to provide a compass for including pollution prevention in all relevant EU policies, maximising synergies in an effective and proportionate way, stepping up implementation and identifying possible

gaps or trade-offs. To steer the EU towards the 2050 vision of a Healthy Planet for All, this action plan sets key 2030 targets to speed up pollution reduction.

The Chemicals Regulation REACH (Regulation (EC) No 1907/2006) [15] - This regulation requires companies to register, evaluate and authorize the use of chemicals in the EU. It includes provisions for the registration and evaluation of nano-form substances, which can include microplastics. A subsequent amendment to REACH was implemented in 2019, which restrict the use of intentionally added microplastic particles to commercially or professionally used products of any kind. The proposed restriction comprises three types of measures: a (1) restriction on microplastics entering the market on their own or in mixtures where their usage will inevitably result in their release to the environment, irrespective of the conditions of usage (2) labeling requirement to minimise releases to the environment for uses of microplastics where they are not inevitably released to the environment but where residual releases could occur if they are not used or disposed of appropriately, and (3) reporting requirement to improve the quality of information available to assess the potential risks in the future.

The Drinking Water Directive (Directive 98/83/EC) [17] - This directive sets out quality standards for drinking water in the EU. It includes provisions for the monitoring and control of substances, including microplastics, that may pose a risk to human health.

The Cosmetics Regulation [56] is an EU legislation that regulates the safety of cosmetic products sold in the EU. It includes provisions to restrict the use of certain ingredients in cosmetic products, including microplastics.

The Environmental Quality Standards Directive [26] sets out EU-wide minimum standards for certain pollutants in surface waters, including microplastics.

EU Action Plan for Circular Economy [3] - This action plan was adopted in 2015 and aims at creating a more sustainable and circular economy in the EU. It includes measures to reduce the amount of plastic waste generated, including microplastics, and to promote the use of sustainable alternatives to single-use plastics.

EU Plastics Strategy [13] - This strategy was adopted in 2018 and aims at tackling the issue of plastic waste in the EU. It includes measures to prevent and reduce plastic pollution,

including microplastics, and to promote the use of sustainable alternatives to single-use plastics.

EU Biodiversity Strategy for 2030 [4]- This strategy was adopted in 2020 and aims at halting the loss of biodiversity and ecosystem services in the EU by 2030. It includes measures to reduce the impact of plastic pollution, including microplastics, on marine ecosystems.

EU Chemicals Strategy for Sustainability [5] - This strategy was adopted in 2020 and aims at ensuring the production and usage of chemicals in a way that protects human health and the environment. It includes measures to reduce the release of hazardous chemicals, including microplastics, into the environment.

EU Farm to Fork Strategy [6] - This strategy was adopted in 2020 and aims at creating a more sustainable food system in the EU. It includes measures to reduce the environmental impact of agriculture, including reducing the use of plastics in agriculture and preventing the release of microplastics from agricultural activities.

EU Strategy on Offshore Renewable Energy [7] - This strategy was adopted in 2020 and aims at increasing the share of renewable energy from offshore sources in the EU. It includes measures to ensure that offshore renewable energy projects are developed in a way that minimizes their impact on the marine environment, including the release of microplastics.

EU Blue Economy Strategy [8] - This strategy aims at promoting sustainable growth in the marine and maritime sectors. It includes measures to prevent and reduce marine litter, including microplastics, and to promote the sustainable use of marine resources.

EU policy framework on biobased, biodegradable and compostable plastics [9] - The aim of this policy framework for biobased, biodegradable and compostable plastics is to provide better understanding of the challenges and benefits that stem from their usage. It also sets out the conditions to ensure that the overall environmental impact of their production and consumption is positive. It aims at filling policy gaps, guiding future EU policy or legislation on such matters, and providing orientation for the market with-a-view to avoiding any unsustainable developments. A common understanding across the EU on the use of these plastic materials will also facilitate a anonymous market and prevent the differences of fragmenting the market at national level. This means also ensuring that the usage of biobased,

biodegradable and compostable plastics does not have negative impacts on biodiversity, ecosystems or land and water consumption.

The European Green Deal [10] - The European Green Deal aims at transforming the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource usage. A zero pollution ambition for a toxic-free environment of the European Green Deal includes the EU's need to better monitor, report, prevent and remedy pollution from air, water, soil, and consumer products. The commission emphasises the need to restore the natural functions of ground and surface water. This is essential to preserve and restore biodiversity in lakes, rivers, wetlands and estuaries, and to prevent and limit the damage from floods. In addition, the Commission will propose measures to address pollution from urban runoff and from new or particularly harmful sources of pollution such as microplastics and chemicals, including pharmaceuticals. The Commission will focus, among other things, on measures to tackle intentionally added microplastics and unintentional releases of plastics, such as those from textiles and tyre abrasion. The Commission will develop requirements to ensure that all packaging in the EU market is reusable or recyclable in an economically-viable manner by 2030, will establish a regulatory framework for biodegradable and bio-based plastics, and will implement measures on single use plastics.

Proposal for a Directive of the European Parliament and of the Council concerning Urban Wastewater Treatment [53] - Under the European Green Deal, the European Commission tabled a proposal for a recast of the Urban Wastewater Treatment Directive in October 2022. Dating back to 1991, and instrumental to the achievement of EU water policy objectives, the directive needs to be updated and adapted to new challenges and realities. The recast proposal introduces new obligations to better control the pollution due to rainwater, impose stricter standards for nutrient removal and require advanced treatment for the removal of micro-pollutants.

EU Taxonomy for sustainable finance - Regulation (EU) 2020/852 [53] on sustainable finance specifically mentions that to ensure the sustainable usage and protection of water and marine resources, it is necessary to reduce emissions of contaminants such as microplastics.

This can be achieved by integrated urban wastewater treatment management, which should also cover stormwater. The definition of the taxonomy is ongoing; however, in the recommendations included in the Technical Platform published in March 2022 microplastics issue is covered under Urban Wastewater Treatment, since it requires the fulfillment of the Urban Wastewater Treatment Directive and thus sufficient treatment is required to remove a critical portion of microplastics.

THE EU LEGISLATION REGARDING MICROPLASTICS IN AIR

The European Green Deal [10]- The European Green Deal aims at transforming the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gasses in 2050 and where economic growth is decoupled from resource usage.

A zero pollution ambition for a toxic-free environment of the European Green Deal includes the EU's need to better monitor, report, prevent and remedy pollution from the air, water, soil, and consumer products. The Commission will propose strengthening provisions on monitoring, modeling, and air quality plans to help local authorities achieve better air quality. The Commission will propose the revision of air quality standards to align them more closely with the World Health Organization recommendations. The Commission will follow up on the 2018 plastics strategy focusing, among other things, on measures to tackle intentionally added microplastics and unintentional releases of plastics, for example, from textiles and tyre abrasion. In addition, the Commission will develop requirements to ensure that all packaging in the EU market is reusable or recyclable in an economically viable manner by 2030, will develop a regulatory framework for biodegradable and bio-based plastics, and will implement measures on single-use plastics.

REACH restriction proposal [15] - The Commission has requested the European Chemical Agency (ECHA) to prepare an Annex XV restriction dossier concerning the usage of intentionally added microplastic particles to consumer or professionally used products of any kind.The proposed regulatory framework consists of three specific measures aimed at addressing microplastic pollution. Firstly, a restriction is to be placed on the marketing of microplastics both independently and when blended with other materials in instances where

their usage will lead to inevitable environmental releases into the air, water, and soil, regardless of the intended conditions of usage. Secondly, a labeling requirement has been proposed to mitigate potential residual releases from microplastic usage, where it is not necessarily inevitable. However, it may occur if the materials are not utilized or disposed of correctly. Thirdly, a reporting obligation is included in the regulatory framework to improve the quality of available information for future risk assessments.

Chemicals Strategy for Sustainability Towards a Toxic-Free Environment [11] - The EU's Chemicals Strategy for Sustainability, published in October 2020, aims at promoting safe and sustainable usage of chemicals, including plastics. The strategy includes a range of measures to reduce the release of hazardous chemicals and to improve the assessment of chemicals' safety, which could indirectly reduce the occurrence of microplastics in air.

Ambient Air Quality Directive 2008/50/EC [27] - Ambient Air Quality Directive sets limits and target values for certain pollutants in outdoor air, such as particulate matter (PM) and nitrogen oxides (NOx). While these limits and target values are not explicitly aimed at microplastics, they could indirectly reduce the number of microplastics in the air if they help to reduce the emissions of larger plastic particles that can break down into microplastics over time.

