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MANAGEMENT OF PLASTIC WASTE PROCESSING AND RECYCLING IN WATER POLLUTION REDUCTION

Nikolay Dolchinkov *
Vasil Levski National Military University,
Veliko Tarnovo, Bulgaria
ORCID iD: 0000-0002-6171-6083

*Corresponding author:
E-mail: n_dolchinkov@abv.bg

Introduction. Plastic decomposition is an exceptionally protracted process, requiring urgent measures to reduce environmental pollution, including that of water resources. Current solutions include increasing measures to sort and recycle plastic waste and developing biodegradable and environmentally friendly substitutes. Although plastic is recyclable, not all types are easily recycled. Therefore, most significant efforts are needed to find sustainable solutions. This highlights the importance of analysing the current situation regarding plastic waste and developing specific measures to reduce pollution.

Aim and tasks. This study aims to analyse the concern of increasing plastic waste in Bulgaria and to develop strategies for its reduction. In particular, measures to reduce the consumption of plastic products, introduce separate waste collection, and recycle and reuse valuable raw materials are considered, emphasising the contribution of these actions to reducing water resource pollution.

Results. This study analysed two main pollution control areas: limiting plastic use and introducing rapidly degradable materials. These approaches do not exclude but complement each other. This study confirms that using biodegradable polymers such as PLA, PHA, and PBS has significant environmental benefits despite their cost and the disadvantages of production technologies. Effective solutions to pollution problems have been shown to require legislative measures and innovations, raising public awareness, and developing a culture of separate waste collection. The research and analysis revealed ways to reduce the pollution of water bodies with plastic and polyethene waste. The effects of this waste on the development of humanity have been examined, and options for solving these problems on a global scale have been proposed.

Conclusions. Plastic products and packaging have a significant negative impact on the environment, including reducing pollution of water and marine ecosystems. It is necessary to improve the efficiency of plastic waste management and recycling. Analysis of these data on the pollution of water bodies and adjacent territories showed the need to develop a system for monitoring and collecting information on pollution, including in hard-to-reach areas. To reduce this impact, it is important to combine limiting plastic consumption and using rapidly degradable bioplastics with the active implementation of recycling and reuse programs.

Keywords: Plastic Waste, Water Bodies, Environment, Pollution, Conservation, Recycling.

1. Introduction.

Plastic products play a significant role in the modern development of humanity, technical progress, and the development of the economy. The positive aspects of plastic use can be indicated, the most important of which are highly flexible materials that can be moulded into various shapes and sizes. This makes them suitable for various packaging, electronics, automotive, medicine, and food applications. Plastic is versatile and inexpensive, making it economical for mass production and indispensable in transporting and storing goods. Plastic products also play a key role in medicine and the food industry.

According to Dolchinkov (2024), Marinov (2024), and Vassilev (2005), packaging is durable, lightweight, and convenient for transportation. Automatic collection points for used plastic packaging have been established in many countries. Along with the positive qualities of this packaging, plastics also have negative aspects when using them, the most significant of which are the following:

1. Plastic is a major source of pollution, especially in oceans, where it can break down into microplastics and harm marine life (Vasiliev et al., 2023; Lazarov (2018).

2. Plastic products are persistent over time, and the degradation of their molecules is extremely slow. This leads to the accumulation of these products and waste as litter, and environmental problems arise on continental surfaces and ocean waters. These problems accumulate over time and worsen; therefore, finding a sustainable solution is necessary.

The primary industries that use plastic products the most can be defined as follows (Nikolov, 2020):

1. Plastic components are the primary materials used to produce various types of packaging, including bottles, buckets, containers, bags and foils (Poisa & Adamovich, 2012).

2. According to the automotive industry, many components are made from plastic, which helps reduce the weight of cars and improve their ergonomics, leading to lower fuel consumption and operating costs (Platace & Poisa, 2012).

3. Electronics, as one of the branches of the economy that has developed extremely rapidly in recent decades, is also a major user of plastic products.

4. According to Anguelov et al. (2023), plastic plays an important role in modern medicine and acts as an indispensable material for the creation of disposable and reusable devices necessary for treatment and diagnosis.

5. Plastics are used in construction to produce pipes, insulation materials, windows, and doors. Plastics are corrosion-resistant, can replace metal products, and have a long life.

6. Consumer goods that have become integral to human lives in recent decades are increasingly made of plastic.

2. Literature Review.

All of the industries listed, and others not mentioned, rely on plastics because of their unique properties and wide application, according to Stanchev (2024). However, it is important to work on sustainable solutions to reduce the negative impact of plastics on the environment, because enough damage has already been done to nature, according to Simeonov and Marinov (2024).

