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Microplastic Pollution in Freshwater – Regulatory Barriers for Better Water Protection[2]

Abstract

Water is an essential, limited natural resource, and yet its sustainability is being increasingly threatened by pollution, particularly from plastics. Rivers and lakes, as critical freshwater sources, are being heavily impacted by plastic waste, including microplastics, referring to tiny plastic particles that pose significant risks to aquatic life and water quality. Since water bodies often cross national borders, pollution in one region can have widespread consequences downstream, emphasising the need for coordinated international management and regulation in such contexts. Despite the rising awareness of plastic pollution, regulatory frameworks addressing microplastics in freshwater systems remain inadequate and fragmented. While global plastic production continues to rise, rivers continue to serve as major streams through which plastic waste gets transported from land-based sources to the oceans, making freshwater pollution a crucial but often overlooked contributor to marine pollution. However, the existing international agreements primarily focus on marine plastic pollution, leaving regulatory gaps in freshwater protection, and an international treaty regulating (micro)plastics remains to be developed. The existing international conventions relating to international waterways also do not regulate the problem of water pollution by (micro)plastics, and European and national regulations continue to be unsatisfactory. This paper explores the challenges of microplastic pollution in freshwater systems, focusing on regulatory barriers that hinder effective water protection. It examines the transboundary nature of water pollution, regulations of international watercourses, the limitations of existing legal frameworks, and the need for stronger international cooperation. By analysing key international conventions and policies, the paper highlights the urgency of establishing comprehensive regulatory measures that address microplastic contamination and safeguard freshwater

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ecosystems for future generations. The paper presents relevant provisions of international conventions, European legislation, and Croatian legal regulations.
Keywords: Freshwater, Microplastic, Pollution, Environment Protection, Legal Regulation.

1. Introduction

Water and its supplies are not unlimited, rendering responsible management of this limited natural resource crucial for the livelihood of future generations. Because pollution in one place can have far-reaching consequences for the entire flow of freshwater sources, primarily rivers, their protection is key and requires coordinated efforts of all countries through which they flow. Owing to the "large-scale water diversion, extraction, or loss"[3] of unpolluted water sources, many rivers and lakes can no longer sustain their natural ecosystems. Plastic pollution intensifies the problem by contaminating water bodies, further endangering aquatic life and disrupting fragile ecosystems.

Although plastic[4] has various practical applications, its durability and uncontrolled disposal pose a significant issue, particularly for marine and freshwater (e.g. rivers, lakes, groundwater) environments. The increasing production and widespread use of plastics have led to the accumulation of large amounts of plastic waste in nature. Global plastic production increased from 1.5 million tons in 1950[5] to more than 367 million tons in 2020, 55 million tons[6] of which were produced in Europe. According to the United Nations Environment Programme (UNEP), only 9% of the total plastic waste has been recycled so far, 12% has been incinerated, and the remaining 79% has accumulated in landfills or the natural environment.[7]

Plastic pollution in freshwater has become a major environmental issue owing to its harmful effects on aquatic ecosystems, water quality, and human health, as well as because plastic waste "may block waterways and cause hygienic problems and plastics-associated chemicals can enter drinking water resources".[8] Freshwater system protection is especially important because these systems serve as channels that carry plastic waste from land-based sources to the sea. In general, plastic waste in rivers originates from improper waste management, littering, industrial

3 | Boyle and Redgwell 2021, 571.
4 | Plastic is a material composed of a polymer, often combined with additives or other substances, serving as the primary structural component of final products. This definition excludes natural polymers that have not undergone chemical modification. See Art. 3, point 1 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, OJ L 155, 12/6/2019, 1–19.
5 | United Nations Environment Programme and GRID-Arendal 2016, 5.
6 | Plastics Europe 2021, 12.
7 | United Nations Environment Programme, n.d.a.
8 | United Nations Environment Programme, n.d.b.

activities, agricultural runoff, from ships, among others.[9] Specifically, land human activity-related waste can be carried into rivers and other waterways by surface runoff, wind, and through direct discarding or releasing into rivers. As rivers transport plastic waste and the journey from freshwater to sea is significantly shorter than the time required for plastic degradation, most of it ultimately ends up in the ocean.[10] Therefore, international watercourses are not only source of transboundary freshwater pollution but also significant contributors to marine pollution.[11,12]

Although extremely important, water plastic pollution is insufficiently researched and presented in the available professional and scientific literature. This has already been emphasised by researchers,[13] such as in Blettler et al.'s remark that freshwater plastic pollution literature "is still scarce and does not appear to be in accordance with global environmental priorities, endangered species, or social demands".[14] In most countries, data on freshwater plastics is fragmented and absent,[15] while it is difficult to estimate the amount of plastic waste that enters the seas through rivers. Despite these numerous limitations and different research models, Lebreton et al. estimated that between 1.15 and 2.41 million tons of plastic waste enter the ocean from rivers each year,[16] while Schmidt et al. estimated around 0.47 and 2.75 million tons annually.[17] Meng et al. highlighted in their review that existing information on microplastics in freshwater ecosystems remains fragmented, incomplete, and biased, as well as that research efforts have generally been directed towards rivers. Meanwhile, related research on other freshwater types (e.g. wetlands, lakes, and reservoirs) is reduced.[18] Furthermore, microplastics regulation continues to be inadequate.

Accordingly, this paper will focus on (fresh)water—referring here to rivers, lakes, groundwater, and other types of water bodies that differ from saltwater and the sea—plastic pollution. Water sources are usually shared between several states, such that river pollution in a country often does not remain within its borders but spreads downstream, endangering neighbouring countries' people, nature, and economy. This entails that freshwater pollution prevention responsibilities are shared and require international cooperation. Considering this international

9 | Chakraborty et al. 2022, 928; Wagner et al. 2014, 3.
10 | United Nations Environment Programme and GRID-Arendal 2016. Microplastics debris in Oceans have been identified as one of the emerging issues by the United Nations Environment Programme, n.d.c.
11 | As a one of the most important conventions related to the sea and sea protection, the United Nations Convention on the Law of the Sea does not explicitly refer to plastic pollution, but requires States "to prevent, reduce and control pollution of the marine environment from any source" (Art. 194(1)). United Nations Convention on the Law of the Sea, United Nations Treaty Series, vol. 1833, 3.
12 | Lebreton et al. 2017, 2.
13 | Azevedo-Santos et al. 2021, 1313; Blettler et al. 2018; Yuchuan et al. 2020; Wagner et al. 2014, 2.
14 | Blettler et al. 2018, 3.
15 | Ibid., 8.
16 | Lebreton et al. 2017, 3.
17 | Schmidt et al. 2017, 12251.
18 | Yuchuan et al. 2020, 11.

context, this paper will analyse the relevant international conventions and provisions of European and Croatian legal regulations regarding plastics, waste, and water. The paper will also attempt to identify solutions to reduce pollution caused by (micro)plastics.