Single-Use Plastics Directive (2019/904/EU) [25] - The Single-Use Plastics Directive aims at reducing the impact of certain single-use plastic products on the environment, including marine litter. While this directive does not explicitly address air quality, it does have the potential to indirectly improve air quality in a few ways: (1) Reduction in plastic waste: The directive aims at reducing the amount of single-use plastics produced and discarded, which could help reduce the amount of plastic waste that ends up in landfills or is burned, potentially reducing the release of pollutants into the air. (2) Promotion of circular economy: The directive includes measures to promote the transition to a more circular economy, where products are designed to be reused, repaired, or recycled. This could help reduce the need for virgin plastic production, an energy-intensive process that can contribute to air pollution. (3) Promotion of sustainable materials: The directive also encourages using alternative materials with a lower environmental impact than traditional plastics. For example, certain biodegradable plastics

could break down into harmless substances in the air, thus reducing the amount of plastic pollution that ends up in the environment and the air.

EU REGULATION REVIEW REGARDING MICROPLASTICS IN FOOD

There is not one specific regulation regarding microplastics in food, but several regulations and the Circular Economy Action Plan [3] are dealing with these thematics.

Circular Economy Action Plan [3] - This was adopted in 2020 by the EC. It is one of the main building blocks of the European Green Deal [10]. The new action plan announces initiatives along the entire life cycle of products. It targets how products are designed, promotes circular economy processes, encourages sustainable consumption, and aims at ensuring that waste is prevented and the resources used are kept in the EU economy for as long as possible.

As part of the Circular Economy Action Plan, in addition to measures to reduce plastic litter, the Commission will address the presence of microplastics in the environment by:

• restricting intentionally added microplastics and tackling pellets taking into account the opinion of the European Chemicals Agency;

• developing labeling, standardisation, certification and regulatory measures on unintentional release of microplastics, including measures to increase the capture of microplastics at all relevant stages of products' lifecycle;

• further developing and harmonising methods for measuring unintentionally released microplastics, especially from tyres and textiles, and delivering harmonised data on microplastics concentrations in seawater;

• closing the gap on scientific knowledge related to the risk and occurrence of microplastics in the environment, drinking water and foods.

In Article 3.3. of the Circular Economy Action Plan regulation regarding Packaging is now explained in more detail. The focus is on the reinforcement of the mandatory essential requirements for packaging to be allowed on the EU market, as well as on consideration of other measures focusing on: reducing (over)packaging and packaging waste, specifically by

setting targets and other waste prevention measures; driving design for re-use and recyclability of packaging, including restrictions on the use of some packaging materials for certain applications and considering reducing the complexity of packaging materials, including the number of materials and polymers used.

The Commission will also establish rules for the safe recycling of plastic materials other than PET into food contact materials. The Commission will also strictly monitor and support the implementation of the requirements of the Drinking Water Directive to make drinkable tap water accessible in public places, which will reduce dependence on bottled water and prevent packaging waste.

In Article 3.4. of the Action Plan, Plastics are considered. The EU Strategy for Plastics in the Circular Economy has set a comprehensive set of initiatives in motion, thus responding to the challenge of serious public concern.

To increase the utilization of recycled plastics and contribute to the more sustainable use of plastics, the Commission will propose mandatory requirements for recycled content and waste reduction measures for key products such as packaging, construction materials and vehicles, taking into account the activities of the Circular Plastics Alliance. In addition to measures to reduce plastic litter, the Commission will address the presence of microplastics in the environment by: restricting intentionally added microplastics and tackling pellets taking into account the opinion of the European Chemicals Agency; developing labelling, standardisation, certification and regulatory measures on unintentional release of microplastics, including measures to increase the capture of microplastics at all relevant stages of products' lifecycle; further developing and harmonising methods for measuring unintentionally released microplastics, especially from tyres and textiles, and delivering harmonised data on microplastics concentrations in seawater; closing the gap on scientific knowledge related to the risk and occurrence of microplastics in the environment, drinking water and foods.

Furthermore, the Commission will address emerging sustainability challenges by developing a policy framework on: sourcing, labelling and usage of bio-based plastics, usage of biodegradable or compostable plastics.

The Commission will ensure the timely implementation of the new Directive on Single Use Plastic Products and Fishing Gear to address the problem of marine plastic pollution while safeguarding the unanimous market.

Article 7 of the Circular Economy Action Plan addresses the leading efforts to support the circular economy at the global level. To support a global shift to circular economy, the Commission will: lead efforts at international level to reach a global agreement on plastics, and promote the uptake of the EU's circular economy approach on plastics; continue promoting circular economy in the accession process with the Western Balkans, and in the context of bilateral, regional and multilateral policy dialogues, fora and environmental agreements.

European Parliament and Council Directive on Waste 2008/98/ec [14] and repealing certain Directives [14]. In Article 9 of this Directive it is stated that by the end of 2011 an interim report will be prepared on the evolution of waste generation and the scope of waste prevention, including the formulation of a product eco-design policy addressing both the generation of waste and the presence of hazardous substances in waste, with a view to promoting technologies focusing on durable, re-usable and recyclable products.

In Article 11 in this Directive it is stated that Member States shall take the necessary measures to ensure that waste management is carried out without endangering human health or harming the environment.

European Parliament and Council Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC [57].

The use of recycled materials and articles should be favored in the Community for environmental reasons, provided that strict requirements are established to ensure food safety and consumer protection. A draft of a specific measure on recycled plastic materials and articles should be made available to the public as soon as possible in order to clarify the legal situation in the Community. The purpose of this Regulation is to ensure the effective functioning of the internal market on occasions when materials and articles intended to come into direct or indirect contact with food enter the market. At the same time the Regulation provides the basis for securing a high level of protection of human health and of the interests of consumers.

European Parliament and Council Directive 94/62/EC on packaging and packaging waste [32]. This Directive covers all packaging placed on the market as well as all packaging waste, whether used or released at industrial, commercial, office, shop, service, household or any other level, regardless of the material used.

Commission Regulation (EU) No 10/2011 [2] on plastic materials and articles intended to come into contact with food Regulation (EU) 10/2011 sets out safety requirements for plastic materials and articles intended to come into contact with food. This regulation is a specific measure for plastic food contact materials as mentioned in the European Framework Regulation (EU) 1935/2004. Regulation (EU) 10/2011 replaced Directive 2002/72/EC and its amendments, the Vinyl Chloride Monomer Directive and the specific directives for migration testing. Regulation 10/2011 applies to: materials and articles and parts thereof, consisting exclusively of plastics; plastic multi-layer materials and articles held together by adhesives; materials that can be printed or covered by coating; plastic layers or plastic coatings, forming gaskets in caps and closures; plastic layers in multi-material and multi-layer materials and articles. Key Regulation Inclusions & Requirements of Regulation 10/2011 are: *Compositional requirements* - Only authorised substances that are positive-listed in Annex I of the Regulation may be intentionally used in the manufacture of plastic materials and articles. *Specific provisions for several categories of plastic materials* - Caps and closures and multi-layer plastic materials or multi-material multilayers. *Declaration of Compliance (DoC)* – DoC is required at all stages of production and marketing (excluding the retail stage) and it needs to be supported by appropriate underlying documentation. *Testing requirements* - Requirements for testing of overall and specific migration, including comprehensive guidance on selecting simulants and conditions for testing. *Risk Assessment Requirements* - Assessment of Non-Intentionally Added Substances (NIAS) and their risk, by the manufacturer of plastic food contact materials and articles.

EC: draft proposal to restrict intentionally added microplastics, Commission Regulation (EU) …/… amending Annex XVII to Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles [1]**Error! Reference source not found.**. The EC has p ublished a draft proposal to restrict intentionally-added synthetic polymer microparticles < 5

mm. It could ban the usage of microplastics in cosmetics, cleaning products, pesticides, and sport fields. The restriction will affect the use of microplastics both on their own and in a variety of products, including fragrances, certain cosmetic products, fertilizing products, plant protection products and biocidal products. Food receives relatively little direct attention in the REACH microplastics proposal. When mentioned, the focus is on supplements and medical food where "microplastics are used in the formulation of food complements (e.g. vitamins) as a 'controlled-release' agent, and to hide unpleasant taste."

Any future EU restrictions on microplastics under REACH will harmonise conditions of manufacture, market placement and usage of specified microplastics. It's understood that Member States will retain the right to self-regulate and determine whether their national measures are compliant.

European Parliament and Council Regulation (EC) No 1907/2006 [15]. Regulation 1907/2006 should ensure a high level of protection of human health and the environment as well as the free movement of substances, on their own, in preparations and in articles, while enhancing competitiveness and innovation. The Regulation should also promote the development of alternative methods for the assessment of hazardous substances.