2. Microplastics

In the context of plastic pollution, plastics vary from large remains, such as bottles and bags, to microplastics from the breakdown of larger items. Physical and chemical weathering break down these synthetic polymers into smaller fragments over time, increasing the number of particles within freshwater ecosystems.[19] Now, there is a problem with plastics classification: due to the various classifications available, authors often highlight challenges associated with inconsistencies in size classification,[20] making it difficult to compare data from different studies.

Plastics are most often categorised by size into nanoplastics, microplastics, and macroplastics, with mesoplastics and megaplastics sometimes also being mentioned,[21] however these categories have not been officially adopted and no standardised definition exists.[22] Most authors define microplastic as a fragment or particle of plastic smaller than 5 mm. Verschoor identified five commonly-applied criteria to define microplastic, as follows: "1. synthetic materials with high polymer content, 2. solid particles, 3. <5 mm, 4. insoluble in water, and 5. not degradable".[23] The European Union recognises this definition, with the "A European Strategy for Plastics in a Circular Economy"[24] describing microplastics as "tiny fragments of plastic below 5 mm in size". Microplastics pose a significant problem, especially because they can enter the food chain, posing health risks to humans. Although they will be discussed later, solutions to reduce plastic pollution, such as from microplastics, include waste reduction, better management, public education, and appropriate regulations.

2. 1. General overview of (micro)plastics legal regulation

Although reduced in terms of numbers, the legal regulation of plastics is varied, spreading from international conventions to other relevant documents.

19 | Azevedo-Santos et al. 2021, 1315.
20 | Andrady 2011, 1597.
21 | Compare: Morreale and La Mantia 2024, 3; Kasavan et al. 2021, 1; Bexeitova et al. 2024; Conti et al. 2021, 2; Wagner et al. 2014, 2; Brennholt, Heß, and Reifferscheid 2017, 256.
22 | Blettler et al. 2018, 12.
23 | Brennholt, Heß and Reifferscheid 2017, 256; Wagner et al. 2014.
24 | 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, COM/2018/028 final.

The following analysis will provide some key points. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes of 1989, which regulates the transboundary movement of hazardous waste,[25] was amended in 2019 (amendments to Annexes II, VIII and IX) and added provisions on plastic waste. "The introduction of provisions restricting the transfer of plastic waste is a major step in the international regulation of plastic waste and a good indication that states are ready and willing to work on solving this problem, especially considering that the Basel Convention has 188 parties."[26]

The inclusion of plastic waste in the Basel Convention "means that the transboundary movement of such waste is now subject to specific requirements, restrictions and prohibitions set by the Convention, for example, consent of the importing States".[27] In its Art. 9(5), this Convention obliges States Parties to introduce appropriate national legislation to prevent and punish illegal traffic.

The Stockholm Convention on Persistent Organic Pollutants[28] of 2001 aims to protect human health and the environment by eliminating or restricting the production, use, and distribution of persistent organic pollutants (POPs), which can be present in plastics along with other hazardous substances. Since, over time, environmental processes lead to the leaching and release of accumulated POPs from plastic wastes, this Convention is extremely important.

Two conventions primarily related to the protection of the sea should also be mentioned. First, the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78),[29] in its Annex V 'Prevention of Pollution by Garbage from Ships', prohibits ships from discharging plastics into the sea (Regulation 3(2)).[30] Second, Art. 4(1) of the Protocol of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter[31] from 1996 prohibits dumping of all waste or other matter into the sea, which certainly includes permanent plastics and other permanent synthetic materials. While addressing marine pollution from "vessels, aircraft, platforms, and man-made structures at the sea"[32] is essential, it is

25 | Basel Convention on the Control of Transboundary Movements of Hazardous Wastes, United Nations Treaty Series 1673, 57.
26 | Činčurak Erceg 2022, 147–148.
27 | Varvastian 2023, 642.
28 | Stockholm Convention on Persistent Organic Pollutants, United Nations Treaty Series, vol. 2256, 119.
29 | International Convention for the Prevention of Pollution from Ships (MARPOL), (1973 and Protocol 1978), United Nations Treaty Series, vol. 1340, br. 22484.
30 | It is prohibited to discharge all plastics into the sea, including, but not limited to, synthetic ropes, synthetic fishing nets, plastic garbage bags, and ashes of incinerated plastic products. Resolution MPEC.201(62).
31 | Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, United Nations Treaty Series 1046, p. 120. Protocol: 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.
32 | Art. 1(4)(1).

not enough in the fight against plastic pollution, as most plastic waste comes from land-based sources.

However, there is no single, comprehensive international treaty that uniformly regulates microplastics across all environmental compartments (i.e. freshwater, sea, soil, and air). In March 2022, the United Nations Environment Assembly adopted Resolution (5/14) "End Plastic Pollution: Towards an Internationally Legally Binding Instrument", which instituted an Intergovernmental Negotiating Committee to complete a draft of an international legally-binding agreement to end plastic pollution.[33] This Committee began its work during the second half of 2022, aiming to complete the negotiations by the end of 2024. After the fifth session in Busan, South Korea, failed to reach an agreement in December 2024, an additional session was scheduled for August 2025 in Geneva, Switzerland, to finalise the agreement. Key points of disagreement include limiting plastic production, managing plastic products and chemicals, and financing for developing countries to implement the agreement.[34] If successfully adopted, this 'Convention' could become one of the most significant international agreements on plastic pollution. According to the Scientists' Coalition for an Effective Plastics Treaty, the following key elements are essential for the success of a Global Plastics Treaty: a comprehensive scope, legally-binding reduction targets, chemical restrictions, microplastics and nanoplastics reduction, phase-out of non-essential plastics, harmonised sustainability criteria, adherence to waste hierarchy, transparency, reporting and monitoring, financial and technical support, and an independent science-policy interface.[35]

To address the global pollution problem and fight plastic pollution, the European Union has introduced various policies, strategies[36] and directives. The control of land-based pollution is primarily embodied in the regulations for solid plastic waste contained in the provisions of the Waste Framework Directive.[37] In 2019, Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment[38] ("Single-Use Plastics Directive") was adopted to reduce the environmental impact of certain plastic products, particularly in marine environments. The Directive targets the most commonly-found plastic

33 | United Nations Environment Assembly of the United Nations Environment Programme, Resolution adopted by the United Nations Environment Assembly on 2 March 2022, 5/14. End plastic pollution: towards an international legally binding instrument.
34 | Volcovici 2025.
35 | Scientists' Coalition for an Effective Plastics Treaty n. d.
36 | 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, COM/2018/028 final.
37 | Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, OJ L 312, 22/11/2008, pp. 3–30. Amended with Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, OJ L 312, 22/11/2008, 3–30.
38 | 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, OJ L 155, 12/6/2019, 1–19.

waste items on European beaches. While it mainly addresses macroplastic pollution, it also indirectly contributes to microplastic reduction by limiting plastic waste generation.

Various European water-related regulations also indirectly tackle the issue of (micro)plastics. The Water Framework Directive[39] aims to prevent the deterioration of inland surface waters, transitional waters, coastal waters, and groundwater in the European Union and achieve good ecological status.[40] Importantly, this Directive does not oblige Member States to take measures against waste in surface waters.[41] While it governs European inland waters, it does not explicitly mention plastic pollution. Still, it does require Member States to collect and maintain information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies in each river basin district are liable to be subject. This requirement makes microplastics relevant candidates for assessment, "especially because they might act as vectors for a wide range of freshwater contaminants".[42] According to Art. 23, Member States determine the penalties—which must be effective, proportionate, and dissuasive—for violating national provisions adopted in accordance with the Water Framework Directive. Ofak warns, nevertheless, that the Water Framework Directive is a hard-to-understand legal regulation with mainly complex and professional provisions.[43]

In October 2022, the European Commission proposed a directive amending Water Framework Directive,[44] aiming to proceed with the following measures: revise and expand the lists of pollutants impacting surface and groundwater; enhance the monitoring of chemical mixtures for more effective assessment; standardise the approach to addressing pollutants in surface and groundwater across the European Union, where applicable; enable quicker alignment of the legal framework with scientific advancements to better tackle emerging contaminants;

39 | Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 22/12/2000, 1–73. Amended several times.

40 | See Annex V of the Water Framework Directive.

41 | A water management system under the Directive must meet several key requirements. Management objectives are based on the overall ecological status of the waters, including biological, physico-chemical and hydromorphological factors. Member States must carry out analyses to assess the impact of human activities and classify water bodies according to their ecological status. All waters must achieve "good ecological status", or "good ecological potential" (for artificial and modified water bodies), or "good status" (groundwater). Water management is implemented through river basin management plans. These plans identify the characteristics of the river basin district, the pressures and impacts of human activities, and prescribe measures to improve the status of the waters and a monitoring system. Ofak 2018, 274.

42 | Wagner et al. 2014, 5.

43 | Ofak 2018, 273.

44 | Proposal for a Directive of the European Parliament and of the Council amending Directive 2000/60/EC establishing a framework for Community action in the field of water policy, Directive 2006/118/EC on the protection of groundwater against pollution and deterioration, and Directive 2008/105/EC on environmental quality standards in the field of water policy, COM/2022/540 final.

increase accessibility, transparency, and reusability of water quality data.[45] This proposal also targets microplastics, as the list of main pollutants is amended to include them, describing that microplastics should be included in the surface and groundwater watch lists and be monitored as soon as the Commission has identified suitable monitoring methods.[46]

The European Marine Strategy Framework Directive,[47] in its Art. 1(1), establishes a framework within which Member States shall take the necessary measures to achieve or maintain a good environmental status in the marine environment. In contrast to the Water Framework Directive, the Marine Strategy Framework Directive addresses marine litter with Descriptor 10 of Qualitative descriptors for determining good environmental status (Annex I). Additionally, Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment[48] in that sense describes litter and micro-litter. Several other directives relate to plastic, such as the Groundwater Directive, Environmental Quality Standards Directive, REACH Regulation, and the Directive on packaging and packaging waste. Varvastian stresses that in addition to not existing a global agreement specifically targeting plastic pollution, "nor does any single country have a comprehensive policy to reduce plastic pollution. Instead, there are fragmented regulatory actions that either limit the movement and disposal of plastic waste or prohibit specific plastic products or the chemicals used in their production. As expected, these measures have been ineffective".[49]

Varvastian further explains that the regulatory response remains highly fragmented, spread across various jurisdictions, sectors, and product categories. This fragmentation is further compounded by the lack of policy coordination between states, insufficient communication between states and international bodies, inconsistency in national and local policies, varying standards, numerous loopholes, inconsistent enforcement, and widespread illegal activities.

To conclude, although the Basel Convention, Stockholm Convention, and MARPOL Convention played a significant role in reducing plastics, their main goal is not to directly address the global plastic pollution crisis. A notable lack also persists of international agreements focused on facing this issue systematically.

45 | European Sources Online 2022.
46 | Ibid.
47 | 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), OJ L 164, 25/6/2008, 19–40.
48 | Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU, C/2017/2901, OJ L 125, 18/05/2017, 43–74.
49 | Varvastian 2023, 636.

While the European Union has taken significant steps to combat plastic pollution and progress has been made in this direction, a more integrated approach is needed.

3. Regulation of international watercourses

International water regulations are founded on the principle that States have national sovereignty over the water resources located within their territory or under their jurisdiction. The legal framework for international watercourses falls into two main categories: treaty law and customary international law.[50] As Seršić explains, the first international treaties on protecting and preserving the environment covered international rivers and lakes. After the Congress of Vienna in 1815, a series of international treaties were concluded that also addressed issues of river environmental protection. Later, express clauses directly related to pollution were included in international river treaties, and waste dumping into transboundary waterways was prohibited.[51] Nations have developed customary international law governing transboundary freshwater resources centred on the principle of equitable utilisation. The first comprehensive result of related legal frameworks was the 1966 Helsinki Rules on the Uses of International Rivers, established by the International Law Association, which summarises the customary international law on transboundary or internationally shared waters. In 1996, the Association began revising these rules to integrate principles from international environmental law and human rights law.[52] In 2004, the International Law Association adopted the Berlin Rules on Water Resources as a new authoritative summary of customary international law on water. Unlike previous frameworks, these rules applied not only to transboundary or international waters but to all water resources.[53]

Following the United Nations Conference on the Human Environment, held in Stockholm in 1972, two rules of general customary international law developed: a rule prohibiting states from polluting the environment, and a rule obliging states to cooperate in environmental protection.[54] According to principle 21 of the Stockholm Declaration,[55] states should ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or areas beyond the limits of their national jurisdiction. The obligation to cooperate implies acting in good faith, including by informing, consulting, negotiating, and assisting.

50 | Grzybowski, McCaffrey, and Paisley 2010, 140.
51 | Seršić 2003a, 14.
52 | Dellapenna 2006, 1.
53 | Ibid., 2.
54 | Seršić 2003b, 257.
55 | Declaration of the United Nations Conference on the Human Environment, 5.