REACH Regulation (EC) No 1907/2006 [15] defines a microplastic as: a material consisting of solid polymer containing particles, to which additives or other substances may have been added, and where ≥ 1% w/w of particles have (i) all dimensions 1nm ≤ x ≤ 5mm, or (ii), for fibres, a length of 3nm ≤ x ≤ 15mm and length to diameter ratio of >3.

Substances used in food or feedstuffs can be restricted under REACH, but there are certain exemptions. Regarding microplastics, one such exemption would include naturally occurring polymers that have not been chemically modified (other than by hydrolysis), and (bio)degradable polymers. According to Article 129 (1) of REACH, national legislation may provide a higher level of protection regarding response to an urgent situation to protect human health or the environment.

European Parliament and Council Regulation (EU) 2019/1009 [58] laying down rules on making fertilising products available on the EU market and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 as well as repealing Regulation (EC) No 2003/2003.

The EU Fertilizing Products Regulation already sets the rules for controlled-release of fertilizers. As such, polymer encapsulation systems for fertilizers and anti-caking/anti-dust additives in fertilizers for agricultural use currently fall within the scope of future restriction but will be outside it if suitable biodegradability criteria were to be developed by the industry by 2026.

The timeline applies to technical additives in fertilizers since controlled-release fertilizers are exempted from the restriction, being covered by the EU Fertilizing Products Regulation. A transition period of 5 years will be applied after the microplastics regulation enters into force. From 2026 onwards, only polymers meeting the biodegradability requirements laid down in the new Fertilizing Products Regulation will be allowed on the market.

SERBIAN LEGISLATION REGARDING MICROPLASTICS

Serbia has made progress in aligning its legislation regarding microplastics with EU laws. The country has been working towards harmonizing its environmental policies and regulations with the EU's environmental acquis, which is a set of laws and regulations that EU member states must comply with.

However, there are still some areas where Serbia needs to improve its compliance with EU laws regarding microplastics.

The legislative framework in RS includes: *the Law on Waste Management* [39], *the Law on Packaging and Packaging Waste* [38] and *the Regulation on the list of waste prevention measures* [61].

According to the *Waste Management Law of the Republic of Serbia* [39] waste management is carried out in a way that ensures the least risk of endangering the life and health of people and the environment, through control and reduction measures in the field of: water, air and soil pollution; dangers to the flora and fauna; risks of accidents, explosions or fires; negative impacts on landscapes and natural assets of special value; level of noise and unpleasant odors.

According to the Waste Management Law, plastic waste was treated as a resource, i.e. as a secondary raw material. Secondary raw material is waste that can be used for recycling to obtain raw material for the production of the same or another product (paper, cardboard, metal, glass, plastic, etc.).

Special waste streams include packaging waste, which is often plastic. Special waste flows are those that require the prescription of special measures related to collection, transport, storage, treatment, i.e. reuse and disposal. The materials used for packaging must be produced and designed in such a way that during their life cycle they meet the requirements of environmental protection, safety and health of people, the healthiness of the packaged product, as well as the conditions for product transport and waste management. Packaging and packaging waste are managed in accordance with a special law.

Plastic waste can be: communal waste (household waste), commercial waste and industrial waste. Depending on the hazardous characteristics that affect human health and the environment, plastic waste can be: inert, non-hazardous and hazardous. The Law on Waste Management prescribes how to manage each type of waste.

Waste can be reused for the same or different purpose, for recycling, or other reuse operations, to obtain raw materials for the production of the same or different product, as a secondary raw material or to use the value of waste through its biodegradation or incineration of waste with the usage of energy.

The disposal and incineration of waste that satisfies the criteria for reusing or recycling is strictly prohibited.

It is prohibited to dispose of waste that has been separately collected for reusing and recycling in a landfill, unless it meets the quality requirements according to the appropriate standard for that type of waste. A person who recycles waste ensures that the resulting products do not cause a more harmful impact on the environment than products that were created from primary raw materials.

The Waste Management Program in the Republic of Serbia for the period 2022 -2031 [69]was preceded by the Waste Management Strategy for the period 2010-2019 [69], which set

the conditions for the establishment and development of an integrated waste management system in the Republic of Serbia.

According to the Waste Management Program, in the Republic of Serbia, there is no systematically organized separate collection, sorting and recycling of municipal waste. Although the source separation in the Republic of Serbia is determined by law and envisages the separation of plastic, paper, glass and metal in specially marked containers, separate collection does not work in practice, except sporadically in some local governments. There are several registered plants for recycling PET and other types of plastic, metal, paper, etc.

The economic instrument that is in use in the Republic of Serbia is a fee for plastic bags. Mandatory fee for plastic bags, in accordance with the Law on Fees for the Use of Public Goods is an economic instrument aimed at waste prevention. According to the waste hierarchy, waste prevention is the most favorable option. The application of this instrument is a way to achieve the implementation of the EU directive on reducing the consumption of plastic bags.

Waste streams separated at the source, such as biowaste, must be directed to biological treatment, and other recyclable materials such as metal, plastic, glass, paper, cardboard and wood, are directed to materials reuse operations in industrial processes.

Achieving separate collection of at least paper, metal, plastic, glass and textiles will be possible by the end of 2029.

Directive (EU) 2019/904 [25] on reducing the impact of certain plastic products on the environment has been partially transposed in RS legislature (transposition being in its initial phase), but the ban on single-use plastic bags is still pending. A deposit system for single-use packaging (plastic, glass or aluminum) has been established in order to achieve national targets and develop packaging waste management system. The Minister defines types of single-use packaging liable to the deposit system, the procedures of the system, the deposit fee, manner of payment as well as deadlines for the system to come into force.

The Law amending the Law on Waste Management introduces certain novelties regarding measurements within the RS Programme of waste management, measurements for reducing bio waste disposal, measurements for incitement of separate collection, as well as the

prevention measures, design, usage and dismantling. Special attention is paid to the measurements for promotion of waste recycling and reusing.

Future plans for transposing EU Directives in RS involve:

- the development of waste prevention programs;
- Circular Economy Roadmap [60];
- full transposition and implementation of the revised package (Directive 2008/98/EC, amendment on the Directive (EU) 2018/851, Directive (EU) 2019/904 on single-use plastics, Regulation on parcels (EU) 1013/2006), especially regarding specific waste issues (Prevention of waste, Managing construction and demolition waste, Reduction of biodegradable waste and food waste, Plastics and plastic waste, Illegal parcels).

To achieve EU requirements, RS needs to specify and prescribe implementation measures through the legislative framework, covering: reduced consumption of single-use plastics; extended producer responsibility, including equipment and facilities for efficient waste management; data collection methodologies, in order to prepare reports in compliance with the Directives; awareness-raising measures regarding harmful environmental influence of disposition or misuse of single-use plastic products; information dissemination to consumers about alternatives, reusage systems and waste management options for single-use plastics.

To transpose and implement EU laws, the Republic of Serbia requires both technical and financial assistance.

2. DETECTION

The detection of microplastics is a crucial step in the scientific roadmap for reducing the presence of microplastics in Serbia.

The first step in addressing the issue of microplastics in Serbia is to understand the extent and sources of the problem. This can be achieved through research studies that focus on the occurrence, distribution, and fate of microplastics in various environmental compartments, including freshwater, marine, and terrestrial ecosystems. Additionally, monitoring programs should be established to track the levels of microplastics in these environments over time.

In the Republic of Serbia, there are currently several research teams actively working on microplastics. The authors primarily conduct laboratory investigations in a controlled environment to study the fate and behavior of various common polymer types. Although the results of research on the presence of microplastics in the environment have not yet been published, there are ongoing major projects dedicated to this topic. Researchers often publish literature reviews in this field, with a limited number of studies focusing on different interactions between microplastics and the living environment. A research team from the University of Novi Sad is specifically engaged in studying the sorption processes of organic pollutants on microplastic particles and their potential use in water purification processes.

In the review articles [50], [51], the authors analyzed 88 + 168 scientific papers, concluding that the consequences of exposure to microplastics depend on the dose. Accumulated microplastics may exhibit biological effects, induce oxidative stress and damage, affect cholinesterase activity, and interact with the effects of other xenobiotics. The majority of studies involved marine animals, such as mollusks and pisces as vertebrates. The need for more comparative studies taking into account the familiar sex and age of animals, as well as organs other than gastrointestinals was emphasized. Furthermore, non-invasive methods for studying microplastic presence in new organisms should be developed.