Additionally, as pointed out by Seršić, one of the key principles is the prohibition of transferring damage from one area to another, which includes the prohibition of transforming one form of pollution into another.[56] River protection within international environmental law is also based on principles that apply to broader environmental protection.

International law governing shared watercourses is based on three key principles: equitable and reasonable use, prevention of significant harm, and cooperation through consultation and timely notification.[57] The most common ways in which international agreements promote the principle of prevention are through obligations for environmental impact assessment and monitoring.[58] The most well-known multilateral agreements of international water law are the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses of 1997 and the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes of 1992. Both tried to modernise the legal regulation on international watercourses. For the purpose of the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, a "watercourse means a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus",[59] and an "international watercourse means a watercourse, parts of which are situated in different States".[60] The term "transboundary waters", for the purposes of the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, means: "any surface or ground waters which mark, cross or are located on boundaries between two or more States; wherever transboundary waters flow directly into the sea, these transboundary waters end at a straight line across their respective mouths between points on the low-water line of their banks".[61]

Transboundary waters refer to surface water or groundwater that either crosses or is located on the borders between two or more states, and particularly emphasise geographic boundaries. A watercourse is a connected system of surface water and groundwater that forms a single hydrological unit due to the physical relationship between them, focusing on the interconnected water system. As stated by Carratta and Jaeckel, "both of them are theoretically applicable to plastic pollution".[62]

56 | Seršić 2003a, 16.
57 | Grzybowski, McCaffrey, and Paisley 2010, 141.
58 | Seršić 2003b, 253.
59 | Art. 2, point a.
60 | Ibid., point b.
61 | Art. 1(1).
62 | Carratta and Jaeckel 2023, 56.

3.1. Convention on the Law of the Non-Navigational Uses of International Watercourses

United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses is widely recognised as reflecting the core principles of customary international law in the field of watercourses. Art. 5 stipulates the obligation of Watercourse States to use the watercourse in their territory in an equitable and reasonable manner in order to achieve its optimal and sustainable use. Art. 7 obligates Watercourse States to take all appropriate measures to prevent significant harm to other Watercourse States. However, Art. 7(2) describes that if significant harm does occur, the state whose use caused the harm and the injured state should take appropriate measures to eliminate and mitigate the harm and negotiate compensation. Andrassy et al. outline that it is particularly controversial that it effectively obliges downstream coastal states to, at least in some cases, accept damage caused by upstream states that falls below the level of 'significant damage'.[63] What these descriptions show that is that the United Nations Convention on the Law of Non-Navigational Uses of International Watercourses centres on the relationship between the principle of equitable utilisation and the no-harm rule. As Dellapenna explains, Art. 7 appears to be subordinate to Art. 5, as completely avoiding harm in shared water use is nearly impossible, which leads the emphasis to be on balancing interests and ensuring reasonable and equitable management of transboundary water resources.[64]

In addition to Art. 20 of the Convention, which prescribes the obligation of Watercourse States to preserve and protect the ecosystems of international watercourses, Art. 21(2) requires States to "individually and, where appropriate, jointly, prevent, reduce and control the pollution of an international watercourse that may cause significant harm to other Watercourse States or to their environment, including harm to human health or safety". Art. 21(3) provides some details on the measures and methods to be employed in pursuit of this imperative. Pollution of an international watercourse is defined in Art. 21(1) as "any detrimental alteration in the composition or quality of the waters of an international watercourse which results directly or indirectly from human conduct". In our opinion, the term "human conduct" would also include plastics. Carratta and Jaeckel also conclude that when plastic pollution occurs in rivers, it appears to fulfil the criteria from Art. 21(1), but state that "the risks posed by plastics are still subject to debate within the scientific community, making it difficult to establish the requirement of 'significant harm' under this provision".[65] Clearly, the obligation under Art. 20 remains applicable. We agree with the statement of the aforementioned authors that this

63 | Andrassy et al. 2010, 201–202.
64 | Dellapenna 2006, 5.
65 | Carratta and Jaeckel 2023, 57.

obligation represents "an important advancement as it calls on riparian States to protect riverine ecosystems, including through international cooperation, and not only based on a mere prohibition of transboundary harm".[66] However, albeit the regulation facilitates and supports transboundary water cooperation, it does not include provisions regarding governance mechanisms or an authority to monitor its implementation.[67]

3.2. Convention on the Protection and Use of Transboundary Watercourses and International Lakes

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes[68] prescribes in Art. 2 that all Parties shall take appropriate measures[69] to prevent, control, and reduce transboundary effects. Where possible, water pollution should be prevented, controlled, and reduced at the source, without causing the transfer of pollution to other parts of the environment. The implementation of the Convention also shall not result in a deterioration of the state of the environment or an increase in transboundary effects. The general duty of riparian states to cooperate envisaged under the Art. 2(6) of the Convention includes interstate cooperation regarding the measures necessary to address land-based pollution. Of particular importance is the provision in Art. 2(8), allowing each Party, either individually or in cooperation with others, to apply more stringent measures than those prescribed by the Convention. This is similar to Art. 3 of the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses.

The Parties are obliged to develop, adopt, and implement appropriate legal, administrative, economic, financial, and technical measures to prevent, control, and reduce transboundary consequences, including the following points: prevention, control, and reduction of pollutant emissions at the source; protection of transboundary waters from pollution from point sources through wastewater

66 | Ibid.

67 | Scocca 2019, 196.

68 | United Nations Treaty Series, vol. 1936, 269. In 1999, the Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes was signed in London. The objective of the Protocol on Water and Health is to promote, at all appropriate levels, nationally and in transboundary and international contexts, the protection of human health and well-being, both individual and collective, within the framework of sustainable development, through the improvement of water management, including aquatic ecosystems, and through the prevention, control, and reduction of water-related diseases.

69 | According to Art. 2(2), the parties shall in particular implement measures aimed at: a) preventing, controlling, and reducing water pollution that may have cross-border effects; b) ensuring ecologically-sustainable and rational management of transboundary waters in order to protect water resources and the environment; c) providing fair and rational use of transboundary waters, considering their international significance and possible transboundary consequences of certain activities; d) preserving ecosystems and, when necessary, their restoration.

discharge permits and discharge monitoring; introduction of stricter restrictions or bans when the ecosystem so requires; application of best practices to reduce nutrient inputs from industrial and municipal sources; promotion of sustainable water resource management; contingency planning; minimisation of the risk of sudden pollution. Accordingly, it "promotes the application of the ecosystem approach as a key strategy for sustainable management of aquatic natural resources",[70] making this Convention suitable for solving the problem of plastic pollution. In its Art. 3(2), it prescribes that each Party shall establish emission limits for discharges from point sources into surface waters, taking into account the best available technologies, and may prohibit, in whole or in part, the production or use of hazardous substances in accordance with international regulations. Additionally, the Parties shall, where possible, define water quality objectives and criteria to reduce transboundary impacts and supplement them as necessary. According to Art. 4, the Parties shall establish programs for monitoring the conditions of transboundary waters.

Analysing the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Carratta and Jaeckel conclude that the obligations therein appear even more promising if applied to global plastics governance. In line with the goal to prevent, control and reduce marine environment pollution, riparian states must cooperate. They further explain that although the Convention primarily targets the protection of transboundary rivers and international lakes, it also recognises the significant impact of land-based human activities, which are crucial for plastic pollution. Therefore, this Convention can potentially provide broader protection than the Convention on the Law of the Non-Navigational Uses of International Watercourses. However, the adoption of bilateral and multilateral agreements remains important for effectively implementing the provisions of the Convention on the Law of the Non-Navigational Uses of International Watercourses,[71] since the Convention is of a framework nature.[72]

3.3. Transboundary water pollution and the need for international cooperation in addressing plastic pollution

Both the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes stipulate that States must prevent, reduce, and control the pollution of an international watercourse/waters that may cause significant harm to other watercourse/causing or likely to cause transboundary impact. They also prescribe the obligation of states to

70 | Carratta and Jaeckel 2023, 58–59.
71 | Carratta and Jaeckel 2023, 58–59; Boyle and Redgwell 2021, 580.
72 | Seršić 2003b, 272.

cooperate. However, under the Convention on the Law of the Non-Navigational Uses of International Watercourses, parties must only 'consider' the creation of the establishment of joint mechanisms or commissions.[73] Vukas points out that the basic provisions of specific treaties on land-based pollution do not contain precise legal obligations of states on issues of prevention, reduction and control of pollution from land-based sources, but rather plans for further cooperation in establishing specific obligations. The adoption of international rules, standards, recommended practices, and procedures in this area require more flexibility and persistence than activities related to other sources of pollution. This is due to differences regarding regional characteristics and state attitudes, rendering regional and subregional solutions potentially more easily achievable than global rules, standards, and practices.[74] Seršić similarly notes that states are more willing to accept obligations under regional treaties concerning the protection of rivers within their territories, as these directly impact their environment.[75] Vukas further emphasises that to strengthen legal frameworks on land-based pollution, it is crucial to go beyond the adoption of international norms and ensure that national laws among neighbouring states are aligned and unified. Additionally, the evolution of international law in this field should focus on rules and standards for pollution prevention, reduction, and control, incorporate principles of liability and responsibility, and consider the unique challenges of land-based pollution (e.g. difficulties in tracing pollution sources to specific damages). In contrast to the rules and standards adopted for pollution prevention, rules on liability should be global.[76]

Some of the most well-known river and freshwater pollution cases highlight the devastating consequences of industrial accidents on aquatic ecosystems and the urgent need for coordinated international response measures. While these cases generally involved chemical spills, an increasingly concerning transboundary pollution issue is the accumulation of plastic waste and microplastics in rivers and lakes. Unlike sudden industrial accidents, plastic pollution is a continuous and widespread problem. Since plastics often flow across national borders, plastic pollution in one state inevitably impacts neighbouring states, underscoring the need for international cooperation.

We can agree that the two main Conventions mentioned thus far (the Convention on the Law of the Non-Navigational Uses of International Watercourses and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes) can be applied to plastic waste, considering how this waste type is a significant contributor to water contamination with transboundary effects. Importantly, addressing water pollution, whether caused by hazardous

73 | Art. 8(2), Boyle and Redgwell 2021, 580.
74 | Vukas 2004, 257.
75 | Seršić 2003b, 250.
76 | Vukas 2004, 258.

chemicals or plastics, requires a comprehensive approach that includes political and legal measures to strengthen environmental regulations, reduce pollution at the source, improve waste management, and facilitate transboundary collaboration. Vukas also points: "The protection and use of transboundary watercourses and international lakes are important tasks, the effective execution of which can only be achieved through increased cooperation".[77]

River commissions, whose members are usually the states through which the rivers flow, play a key role in river environment protection since they enable interstate cooperation, shared water resources management, decision making, and the implementation of rules for the protection of rivers and their ecosystems. In Europe, examples include the International Commission for the Protection of the Danube River, the International Commission for the Protection of the Rhine, the International Commission for the Sava River Basin, each responsible for adopting international treaties regulating the environmental protection of rivers under their jurisdiction. Other relevant conventions for these rivers include the Convention on Cooperation for the Protection and Sustainable Use of the Danube River, the Protocol on the Prevention of the Water Pollution Caused by Navigation to the Framework Agreement on the Sava River Basin, and the Convention for the Protection of the Rhine. Worthy of note is that while the scope and subject of interest of this paper exclude more comprehensive examinations into these conventions, related analyses are warranted in future research.

Adopted in 1994, the Convention on Cooperation for the Protection and Sustainable Use of the Danube River aims to protect the waters of the Danube River from pollution, including hazardous substances, nutrients, and other pollutants that can adversely affect the aquatic ecosystem (Art. 5). Given that plastics, and particularly microplastics, are increasingly recognised as a serious pollutant of aquatic systems, measures under the Convention may also address (micro)plastic waste problems. In addition, the International Commission for the Protection of the Danube River, which implements the provisions of the Convention, has included microplastics in its research activities, and some State Parties have also carried out monitoring in their rivers.[78]

Environmental pollution causes high costs for those affected, which is why countries want to reduce pollution by establishing environmental protection goals and strategies. Specifically, there are goals associated with limiting waste disposal and the release of harmful emissions, setting production standards (especially in the chemical industry and fuel production) and wastewater discharge, monitoring regulation implementation, collecting various fees for environmental pollution, among others.[79]

77 | Činčurak Erceg 2013, 184.
78 | International Commission for the Protection of the Danube River n.d.
79 | Činčurak Erceg 2013, 165–179.