Petrović et al. [48] review presented results from 49 scientific papers on the presence of microplastics in leachate, soil, and air near landfills. The review indicated a stronger focus on micro particles in leachate compared to those in the landfill body, soil, or air nearby. Primary source of MPs in leachate are surface runoff, waste disposal and incineration. MPs occur in

different sizes, types and concentration. Fiber MPs most often stay on soil while smaller MPs are rinsed into leachate. There are various combined technologies for removing MPs from leachate exist, but some treatments may still lead to microplastic emissions at different stages. These treatments are usually more efficient for larger MPs, while the destiny of smaller MPs is still undefined.

Lončarski et al. [40] investigated the kinetics of transferring organic pollutants, particularly polycyclic aromatic hydrocarbons (PAHs), through adsorption on selected types of microplastics. In the research, the following types of polymers were examined: polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), as well as the biodegradable polymer PLA. The study indicated that PAHs had the lowest adsorption affinity for polylactic acid polymer (PLA), a biodegradable type of plastic. This practically means that this type of microplastic from PLA contributes significantly less to the mobility and distribution of nonpolar organic pollutants such as PAH. One reason for this behavior of PLA is the polar nature of this polymer, which, due to its affinity for water, has a short degradation period

Lončarski et al. [41] investigated the adsorption of chlorophenols on microplastic particles isolated from cosmetic products under laboratory conditions. The results obtained indicated that the adsorption rate depends on hydrophobic interactions as well as the size of chlorophenol molecules. The final conclusion is that MPs can contribute to the transport of adsorbed phenols through ambient waters.

Vujić et al. [68] focused on separating plastic fibers from accompanying residues during textile and clothing tumble drying. This is crucial since household textile washing and drying are among the most significant sources of microplastic pollution. The remaining fibers and organic residues after drying are collected on the filter. Separation of this mixture is particularly challenging due to the use of various types of polymeric fibers in fabric production. The removal of mineral materials was examined using density separation in a saturated solution of ZnCl2, after which organic matter was eliminated with hydrogen peroxide. The identification of microplastic fibers was conducted using an optical microscope with detection through FTIR (Fourier-transform infrared) analysis.

Tubić et al. [67] explored the interactions between microplastics and synthetic dyes used in printers, studying five types of synthetic polymers: polyethylene powder, polyethylene in granules, polyvinyl chloride, polyethylene terephthalate, and polypropylene, as well as dyers cyan (phthalocyanine) and magenta (azo dye), both of which belong to the group of aromatic compounds. The study indicated a high affinity between dyes and polymers, with polyvinyl chloride (PVC) showing the highest binding capacity. The developed model indicates that the procedures can be applied to other printing inks as well as wastewater treatment technologies. It was discovered that the sorption processes, which are irreversible, are influenced by the type of microplastic and the properties of the dyers, while particle size and molecular mass of the dyers are not significant factors for sorption.

Tubić et al. [66], prove that the presence of microplastics in aquatic environments can have a significant impact on the transport of certain chlorophenol species. Sorption of the following chlorophenols was examined in the aquatic environment: 4-chlorophenol (4-CP), 2,4-dichlorophenol (2,4-DCP), 2,4,6-trichlorophenol (2,4,6-TCP), and pentachlorophenol (PCP) on three different polymers: polyethylene (PE), polypropylene (PP), and polylactic acid polymer (PLA). PP exhibited the highest adsorption of chlorophenols, while the adsorption on PP and PLA depended on the structure of chlorophenols. A significant difference was observed in the results obtained under laboratory conditions (deionized water) and in natural conditions (water from the Danube).

In the study by Tubić et al. [65], the adsorption potential of standard polyethylene and micro-particles of PE isolated from cosmetic products was examined for various chlorobenzenes (1,2,3-TCB, 1,3,5-TCB, and 1,2,4-TCB), pentachlorobenzene (PeCB), hexachlorobenzene (HeCB), and trifluralin in a water model solution and in water from the Danube. The properties of these chemical pollutants affect their adsorption on micro-particles. It was also established that micro-particles isolated from cosmetic products have a higher adsorption potential than standard polyethylene. The maximum absorbed amount on polyethylene ranged from 227 μg/g for 1,2,3-TCB to 333 μg/g for trifluralin.

de Guzman et al. [18] investigated interactions between polystyrene particles and pepsin in a simulated human gastric environment. The study also examined digestion through the hydrolysis kinetics of protein in a cow's in vitro digestive tract. The results have shown that

during a shorter exposure period (10 minutes) to increasing concentrations of polystyrene microplastics (MP), there was no alteration in enzymatic activity. However, with prolonged exposure (1-2 hours), structural changes occurred in pepsin, leading to a significant reduction in its activity.

Stojanović et al. [63] studied the potential toxic effects of microplastics of various dimensions originating from polyethylene terephthalate bottles. The signs of toxicity, sensorimotor functions, and relative brain mass were monitored in young male rats. The results indicate that no signs of clinical toxicity were observed, nor were there changes in sensorimotor functions. The only observed change is an increase in relative brain mass compared to the control, for microplastics of smaller dimensions. This suggests that finer particles may pass the blood-brain barrier and accumulate in the brain causing oxidation, stress and inflamatory response. However, additional synergy of factors should not be neglected, as it was not the focus of the study.

The research team led by Tanja Ćirković Veličković from the Faculty of Chemistry at the University of Belgrade focuses on interactions between the human body and microplastic particles. Research by Kaseke et al. [37] investigated the migration of nano- and microplastics from packaging into dairy products and their consequences on digestion, absorption, and metabolism of nutrients. Different types of dairy products, such as skimmed milk, whole milk, powdered milk, and baby formula, were found to contain microplastic particles. The presence of microplastics can lead to interactions with proteins, carbohydrates, and fats and may have a detrimental impact on the digestion and absorption of nutrients in the body.

Lujić et al. [43] examined the impact of microplastics on the enzyme trypsin, finding that micro particles of polypropylene and polyethylene terephthalate affect the activity of this enzyme in the digestive tract.

Lujić et al. [42] also conducted research on the influence of incubation of ovalbumin with micro-particles of polyethylene terephthalate and polystyrene on the digestion of ovalbumin by gastrointestinal enzymes under in vitro conditions. Digestion with two proteases

(pepsin and trypsin) was examined. The results suggest the potential for structural stabilization, but further research is needed, and the results must be confirmed with new experiments.

Several ongoing projects in the Republic of Serbia are dedicated to the issue of microplastics.

"The Microplastic-free Environment – GreenLand" Project (https://project-greenland.com/) aims at enhancing the capacity of researchers in microplastics in collaboration with partner institutions from Ireland and Germany. The project objectives include:

- Improving the overall understanding of this ecological issue, its sources, fate and transport in selected pilot areas;
- Optimizing analytical protocols for extracting and detecting microplastics in water and soil;
- Development of PDP framework for a national microplastics management (environmental legislations and its implementations) as the basis of the scientific roadmap;
- Establishing a Project Incubator Hub (PIH) that will translate new scientific ideas into the project;
- Establishing a Technology Transfer Hub (TTH) that will translate new technologies and scientific discoveries into the economy.

"Evaluation of the Microplastic in the Soils of Serbia - EMIPLAST-SoS" Project (https://www.imsi.bg.ac.rs/en/evaluation-of-the-microplastic-in-the-soils-of-serbia-emiplast-sos-2/) aims at providing the first insights into the impact of MP on soil ecosystem services and biological communities in the alluvial plains of Serbia.

Specific project objectives include:

- Development of simple protocol for isolation and quantification of MP particles from soil;
- Brief mapping of MP pollution in the alluvial plains and assessing vertical redistribution of MP through soil profiles;

- Evaluation of the MP impact on soil properties and its ecosystem services in coexisting agro- and forest ecosystems in Serbia;
- Elucidation of interaction between MP and the soil biota in agro-/forest ecosystems;
- Investigation of the possibility of selected fungi and insect to perform biodegradation of actual MP particles isolated from environmental samples;Evaluation of the economic impact of plasticulture and MP impact on crop production in agroecosystems;
- Evaluation of environmental risks of MP;
- Providing information on the pollution caused by plastic disposition and its influence on soil and nature in general in Serbia to diverse groups of stakeholders.