Because one of the primary destinations of microplastics are water systems, it is crucial to regulate industrial polluters and manage plastic products made and discarded on land to reduce plastic waste amounts reaching water bodies. Bexeitova et al. correctly conclude that interdisciplinary approaches and international collaboration are essential for sustainable solutions and freshwater ecosystem protection. They describe that effective microplastic pollution management requires strategies that consider regional conditions and pollution levels,[80] with improved control over drainage systems and more efficient waste management being essential measures. They add that addressing these matters requires global cooperation and regulations, as efforts in just a few countries will not suffice to reduce microplastics.[81] Accordingly, they remark that reducing the presence of microplastics in freshwater systems necessitates considerations of their sources and current global efforts, and that despite progress through national laws, international agreements, business actions, and technological advances, more coordinated worldwide efforts are needed.[82]

Moreover, because plastic waste continues to rise, it is necessary to reduce and eliminate it in affected areas. Recognising that the basis of plastic waste management is to reduce waste at the source, and considering the persistent and far-reaching effects of plastic pollution in watercourses, it is crucial to integrate plastic waste management into existing water protection frameworks. However, when waste cannot be entirely prevented, its effective management is necessary. In light of these remarks, and with the intention of mitigating waste and its environmental consequences, the European Union has set ambitious recycling and landfill targets, and is actively addressing packaging waste.[83] Specifically, the European Union adopted Directive (EU) 2019/904 on reducing the impact

80 | Bexeitova et al. explain that in countries with severe microplastic pollution, where large quantities of plastic waste are generated and often enter water systems, targeted measures are essential to mitigate pollution and prevent further environmental harm. Key strategies include establishing monitoring networks, conducting regular water quality control using advanced analytical techniques to detect and measure microplastics, and improving the infrastructure for plastic waste management and disposal. This may involve installing specialised filtration systems at treatment plants. Additionally, regulatory initiatives should be introduced to restrict single-use plastics and encourage the adoption of environmentally-friendly alternatives. In regions with moderate microplastic pollution levels, a balanced approach is needed that integrates systematic microplastic pollution monitoring with public awareness campaigns and technological innovations to reduce pollution. For regions with relatively low microplastic pollution, the emphasis should be on prevention and early detection. Efforts should focus on implementing proactive measures like restricting plastic imports, encouraging alternative material use, and setting up local monitoring programs to track changes in microplastic concentrations in water bodies. Bexeitova et al. 2024, 11–12.

81 | Bexeitova et al. 2024, 11.

82 | Ibid.

83 | See Waste Framework Directive, Regulation (EU) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC, OJ L, 2025/40, 22/1/2025.

of certain plastic products on the environment, aiming to reduce the negative impact of certain plastic products on the environment. This Directive includes a European Union-wide ban on certain single-use plastic products, which have importantly not caused difficulties for users seeing that there are suitable alternatives. However, it is important to ensure that banning single-use plastics does not lead to other negative consequences, especially considering that wooden products are being increasingly used instead of plastic.[84] Although the European Union has a comprehensive legal framework for environmental protection, the biggest challenge remains the application of related regulations in Member States. Unfortunately, infringements of environmental law represent the largest share of cases handled by the European Commission, making up approximately 20% of the total.[85]

As stated by Brennholt et al., regulatory measures to reduce microplastic emissions into freshwater environments do not necessarily have to directly target production or application, but can rather be focused on improving wastewater and solid waste management. Economic instruments for achieving these environmental objectives range from financial penalties to market-based mechanisms (e.g. tradable permits and financial incentives) to boost recycling rates. For example, introducing a container deposit system in several European countries has significantly increased recycling rates for plastic bottles and other beverage containers. Similar deposit systems could be extended to additional plastic products, such as packaging and carrier bags.[86]

Regardless of the potentials, states remain insufficiently implementing the existing regulations and often failing to fulfil their commitments. As stated earlier in this paper, there are many efforts toward developing and adopting a convention for plastics regulation, but we must also consider that both adoption and the process of entering into force will take time. Therefore, more short-term solutions should be sought through amendments to the existing legal frameworks, such as explicitly banning plastic pollution, incorporating and reinforcing prohibitions on plastic dumping from all sources into rivers, seas, and other bodies of water, explicitly mentioning plastics in waste-related regulations, monitoring for microplastics, and strengthening enforcement measures. While international, global, and regional approaches to addressing plastic pollution are all and each valuable, they are not sufficient alone, as national legislation and the effective implementation of these regulations remain extremely important.[87]

84 | Činčurak Erceg 2022, 165.
85 | European Commission n.d.
86 | Brennholt, Heß, and Reifferscheid 2017, 261.
87 | Činčurak Erceg 2022, 165.

4. Water protection and waste management in the Republic of Croatia

According to the available data, the Republic of Croatia has not participated in any projects or measurements of the amount of microplastics in Croatian waters[88] entailing the need for further research into the matter and assessing the impact of microplastics on freshwater ecosystems. According to current European and national legislation, there are no mandatory parameters prescribed for the measurement of microplastics levels in water and, accordingly, their presence is not measured in Croatia. Notwithstanding, the Republic of Croatia is a party to the following conventions: Basel Convention,[89] the London Convention[90] (but not the 1996 Protocol), the MARPOL 73/78 Convention and Annex V,[91] the Convention on the Protection and Use of Transboundary Watercourses and International Lakes,[92] the Protocol on Water and Health,[93] the Convention on Cooperation for the Protection and Sustainable Use of the Danube River,[94] Protocol on the Prevention of the Water Pollution Caused by Navigation to the Framework Agreement on the Sava River Basin.[95] It is not a party to the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses.[96]

According to Art. 52(1) of the Constitution of the Republic of Croatia, waters, as well as goods of particular ecological significance, which are specified by law to be of interest to the Republic of Croatia, are subject to its special protection. According to Art. 69 of the Constitution, "the State shall ensure conditions for a healthy environment. Everyone is obliged, within the scope of their powers and activities, to pay special attention to the protection of human health, nature and the human environment". Ofak points that Croatian legal theory considers that the Constitution protects the right to a healthy environment.[97]

88 | A good example of research on microplastics in water is the Interreg Danube Transnational Program Tid(y)Up, which dealt with the improvement of water quality and reduction of plastic pollution in Tisza. There is also research on plastic pollution and its effect on the Danube, in which Austria, Bulgaria, Hungary, Romania, Slovakia, Serbia, and Ukraine were involved. Interreg Danube Transnational Program Tid(y)Up, 2020.
89 | Basel Convention, Countries Status of Ratifications n.d.
90 | IMO, Status of Conventions n.d.a.
91 | IMO, Status of Conventions n.d.b.
92 | United Nations Treaty Collection, Status of Treaties Convention on the Protection and Use of Transboundary Watercourses and International Lakes n.d.
93 | United Nations Treaty Collection, Status of Treaties, Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes n.d.
94 | International Sava River Basin Commission, Contracting Parties n.d.
95 | International Sava River Basin Commission, Protocols to the FASRB n.d.
96 | United Nations Treaty Collection, Status of Treaties, Convention on the Law of the Non-Navigational Uses of International Watercourses n.d.
97 | Ofak 2021, 86. For the constitutional framework of Croatian protection of the right to a healthy environment see: Ofak 2021, 85–98; Staničić 2023, 143–145.

In the Republic of Croatia, the principles of environmental protection, along with the protection of its components (e.g. air, water, sea, soil, landscape, flora and fauna, and the Earth's crust), are regulated by the Environmental Protection Act.[98] According to Art. 5(5) of this Act, environmental protection issues not regulated by it, and relating to specific components of the environment, are subject to special regulations governing their protection or protection from specific forms of pollution. Accordingly, the Inland Waterway Navigation and Ports Act regulates the protection of inland waterways from pollution caused by vessels.[99]

The Water Act[100] transposes the Water Framework Directive, Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment, and Directive 2006/7/EC of 15 February 2006 concerning the management of bathing water quality into the national legal framework. The provisions of the Water Act apply to groundwater and surface water, including coastal waters and territorial sea waters, with regard to their chemical status, and prescribes that waters are a common good and are subject to special protection of the Republic of Croatia.[101] According to Art. 6(2) of the Water Act, waters are managed according to the principle of unity of the water system and the principle of sustainable development.[102]

As mentioned earlier in this paper, water management efforts with transboundary impacts are achieved through cooperation with other states, the conclusion and implementation of international agreements, notification of transboundary impacts on water and the freshwater environment, and the international exchange of information on water and the aquatic environment. The primary objectives of this type of cooperation in water protection issues are to prevent further deterioration, protect and improve aquatic ecosystem conditions, promote sustainable water use based on the long-term protection of available water resources, and better protect and improve the condition of aquatic environments (e.g. through

98 | Official Gazette of the Republic of Croatia, Nos. 80/2013, 78/2015, 12/2018, 118/2018.

99 | Official Gazette of the Republic of Croatia, No. 144/2021. The Inland Waterway Navigation and Ports Act regulates protection against pollution from inland waterway facilities (vessels and floating objects). In Art. 32(1), it prohibits the discharge and/or spillage of waste, objects, substances (i.e. harmful and dangerous substances), oil, oily water, and a mixture of such waste from water that may pose an obstacle or danger to the safety of navigation from inland waterway objects; plastic is not specifically mentioned, and waste is not defined either. It prohibits any activity that endangers the safety of persons or vessels, or pollutes the environment in the port (Art. 211). However, Art. 34(1) stipulates the obligation for the captain and crew members of a ship, and for professional workers on floating facilities and persons supervising a floating facility, to "comply with international, European and Croatian regulations and standards on protection against water and air pollution from inland waterways, regardless of the navigation area". It also stipulates that waste generated on the board of a ship, as well as cargo waste, must be collected and delivered to reception stations in ports or other places designated for the reception of such types of waste.

100 | Official Gazette of the Republic of Croatia, Nos. 66/2019, 84/2021, 47/2023.

101 | Art. 8 of the Water Act.

102 | The protection and use of waters is based on the precautionary principle, taking preventive measures, eliminating damage to the water environment at the place of its origin, and the principles of "polluter pays" and "user pays". Art. 6(5) of the Water Act.

specific measures to gradually reduce discharges, emissions and spills of hazardous substances).[103]

Considering the border and cross-border character of many Croatian waters, it is necessary to consider the obligations of multiple harmonisation and reporting as prescribed by bilateral or multilateral agreements. The Republic of Croatia has concluded bilateral agreements on water management relations with the Republic of Hungary,[104] the Republic of Bosnia and Herzegovina,[105] the Republic of Slovenia,[106] and the Republic of Montenegro.[107] Moreover, as stated in the River Basin Management Plan from 2022 to 2027,[108] the adoption of a bilateral agreement with the Republic of Serbia is being prepared. To enable the management of river basins in the territory of the Republic of Croatia, the Danube River Basin District and Adriatic River Basin District[109] have been established. According to the Water Act, relevant water management planning documents are the Water Management Strategy, the River Basin Management Plan, long-term construction programs, the financial plan of Croatian Waters, and the Water Management Plan.

Additionally, according to Art. 46(3) of the Water Act, water protection is achieved by engaging in the following efforts: adopting implementing regulations; monitoring water quality status and pollution sources; pollution control; prohibition of pollutant discharge into water and of other actions and behaviours that may cause pollution of the aquatic environment and the environment as a whole; wastewater treatment; other measures aimed at preserving and improving the quality and intended usefulness of water. According to Art. 49, it is prohibited to discharge or introduce hazardous or other pollutants into water and dispose of them in places in which there is a possibility of water and aquatic environment pollution. Supervision of the status of water is also carried out through systematic monitoring of the water status.

These analyses allow the conclusion that Croatia has a comprehensive legal and regulatory framework for water protection that includes international cooperation efforts regarding transboundary water management. However, there is no explicit

103 | Art. 46(1) of the Water Act.
104 | Agreement on water management relations between the Government of the Republic of Croatia and the Government of the Republic of Hungary, Official Gazette of the Republic of Croatia, International Agreements, No. 10/94.
105 | Treaty between the Government of the Republic of Croatia and the Government of Bosnia and Herzegovina on the establishment of water management relations, Official Gazette of the Republic of Croatia, International Agreements, No. 12/96.
106 | Treaty between the Government of the Republic of Croatia and the Government of the Republic of Slovenia on the settlement of water management relations, Official Gazette of the Republic of Croatia, International Agreements, No. 10/97.
107 | Agreement between the Government of the Republic of Croatia and the Government of the Republic of Montenegro on Mutual Relations in the Field of Water Management, Official Gazette of the Republic of Croatia, International Agreements, No. 1/08.
108 | Official Gazette of the Republic of Croatia, No. 84/2023.
109 | Art. 34(1) of the Water Act.

mention of (micro)plastics or specific regulations addressing their discharge into water bodies. The general prohibition on discharging pollutants (Art. 49) and the commitment to reduce hazardous substances in the aquatic environment could imply that microplastics are regulated under these broader pollution control measures. While microplastics are not explicitly listed, they are increasingly being recognised as pollutants and hazardous due to their persistence and potential toxicity. Connectedly, Boyle and Redgwell state that "the modern trend is to require states to regulate and control river pollution, prohibiting only certain forms of pollutant discharge, and distinguishing between new and existing sources". Accordingly, the contemporary focus is on broader issues of environmental protection.[110] Nevertheless, according to the policy recommendation from the Interreg project "City Water Circles", Croatia lacks not only relevant legislation but also guidelines, standards, and other relevant measures on water reuse and recycling, and the Croatian water sector lags considerably behind European Union standards.[111]