"An Innovative Analytical Platform to Investigate the Effect and Toxicity of Micro and Nano Plastics Combined with Environmental Contaminants on the Risk of Allergic Disease in Preclinical and Clinical Studies – IMPTOX" Project (https://www.chem.bg.ac.rs/projekti/137/index-en.html) aims at creating a cross-disciplinary platform to design suitable analytical approaches for determining the extent of the problem in the environment and its influence to human health by evaluating the influence of ingested and inhaled exposure of micro and nano plastics (MNPs) contaminated with metals, allergens, pathogenic bacteria and toxins on allergic responses. The outcome of this state-of-the-art project includes novel tools for MNP detection; improved understanding of the effects of MNPs combined with critical contaminants in the air, water and food on human health and discovery of predictive biomarkers; increased awareness of disease risk in response to MNPs and contaminants; improved communication strategies between science and relevant stakeholders and contribution to blue growth and the health-relevant aims of the European Strategy for Plastics in the Circular Economy; policy-relevant scientific data in support of improved human health hazard and risk assessment and for response and mitigation policies at the national and EU level for policymakers.

"Plastics Monitoring Detection Remediation Recovery – PRIORITY" COST Action (https://ca-priority.eu/about/#description) is a large international project involving numerous researchers from Serbia. PRIORITY is a science and technology research network focused on developing, implementing, and consolidating strategies to tackle the global

challenges of micro- and nanoplastics in the environment. This COST Action combines expertise in chemistry, physics, life science, engineering, standards, economy, and law. The network creates a robust infrastructure for scientific communication, exchange, and collaboration to foster new research activities and citizen science. PRIORITY aims at enhancing the technical standards for sampling and analysis of micro- and nanoplastics in the environment, at developing a more reliable assessment of exposure and biological effects, and at advancing activities in terms of environmental remediation and recovery. The Action will support the harmonization of European regulation associated with microplastics. It will assist the European Commission in critical aspects of environmental and ecosystems protection, food safety, and life science.

"Integrated Cross-Sectoral Solutions to Micro- and Nanoplastic Pollution in Soil and Groundwater Ecosystems" Project (https://cordis.europa.eu/project/id/101072777). The Plastic Underground Doctoral Network creates supra-disciplinary intersectoral capacity for analysing the fate, transport and impacts of MNP in soils and groundwater to develop solutions for reducing their environmental and public health risks, supporting the EC's circular plastic economy strategy. The central aim of the PlasticUnderground Doctoral Network is to deliver international scientific excellence through a holistic supra-disciplinary and inter-sectoral research and training network on solutions to the emerging crisis of MNP pollution in subsurface ecosystems in soils and groundwater, integrating knowledge across traditional discipline boundaries to benefit both public and private sectors. The supra-disciplinary research programme includes unique training opportunities for a cohort of 10 Doctoral Candidates (DCs) (plus one individually funded through ETHZ [CH] and three funded through UoB, RU and Polymateria [UKRI] as Associated Partners) in environmental and social science, ecotoxicology, soil science and aquatic ecology, analytical chemistry, agronomy, data science and numerical modelling as well as responsible innovation, method standardization for use in regulatory decision making and risk assessment. The integrated training programme will prepare DCs with skill sets that are urgently required in agricultural, water, chemical, and manufacturing industries, environmental and regulatory agencies, academia, and the public sector. It includes training provision by key stakeholders that will directly benefit from the training in this network.

"Investigation of Microplastic Influence on Water Resources" Project (https://www.pmf.uns.ac.rs/en/2020/03/12/investigation-of-microplastic-influence-on-water-resources/)

"**Influence of aging on the analysis of microplastics":** Hubert Curien Partnership with the University of Novi Sad (Serbia) (E-BICOM Team) (https://ic2mp.labo.univ-poitiers.fr/sustainable-food-packaging-solutions-the-role-of-biomaterials-in-microplastics-reduction-phc-with-the-university-of-novi-sad-serbia/) is a project that combines the skills of the Serbian and French teams in the fields of polymers and physicochemical analysis to characterize, by spectroscopic and thermal methods, a wide range of polymers having undergone aging under controlled conditions. A database could thus be developed with the data obtained and made available to the scientific community.

3. PURIFICATION

The most effective way to reduce the amount of microplastics in the environment is to reduce the amount of plastic waste that enters it in the first place. This can be achieved through a range of measures, such as promoting the use of reusable products, implementing plastic bag bans, and improving recycling and waste management infrastructure.

According to the data presented in the Waste Management Program in the Republic of Serbia [69], the total amount of generated municipal waste in 2020 in Serbia was 2.95 million tons. The share of generated plastic waste was 12.1% of the total amount of generated municipal waste. Of the total amount of generated plastic waste, 15.5% was separately collected, 12.7% was recycled, 1.01% was energetically utilized, and 1.69% was used in other ways. The system of separate collection of packaging waste from households in Serbia has not been adequately established, with the majority of packaging waste from households being included in mixed municipal waste. Estimates show that the total mass of packaging waste, including plastic waste, within the municipal waste stream is about 240,000 tons of dry fraction, of which only a few tens of thousands are separately collected.

According to the official data from the Environmental Protection Agency of the Republic of Serbia [45], the quantity of plastic packaging (PET and other types of plastic)

placed on the market in the Republic of Serbia by legal entities or entrepreneurs who have transferred their obligations to operators in 2022 was 96,526.9 tons, of which 40,835.9 tons were recycled (42.3%). The Regulation on establishing a plan for the reduction of packaging waste for the period from 2020 to 2024 [59] pinpoints specific targets, including recycling 34% of plastic in 2022 and 38% in 2023. Based on these data, it can be concluded that the national specific targets for the recycling of plastic packaging waste in 2022 have been achieved. Considering Serbia's aspiration to join the EU and the obligation to align domestic legislation with the legislation of EU member states, additional efforts are needed for a more intensive implementation of separate collection, reuse, and recycling of plastic.

The first step in microplastics management involves measures supporting the waste management hierarchy principle, aiming to extend the product's lifespan and return waste materials to the production process. The waste management hierarchy concept indicates that waste prevention is the most effective environmental solution. However, where further reduction is not practically applicable, products and materials can be reused, either for the same or a different purpose. If that option is not feasible, waste can be further utilized through recycling or composting, or by obtaining energy. Only if none of these options provides a suitable solution should waste be deposited in landfills [69].

The waste management hierarchy defines the priority order in waste management practices [39]**Error! Reference source not found.**. Waste prevention, which includes reuse of p roducts or extending the product's lifespan, is at the top of the waste management hierarchy. Prevention aims at reducing [69]:

- the quantity of waste, including the reuse of products or extending their lifespan;
- harmful impacts of generated waste on the environment and human health;
- the content of harmful substances in materials.

Waste prevention, including plastic waste, can be achieved at two levels [44]:

- by manufacturers, responsible for their products, preventing waste generation during production and ensuring that final products are easily recyclable;

- by consumers, responsible for the products they acquire or purchase, which will become waste after some time (e.g. purchasing products with a longer lifespan, avoiding unnecessary packaging, buying recyclable products, using cloth bags instead of plastic bags, etc.).

Manufacturers, importers, distributors, and sellers of products that contribute to an increase in waste are responsible for the waste generated by their activities. Manufacturers bear the greatest responsibility as they influence the composition and characteristics of products and their packaging. Manufacturers are obliged to reduce waste generation, develop products that are recyclable, develop markets for the reuse and recycling of their products [39]. Already in the product design phase, manufacturers must consider the impact the product will have on human health and the environment when it loses its utility value and becomes waste. *The Design for Environment (DfE)* concept, as well as tools such as *Life Cycle Analysis (LCA)* and *Extended Producer Responsibility (EPR)*, are key tools used by advanced companies to develop new and improve existing product characteristics [62].

Relevant institutions, manufacturers and consumers in Serbia should be familiar with the guidelines of Directive (EU) 2019/904 on reducing the impact of certain plastic products on the environment, which aims at preventing and reducing the impact of certain plastic products on the environment and promoting the transition to a circular economy in the EU. The Directive prescribes a series of measures to ensure that single-use plastic products, for which appropriate and affordable sustainable alternatives are available, cannot be placed on the market [25]. As Serbia is in the process of transitioning to a circular economy, with the biggest challenge being the adaptation of the industry producing plastic packaging, addressing the issue of single-use plastic packaging requires [60] the development of a plan for the transposition of Directive (EU) 2019/904 into the legislation of the Republic of Serbia, as well as further harmonization of regulations for the management of packaging and packaging waste, including plastic packaging waste. One way to reduce the generation of plastic waste is to introduce subsidies and tax incentives for packaging manufacturers who use "environmentally friendly" materials instead of plastic. In this regard, collaboration between the scientific community, decision-makers, representatives of the industry, and even consumers is essential to encourage the production of biodegradable plastics, raise public awareness of the consequences of using

single-use plastics on environmental quality and human health, and apply the experiences of European and global associations dealing with the issues of single-use plastic products.

In many local self-governments in Serbia, decisions have been adopted in recent years regarding the conditions for the use of bags for the delivery of goods at the point of sale of goods and services. These decisions eliminate the use of plastic bags at the point of sale in all retail, service, and other activities in the local self-government area to prevent or reduce waste generation and their harmful effects on the environment. As an alternative, traders provide consumers with paper or cloth bags [19]. Additionally, a fee for plastic bags has been introduced in Serbia as an economic instrument aimed at waste prevention, which is the most favorable option according to the waste management hierarchy. The Law on Fees for the Use of Public Goods prescribes the amount of the fee for plastic bags, as well as the obligation to report to the Environmental Protection Agency of the Republic of Serbia [30]

The next step in the waste management hierarchy that should not be neglected concerning plastic waste is the principle of preparation for reuse, especially considering the content of plastic in certain products. Procedures related to the reuse of waste include cleaning, functional testing (e.g. of electrical and electronic devices or their components), repair or refurbishment of discarded equipment, through which products or components of products that have become waste are prepared for reuse, without any other prior processing [69]. The benefits of this approach can be seen in extending the product's lifespan, reducing the amount of waste, and delaying the time for a product to become waste. Additionally, the application of the preparation for reuse principle opens up new job opportunities within recycling centers, reduces pressure on the environment, and reduces the emission of gases contributing to global warming [44].

Recycling is considered to be any operation of reprocessing waste into a product, material, or substance, whether for the original or different purpose, including the reprocessing of organic materials, except for the reuse for energy purposes and the processing into materials intended to be used as fuel or as landfill cover [39]. According to the Regulation on establishing a Plan for the reduction of packaging waste for the period from 2020 to 2024 [59], general targets for reuse and recycling of packaging and municipal waste have been introduced, as well as specific targets for individual recyclable components, including plastic. General goal is that

by the end of 2024, 67% of packaging waste will be reused, while 58% will be recycled. Specific goals for plastic recycling are 40% for total packaging waste, and 8% for municipal packaging waste. The Waste Management Program of the Republic of Serbia has set targets of 50% for plastic by 2025 and 55% by 2030 [69]. The significance of introducing recycling into the waste management system is manifold [49]:

- Introducing recycling reduces the use of finite natural resources;
- Recycling reduces the amount of waste that needs to be deposited in landfills, thereby increasing the lifespan or exploitation of landfills;
- Recycling yields economic benefits through direct sales and indirect participation in other manufacturing sectors;
- Separated useful components of waste become secondary raw materials in many manufacturing industries (such as paper and glass production), reducing the need for importing secondary raw materials and preserving existing resources;
- The use of secondary raw materials saves energy, as less energy is consumed during the production from secondary raw materials;
- Processing secondary raw materials reduces production costs compared to processing primary raw materials;
- Introducing recycling provides the opportunity to create new jobs;
- The application of recycling contributes to environmental protection and conservation;
- The application of recycling aligns with EU legislation regarding waste management.

Today, there are many methods for recycling different types of plastic. Efficient sorting of plastic and continuous monitoring of various streams of plastic waste are two key issues for developing an optimal strategy for recycling solid plastic waste. Viewed from this perspective, plastic recycling technologies can be divided into four basic categories [64]:

- Primary: Re-extrusion, or the reintroduction of plastic with the same characteristics into the manufacturing process;

- Secondary: Mechanical, developed for the recycling of various plastic products through physical processes;
- Tertiary: Chemical, designed to produce raw materials for the chemical industry;
- Quaternary: Energy recovery, involving the complete or partial oxidation of plastic waste materials to produce heat and/or gaseous fuels, oils, and/or materials that are deposited (such as ash).

Mechanical recycling is one of the oldest and most common methods of plastic recycling. The basis of this method is the ability to melt plastic again, with little or no change to the macromolecular structure. This can be achieved with thermoplastics. After shredding and pressing plastic waste using special devices, the next steps include separation and washing. The output material is granules, which are stored and further used for various purposes [44].

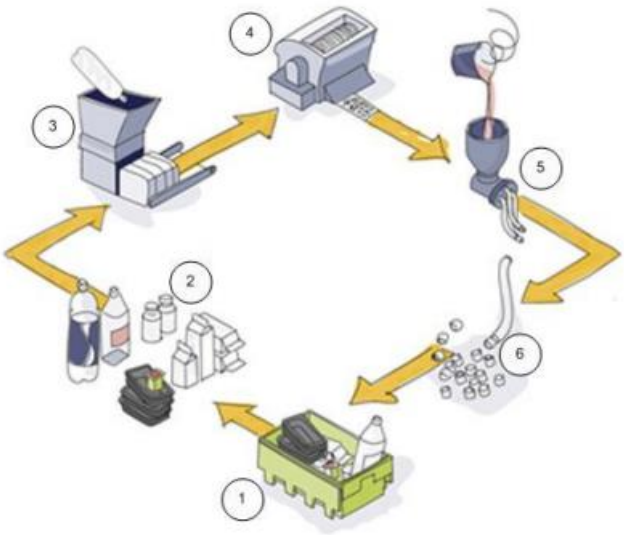

Figure 1. Mechanical recycling of plastics [44]

(1- collecting plastic packaging; 2- sorting regarding types of plastics; 3- pressing; 4 – shredding and melting; 5 – moulding; 6 – granules extraction)

Chemical recycling of plastic has an advantage over mechanical recycling because chemical processes can treat mixed and contaminated components of plastic waste. One way of chemical processing of plastic is by converting macromolecular substances (polymers) into low-molecular-weight substances. Another plastic processing method is to obtain

hydrocarbons in the form of gas or oil from macromolecules. Hydrocarbones can be further processed by petrochemical methods in refineries [44].

The energy utilization of plastic is based on using waste plastic to produce energy in the form of heat, steam, or electricity. Since waste plastic is a product of crude oil, burning it generates a high calorific value. Such a solution can be considered technically and economically viable when other recycling strategies (such as sorting, mechanical, chemical, etc.) cannot be applied profitably.

To reduce the demand for plastic products, sustainable alternatives should be developed and promoted. This could include the development of biodegradable plastics, as well as the promotion of alternative materials, such as glass, metal, and paper.

To address the issue of microplastics in the environment, in addition to implementing waste management hierarchy, measures need to be taken to achieve solutions that will create the best possible overall outcome for the environment. General environmental protection principles such as the precautionary principle and sustainability, technical feasibility, and economic viability, resource protection, as well as the overall impact on the environment, human health, the economy, and social aspects must also be considered [69].

Key areas of action regarding the management of (micro)plastics can be divided into several crucial groups:

1. **Improvement of the economic framework and quality of plastic recycling**

   Increasing the level of plastic recycling, comparable to levels for other materials, can be achieved through improvements in the production and design of plastic and plastic products. It is also essential to enhance collaboration throughout the value chain: from the plastic industry, manufacturers, and processors to public and private waste management companies. Key stakeholders should particularly collaborate on:

- Enhancing design and supporting innovations to facilitate the recycling of plastic and plastic products;

- Expanding and improving the separate collection of plastic waste to ensure high-quality input materials for the recycling industry;
- Expanding and modernizing sorting and recycling capacities in Serbia;
- Creating sustainable markets for recycled and renewable plastics.

2. **Recyclable design**

Plastic packaging is a priority area when it comes to designing products for recycling, as product design is a key factor in improving recycling rates. Research has shown that improving product design can significantly reduce the costs of recycling plastic packaging [35]. Therefore, standardization in the construction and design of plastic products in Serbia is necessary, as well as providing financial incentives for eco-design and the implementation of new technologies.

3. **Increasing demand for recycled plastic**

Low demand for recycled plastics represents another significant obstacle in transforming the plastic value chain. In the Republic of Serbia, the use of recycled plastics in new products is low and often limited to low-value or specific-purpose products. Market uncertainties and profitability concerns hinder the investments necessary to increase and modernize plastic recycling capacities in Serbia and promote innovation. Therefore, increasing demand for recycled plastic is crucial in creating markets for these materials. Consumer education about the benefits of using recycled plastic and support for industries opting for sustainable alternatives contribute to this goal.

4. **Improved and more consistent separate collection and sorting of plastic waste**

The increase and improvement of plastic recycling are also limited by insufficient volumes and quality of separate waste collection and sorting. This is crucial to avoid introducing contaminants into recycling streams and maintain the high quality of recycled materials. National and local authorities, in collaboration with waste management operators, play a key role in raising public awareness and ensuring high-quality separate waste collection. Financial resources collected through extended

producer responsibility programs can significantly contribute to strengthening such efforts. Similarly, deposit systems can contribute to achieving very high levels of recycling.