In 2021, the Waste Management Act[112] was adopted, prescribing measures to protect the environment and human health by preventing or reducing waste generation, the negative effects of waste generation, and improving waste management. It also prescribes measures to prevent and reduce the impact of certain plastic products on the environment, particularly the aquatic environment, and human health, as well as to promote the transition to a circular economy (Art. 1(4)). Additionally, an Ordinance on packaging and waste packaging, single-use plastic products and fishing gear containing plastic[113] was adopted, containing rules on the Waste Management Fee and the Refundable Fee System (deposit refund). Still, the Waste Management Act does not apply to wastewater, "to the extent prescribed by other regulations" (Art. 3(2)(1)). According to Art. 5(1), waste management must be carried out in a way that does not endanger human health nor leads to harmful environmental consequences, and should particularly not cause risks of pollution to the sea, water, soil, and air, as well as not endanger biodiversity. Art. 5(2) emphasises that the prevention of pollution of the sea, water, soil, and air and the preservation of biodiversity in the context of waste management is achieved through the application of regulations governing spatial planning, construction, protection of the environment, nature, and water, as well as the protection of the sea from pollution of maritime objects. Some of the key obligations of waste producers and holders include a ban on dumping waste into the environment (Art. 18); mandatory waste categorisation (Art. 19); an obligation for waste producers or holders to ensure waste treatment (Art. 21); an obligation to separately collect different types of waste, including hazardous waste, paper, metal, plastic, glass, bulky waste, textiles, footwear, packaging, and special categories of waste (Art. 22). The Waste

110 | Boyle and Redgwell 2021, 581–582.
111 | Interreg 2021, 9.
112 | Official Gazette of the Republic of Croatia, Nos. 84/2021, 142/23.
113 | Official Gazette of the Republic of Croatia, No. 137/23.

Management Act also regulates extended producer responsibility (Art. 91–98). The adoption of this Act seeks to reduce the negative impact of certain plastic products on the environment, which also contributes to reducing water pollution. In 2023, Croatia's recycling rate rose by two percentage points compared to 2022, reaching 36%, but the country still has to reach the 50% target set by the Waste Framework Directive. Also in 2023, 282 recycling yards were in operation, and the recovery rate stood at 38%; the trend of increasing separately collected municipal waste continued, reaching 48%; the municipal waste disposal rate in 2023 was 52%, but it must be reduced to just 10% by 2035.[114]

The Republic of Croatia has harmonised its legislation with the European Union's directives, and is a party to the most important international treaties. However, as Seršić points, the enforcement of international legal rules is the weakest point of the existing international environmental protection efforts.[115]

5. Conclusion

Plastic pollution has gained significant global attention, emerging as a pressing contemporary challenge on the international agenda. Plastic pollution in freshwater ecosystems has often been overlooked, despite plastics being the primary pollutants in these ecosystems, especially near urban areas. At the international level, existing frameworks like the Stockholm Convention, Basel Convention, and MARPOL provide some regulation of plastics, but still lack specific provisions addressing freshwater microplastics. The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses and the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes do not explicitly mention plastic pollution, but are in wider sense applicable to plastic pollution through principles of cooperation, prevention, and pollution control. Strengthening these frameworks, like by integrating microplastics into monitoring programs, setting specific plastic pollution targets, and enhancing enforcement, would improve their effectiveness in combating freshwater plastic pollution.

Microplastics regulation still faces several challenges. A major matter is the lack of a uniform international framework, as most existing agreements primarily address marine plastic pollution while neglecting microplastics in freshwater environments. Additionally, microplastics monitoring and the enforcement of related regulations remain difficult due to their size and widespread occurrence, making their detection and management a particularly complex task. Consequently, addressing transboundary water pollution, particularly (micro)plastic

114 | Environmental Protection and Energy Efficiency Fund 2024.
115 | Seršić 2003a, 10.

pollution in freshwater systems, requires a comprehensive and coordinated approach. Additionally, the principles of transboundary pollution (e.g. prevention, precautionary principle, the duty to cooperate, and the "polluter pays" principle) must be reinforced through legal, economic, and cooperative mechanisms. Therefore, strengthening legal frameworks, improving enforcement, and fostering international cooperation will be key to mitigating this environmental challenge.

There is a pressing need for a binding international treaty on plastics to close regulatory gaps and ensure effective pollution control, while those already existing should be strengthened by introducing stricter obligations, clear pollution limits, and robust legal frameworks for polluter liability. Additionally, enhancing monitoring and reporting systems, intensifying enforcement, and reinforcing the role of river commissions can help improve transboundary water pollution management. Addressing freshwater pollution at its source will also significantly benefit the global marine environment. Integrating freshwater protection into the existing marine and waste policies, particularly within the European Union, can also contribute to reducing plastic pollution from sources to sea. Policy measures should address freshwater microplastic pollution with the same urgency and commitment as marine microplastic pollution.

Despite existing regulations at the European Union level, significant challenges remain due to regulatory gaps, a lack of enforcement, economic pressures, and public behaviour. Although the Single-Use Plastics Directive and the Circular Economy Action Plan relate to plastic waste, specific water pollution regulations are missing. The Water Framework Directive also does not explicitly regulate microplastics and national-level solutions vary, leading to inconsistent implementation. Expanding the Water Framework Directive to include microplastics as priority pollutants with strict reduction targets and mandatory monitoring across all river basins is essential. The current lack of adequate monitoring systems makes it difficult to track plastic pollution and generate reliable data on microplastics in freshwater ecosystems. Therefore, it is necessary to develop a standardised freshwater protocol for sampling, analysis, and result interpretation to improve the monitoring of freshwater microplastics and identify pollution sources. Since identifying the primary sources of pollution is often a challenge, this is still a key task, one that will require integrated, comprehensive, and cross-sectoral approaches to ensure the realisation of measures to effectively address the microplastics problem.

However, regulatory measures alone will likely be insufficient, as public engagement and behavioural change are also necessary for successful enforcement. Encouraging proper waste sorting, promoting reusable plastic products, and implementing educational initiatives are important steps in reducing plastic pollution. Another critical matter is institutional support, which should be afforded to public engagement and civil society pollution mitigation initiatives to secure their long-term success. Organised, community-driven efforts such as river clean-ups

can further strengthen public participation. Strengthening penalties for improper plastic waste disposal; prioritising prevention by reducing the overall use of plastic products; promoting the reuse of manufactured products to support circular economy and industrial symbiosis are crucial to increase enforcement to achieve the set objectives. Enhancing waste management is also very important seeing that recycling rates remain low. Harmonising waste collection systems across the European Union will help reduce pollution. Industries generating plastic waste must be held responsible through Extended Producer Responsibility schemes.

Future research should focus on enhancing the effectiveness of existing policies, developing innovative plastic waste management technologies, assessing the long-term impacts of microplastics on human health and ecosystems, analysing the liability for damage, assessing various national measures to reduce plastic pollution. By reinforcing legal frameworks, harmonising regulations, strengthening international cooperation, and fostering public engagement, we can effectively mitigate plastic pollution in freshwater ecosystems and marine environments, as well as prevent long-term environmental degradation.

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