5. **Finding alternative solutions**

To address the issue of releasing large amounts of (micro)plastics into the environment and its negative impact, efforts should be made to design biodegradable and compostable plastics. Targeted applications, such as using compostable plastic bags for separate collection of organic waste, have shown positive results. However, most currently available plastics labeled as “biodegradable” usually degrade under certain conditions that may not always be easily found in the natural environment, therefore, they can still impact the environment negatively. Additionally, plastics labeled as 'compostable' may not necessarily be suitable for home composting. If compostable and conventional plastics are mixed in the recycling process, it can affect the quality of the resulting recycled products.

It is important to ensure that consumers are provided with clear and accurate information and to ensure that biodegradable plastic is not presented as a solution for waste disposal. This can be achieved by specifying which plastics can carry the 'compostable' or 'biodegradable' label and how they should be treated after use. It is necessary to first identify when the usage of biodegradable or compostable plastic is environmentally beneficial and then implement measures to stimulate innovation and market development. Conducting a product lifecycle analysis is also necessary to identify when the use of biodegradable or compostable plastic is beneficial, as well as the criteria for their application.

6. **Developing a clear legal framework for biodegradable plastic**

Establishing a clear legal framework for biodegradable plastic creates the basis for the responsible use of these materials. This includes legal frameworks related to the production, labeling, and disposal of biodegradable materials to ensure their effective integration into wider society.

7. **Increased awareness of microplastics**

Awareness of microplastics becomes a crucial area that requires additional attention. Research, education, and legal regulations focusing on reducing microplastic emissions are necessary to preserve human health and the environment. Individuals can make better choices by increasing awareness of the environmental consequences of plastic consumption. Schools, social organizations, and the media play a crucial role in disseminating information and promoting a plastic-free mindset. Understanding the product lifecycle, the consequences of plastic pollution, and available alternatives enable individuals to align their choices with a sustainable future.

8. **Mobilizing innovation and investments for circular solutions**

Innovation and investments become drivers of circular solutions. Encouraging research and development of sustainable materials and technologies that support a circular model lead to creating a future without plastic pollution.

9. **Support measures at the global level**

Global cooperation is necessary to achieve a sustainable plastic-free future. Exchange of experiences, joint research projects, and alignment of international standards support the global effort in addressing this challenge [34] [13]

Promoting sustainable practices becomes a key focus in the effort to tackle plastic waste. Manufacturers play a crucial role in driving change, influencing consumer choices through the design and production of environmentally friendly products. From packaging innovations to product redesign, companies can contribute to a circular economy where the amount of generated waste is minimized and resources are preserved.

CONCLUSIONS

The scientific roadmap defines a clear set of goals, including policy development, public awareness, research, and collaboration with stakeholders, aimed at reducing the presence of microplastics in the environment.

Through a combination of scientific research, technological innovation and policy interventions, the scientific roadmap presents a series of strategic options for addressing the sources, pathways and impacts of microplastics in Serbia. These options include improving waste management practices, promoting sustainable consumption and production, implementing better industrial practices, and improving water and soil quality monitoring.

Furthermore, the roadmap highlights the importance of interdisciplinary collaboration and knowledge sharing among scientists, policy makers, industry leaders and the public to develop and implement effective solutions.

The roadmap emphasizes the need for increased investment in research and development in order to better understand the behavior and effects of microplastics in the Serbian environment. It also emphasizes the importance of using existing international frameworks and cooperation in order to harmonize Serbia's efforts with global initiatives aimed at solving this issue.

Overall, the scientific roadmap for strategic options to reduce microplastics in Serbia provides a comprehensive and systematic framework for action. By implementing the strategic options outlined in the roadmap, Serbia can work to mitigate the impact of microplastics on the environment, human health and ecosystems, while contributing to broader international efforts to address this global challenge.

LITERATURE

[1] Commission Regulation (EU) …/… amending Annex XVII to Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles, 2023 https://single-market-economy.ec.europa.eu/publications/commission-regulation-eu-amending-reach-regulation-regards-synthetic-polymer-microparticles_en

[2] Commission regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:012:0001:0089:en:PDF

[3] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions; A new Circular Economy Action Plan For a cleaner and more competitive Europe COM/2020/98 final https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

[4] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions EU; Biodiversity Strategy for 2030 Bringing nature back into our lives COM/2020/380 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020DC0380

[5] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions; Chemicals Strategy for Sustainability Towards a Toxic-Free Environment Brussels, 14.10.2020 COM(2020) 667 final https://environment.ec.europa.eu/strategy/chemicals-strategy_en

[6] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions; A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system COM/2020/381 final https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf

[7] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions; An EU

Strategy to harness the potential of offshore renewable energy for a climate neutral future COM/2020/741 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:741:FIN&qid=1605792629666

[8] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions on a new approach for a sustainable blue economy in the EU; Transforming the EU's Blue Economy for a Sustainable Future COM/2021/240 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:240:FIN

[9] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions EU policy framework on biobased, biodegradable and compostable plastics https://environment.ec.europa.eu/system/files/2022-12/COM_2022_682_1_EN_ACT_part1_v4.pdf

[10] Communication from the commission to the european parliament, the european council, the council, the european economic and social committee and the committee of the regions; The European Green Deal COM/2019/640 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640

[11] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions; Chemicals Strategy for Sustainability Towards a Toxic-Free Environment, Brussels, 14.10.2020 COM(2020) 667 final, https://circabc.europa.eu/ui/group/8ee3c69a-bccb-4f22-89ca-277e35de7c63/library/dd074f3d-0cc9-4df2-b056-dabcacfc99b6/details?download=true

[12] Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions EU; Strategy for Sustainable and Circular Textiles COM/2022/141 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0141

[13] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions; A European Strategy for Plastics in a Circular Economy (2018) Brussels, January 16th 2018 COM (2018). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2018%3A28%3AFIN

[14] Consolidated text: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives http://data.europa.eu/eli/dir/2008/98/2018-07-05

[15] Consolidated text: Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC http://data.europa.eu/eli/reg/2006/1907/2022-12-17

[16] Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste http://data.europa.eu/eli/dir/1999/31/oj

[17] Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption http://data.europa.eu/eli/dir/1998/83/oj

[18] de Guzman, M. K., Stanic-Vucinic, D., Gligorijevic, N., Wimmer, L., Gasparyan, M., Lujic, T., & Velickovic, T. C. 2023. „Small polystyrene microplastics interfere with the breakdown of milk proteins during static in vitro simulated human gastric digestion.“ Environmental Pollution 335.

[19] Decision on amendments and additions to the Decision on the conditions of using bags for the delivery of goods at the point of sale of goods and services ("Official Gazette of the City of Belgrade", no. 74-2/2019)

[20] Directive (EU) 2015/720 of the European Parliament and of the Council of 29 April 2015 amending Directive 94/62/EC as regards reducing the consumption of lightweight plastic carrier bags http://data.europa.eu/eli/dir/2015/720/oj

[21] Directive (EU) 2018/849 of the European Parliament and of the Council of 30 May 2018 amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment http://data.europa.eu/eli/dir/2018/849/oj

[22] Directive (EU) 2018/850 of the European Parliament and of the Council of 30 May 2018 amending Directive 1999/31/EC on the landfill of waste http://data.europa.eu/eli/dir/2018/850/oj

[23] Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste http://data.europa.eu/eli/dir/2018/851/oj

[24] Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste http://data.europa.eu/eli/dir/2018/852/oj

[25] Directive (EU) 2019/904 of the european parliament and of the council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment http://data.europa.eu/eli/dir/2019/904/oj

[26] Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council http://data.europa.eu/eli/dir/2008/105/oj

[27] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe http://data.europa.eu/eli/dir/2008/50/oj

[28] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) http://data.europa.eu/eli/dir/2008/56/oj

[29] Directive 2011/65/EU of the european parliament and of the council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment(recast) https://eur-

lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:174:0088:0110:en:PDF#:~:text=This%20Directive%20lays%20down%20rules,and%20disposal%20of%20waste%20EEE.

[30] Environmental Protection Agency of the Republic of Serbia, Plastic bags in the Republic of Serbia in 2021, Belgrade https://www.sepa.gov.rs/download/Kese_2021.pdf

[31] EU Commission: EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil" , COM(2021) 400 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827

[32] European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31994L0062

[33] Federici, S.; Ademovic, Z.; Amorim, M.J.B.; Bigalke, M.; Cocca, M.; Depero, L.E.; Dutta, J.; Fritzsche, W.; Hartmann, N.B.; Kalˇcikova, G.; et al. COST Action PRIORITY: An EU, Perspective on Micro- and Nanoplastics as Global Issues. Microplastics 2022, 1, 282–290. https://doi.org/10.3390/ microplastics1020020

[34] Guidelines for the value chain for the use of plastic packaging waste oriented towards a circular economy, GIZ, 2020. https://www.giz.de/en/downloads/giz2020-sr-smernice-za-lanac-vrednosti-orijentisan-ka-ce-plasticni-ambalazni-otpad.pdf

[35] Handbook of circular product design, UNDP, 2019, https://www.undp.org/sites/g/files/zskgke326/files/migration/rs/0fd7ec08950be00e373aaa4bc9273bd22611dc7c9591be79d30044cc451dee3e.pdf

[36] How can EU legislation tackle microplastic pollution, https://rethinkplasticalliance.eu/wp-content/uploads/2022/07/RPa-Microplastics-Position-Paper-July-2022.pdf

[37] Kaseke, T., Lujic, T., & Cirkovic Velickovic, T. 2023. „Nano-and Microplastics Migration from Plastic Food Packaging into Dairy Products: Impact on Nutrient Digestion, Absorption, and Metabolism.“ Foods 12 (16): 3043.

[38] Law on packaging and packaging waste, "Official Gazette of RS", no. 36/2009 and 95/2018 - other law

[39] Law on Waste Management ("Official Gazette of the Republic of Serbia", no. 36/2009, 88/2010, 14/2016, 95/2018 - other laws and 35/2023

[40] Lončarski, M., Gvoić, V., Prica, M., Cveticanin, L., Agbaba, J., & Tubić, A. 2021. „Sorption behavior of polycyclic aromatic hydrocarbons on biodegradable polylactic acid and various nondegradable microplastics: Model fitting and mechanism analysis.“ Science of the Total Environment 785 (147289).

[41] Lončarski, M., Tubić, A., Isakovski, M. K., Jović, B., Apostolović, T., Nikić, J., & Agbaba, J. 2020. „Modelling of the adsorption of chlorinated phenols on polyethylene and polyethylene terephthalate microplastic.“ Journal of the Serbian Chemical Society 85 (5): 697-709.

[42] Lujić, T., Gligorijević, N., Stanić-Vučinić, D., & Ćirković Veličković, T. 2023. „Investigation of structural changes in ovalbumin induced by two types of MPs and its impact on protein digestibility.“ XXII EuroFoodChem Congress. Belgrade, 16-16 june: Serbian Chemical Society. 153-153.

[43] Lujić, T., Gligorijević, N., Stanić-Vučinić, D., Bićanin, M., & Ćirković Veličković, T. 2023. „Impact of MPs on trypsin activity in simulated intestinal fluid.“ Serbian Biochemical Society Twelfth Conference, International scientific meeting,“Biochemistry in Biotechnology". Belgrade. 145-145.

[44] Markić, N. D., Bjelić, S. Lj., Ilić, P., Sustainable waste management. Panevropski univerzitet "APEIRON", Banja Luka, 2021.

[45] Ministry of Environmental Protection of the Republic of Serbia, Environmental Protection Agency, Report on packaging and packaging waste management in 2022, Beograd, 2023. http://www.sepa.gov.rs/download/Ambalaza_2022.pdf

[46] Mitrano, D.M.; Wagner, M. A sustainable future for plastics considering material safety and preserved value. Nat. Rev. Mater. 2022, 7, 71–73.

[47] Molnar Jazić, J., & Agbaba, J. 2021. „Adsorption mechanisms of chlorobenzenes and trifluralin on primary polyethylene microplastics in the aquatic environment.“ Environmental Science and Pollution 28 (42): 59416-59429.

[48] Petrović, M., Mihajlović, I., Tubić, A., & Novaković, M. 2023. „Microplastic in municipal solid waste landfills.“ Current Opinion in Environmental Science & Health. T. 31. br. 100428. 1-5.

[49] Prokić D, Ćurčić Lj, Stojić N, Pucarević M, Panin B, Mitić D. L: Circular economy as a mechanism for reducing plastic waste, Proceedings of the scientific conference: "Green transition in the economy - situation and perspectives", Sremska Kamenica, Novi Sad, 12. oktobar 2023. godine, str. 145-154. ISBN 978-86-82088-13-4

[50] Prokić, M. D., Gavrilović, B. R., Radovanović, T. B., Gavrić, J. P., Petrović, T. G., Despotović, S. G., & Faggio, C. 2021. „Studying microplastics: Lessons from evaluated literature on animal model organisms and experimental approaches.“ Journal of Hazardous Materials 414 (125476).

[51] Prokić, M. D., Radovanović, T. B., Gavrić, J. P., & Faggio, C. 2019. „Ecotoxicological effects of microplastics: Examination of biomarkers, current state and future perspectives. .“ TrAC Trends in analytical chemistry 111: 37-46.

[52] Proposal for a Directive amending the Water Framework Directive, the Groundwater Directive and the circular ecoDirective (26 October 2022) https://environment.ec.europa.eu/publications/proposal-amending-water-directives_en

[53] Proposal for a Directive of the european parliament and of the council concerning urban wastewater treatment (recast) COM/2022/541 final
EU Taxonomy for sustainable finance - Regulation (EU) 2020/852 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0541

[54] Protecting environment and health: Commission adopts measures to restrict intentionally added microplastics, Press release, 25 September 2023, Brussels https://ec.europa.eu/commission/presscorner/detail/%20en/ip_23_4581

[55] Reducing Marine Litter: action on single use plastics and fishing gear; Available at: https://circabc.europa.eu/ui/group/6e9b7f79-da96-4a53-956f-

e8f62c9d7fed/library/00ead6c8-85d9-47c4-91a5-91b91bc75b3e/details?download=true

[56] Regulation (EC) No 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products (recast) http://data.europa.eu/eli/reg/2009/1223/oj

[57] Regulation (EC) No 1935/2004 of the european parliament and of the council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:338:0004:0017:en:PDF

[58] Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 http://data.europa.eu/eli/reg/2019/1009/oj

[59] Regulation on determining the plan for the reduction of packaging waste for the period from 2020 to 2024 ("Official Gazette of the Republic of Serbia", No. 81/2020, No. 93/2023) https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/uredba/2020/81/3/reg

[60] Roadmap for circular economy in Serbia; https://www.ekologija.gov.rs/sites/default/files/2021-01/mapa-puta-za-cirkularnu-ekonomiju-u-srbiji.pdf

[61] Rulebook on the list of waste prevention measures ("Sl. glasnik RS", br. 7/2019)

[62] Stevanović Čarapina H, Jovović A, Stepanov J. LCA (Life Cycle Assessment) as an instrument in strategic waste management planning, Univerzitet Edukons, Sremska Kamenica 2010.

[63] Stojanović, Z., Drakulić, D., Veljković, F., Martinović, J., Todorović, A., Filipović, N.,& Guševac Stojanović, I. 2022. „Effects of single orally administrated different sized microplastic particles–acute toxicity study in adult male rats.“ In 35the ECNP Congress, 15-18 October 2022, Vienna, Austria. P-0244.

[64] Trumić, M., Trumić, M., Bogdanović G., Postupci reciklaže plastičnog otpada sa posebnim osvrtom na mehanički tretman. Reciklaža i održivi razvoj 5 (2012) 39 – 52.

[65] Tubić, A., Lončarski, M., Apostolović, T., Kragulj Isakovski, M., Tričković, J., Molnar Jazić, J., & Agbaba, J. 2021. „Adsorption mechanisms of chlorobenzenes and trifluralin on primary polyethylene microplastics in the aquatic environment.“ Environmental Science and Pollution 28 (42): 59416-59429.

[66] Tubić, A., Lončarski, M., Maletić, S., Molnar Jazić, J., Watson, M., Tričković, J., & Agbaba,. 2019. „Significance of chlorinated phenols adsorption on plastics and bioplastics during water treatment. Water.“ Water 11 (11): 2358.

[67] Tubić, A., Vujić, M., Gvoić, V., Agbaba, J., Vasiljević, S., Cveticanin, L., & Prica, M. 2023. „Sorption potential of microplastics for azo-and phthalocyanine printing dyes.“ Dyes and Pigments 209: 110884.

[68] Vujić, M., Vasiljević, S., Rocha-Santos, T., Agbaba, J., Čepić, Z., Radonić, J., & Tubić. 2023. „Improving of an easy, effective and low-cost method for isolation of microplastic fibers collected in drying machines filters.“ Science of The Total Environment (892).

[69] Waste management program of the Republic of Serbia for the period 2022-2031, Official Gazette of the RS, No. 29/10