Plastics are used to produce sterile medical devices and in healthcare, as indicated by Vambol S. et al. (2024), Popov et al. (2021), Stoykov (2019) and Poysa et al. (2015).

Plastic products have serious drawbacks, mainly related to environmental pollution. The slow decomposition of plastics leads to their natural accumulation. This problem is acute in ocean waters because small particles of these products are obtained from the mechanical impact of waste. Marine inhabitants easily swallow these particles, and once they enter their digestive system, they cause irreversible problems in metabolism and lead to a lethal outcome.

Oil is the primary raw material for producing plastic products, and the Earth's resources are finite.

Although plastics can be recycled, the process is often complex and not all types of plastics are easily recyclable. This is one of the areas with the most significant development prospects.

In many countries, in addition to separate waste collection, a fee has already been introduced for the purchase of plastic packaging, providing the opportunity for its redemption. Plastics are an integral part of modern life, have numerous applications that make our daily lives easier, and their presence around us constantly increases, according to Marinov et al. (2019) and Ilieva et al. (2019). However, it is important to find sustainable solutions to reduce their negative impacts on the environment and health, because measures must be taken before it is too late and irreversible.

Plastic products have replaced many other raw materials over the last century. However, humanity now sees a need to limit the use of plastic products and return to proven materials or create new, environmentally friendly plastic products, according to Koynakov (2021). Time-tested materials such as glass and metals, which can be recycled indefinitely, are used as eco-friendly alternatives to plastic. Renewable resources are also being introduced: paper, bioplastics, natural fibres, and bamboo.

Using alternatives to plastic, such as glass and paper, helps reduce environmental pollution.

1. Reducing single-use plastic products in favour of reusable ones. European countries are already introducing legislation supporting the transition to more environmentally friendly packaging, such as glass.

2. It is necessary to avoid plastic packaging consciously. When choosing a product, choosing products with minimal or no plastic packaging is good.

3. It is necessary to increase the recycling rate of plastic products. Consumers must be confident that they are recycling all plastic waste correctly.

4. Supporting sustainable companies is also important in limiting plastic waste. It is necessary to support companies that use environmentally friendly packaging and reduce plastic waste. Such campaigns are periodically organised in European countries, but this work should not be based only on campaigns, but should be permanent, and people should realise its importance

5. Using alternative materials as a producer or as a consumer. It is necessary to choose products made of glass, metal, paper or bioplastics, which are more environmentally friendly and do not pollute the environment to such an extent.

6. Awareness of humanity and acquisition of the necessary education regarding the use of resources. It is necessary to inform oneself and others about the importance of reducing plastic waste, as indicated by Koynakov (2025) and Yotkov et al. (2021).

Recycling not only helps reduce environmental pollution and conserve natural resources, but also creates new economic opportunities and has a positive impact on the quality of life of society Vassilev et al. (2023) and Nedev (2024).

To present the benefits of waste recycling, a flow chart (Fig. 1) was drawn up, reflecting the main environmental, economic and social aspects, as well as their interrelations.

Recycling stimulates the national economy by creating new business opportunities and reducing waste management costs, according to Anguelov and Angelova (2023) and Pavlov (2019).

Pollution monitoring is done to measure the concentrations of plastics and microplastics in different environments such as water, soil and air as indicated by Poiša L. et al (2015), Popov et al. (2021) and Petlyankov (2024a).

Popov et al. (2021) and Petlyankov (2024b) point out that economic analyses assess the economic costs and benefits of different plastic waste management strategies.

According to Minevski (2018), the living body and its systems cannot process small plastic particles, and this can disrupt the functioning of these systems, leading to failure of individual organs, cessation of their normal functioning, and even death if emergency medical care is not provided.

Research shows that the most harmful are polyvinyl chloride (PVC), which contains phthalates and bisphenol-A, polystyrene (PS), which releases the potential carcinogen styrene, and polyethene terephthalate (PET), which can release toxic antimony.

There is a global trend for manufacturers to reduce the production of single-use plastic products and use more environmentally friendly materials instead (Stefanova et al., 2023).

These measures encourage a better understanding of plastics' environmental impact and developing effective strategies to address the problem.

This approach is still not used well enough, and regulatory documents are circumvented by exporting production to other countries where the legislation is not as strict and then importing the production back, according to Padarev (2024). European countries have conducted active information campaigns on the separate collection and recycling of waste.
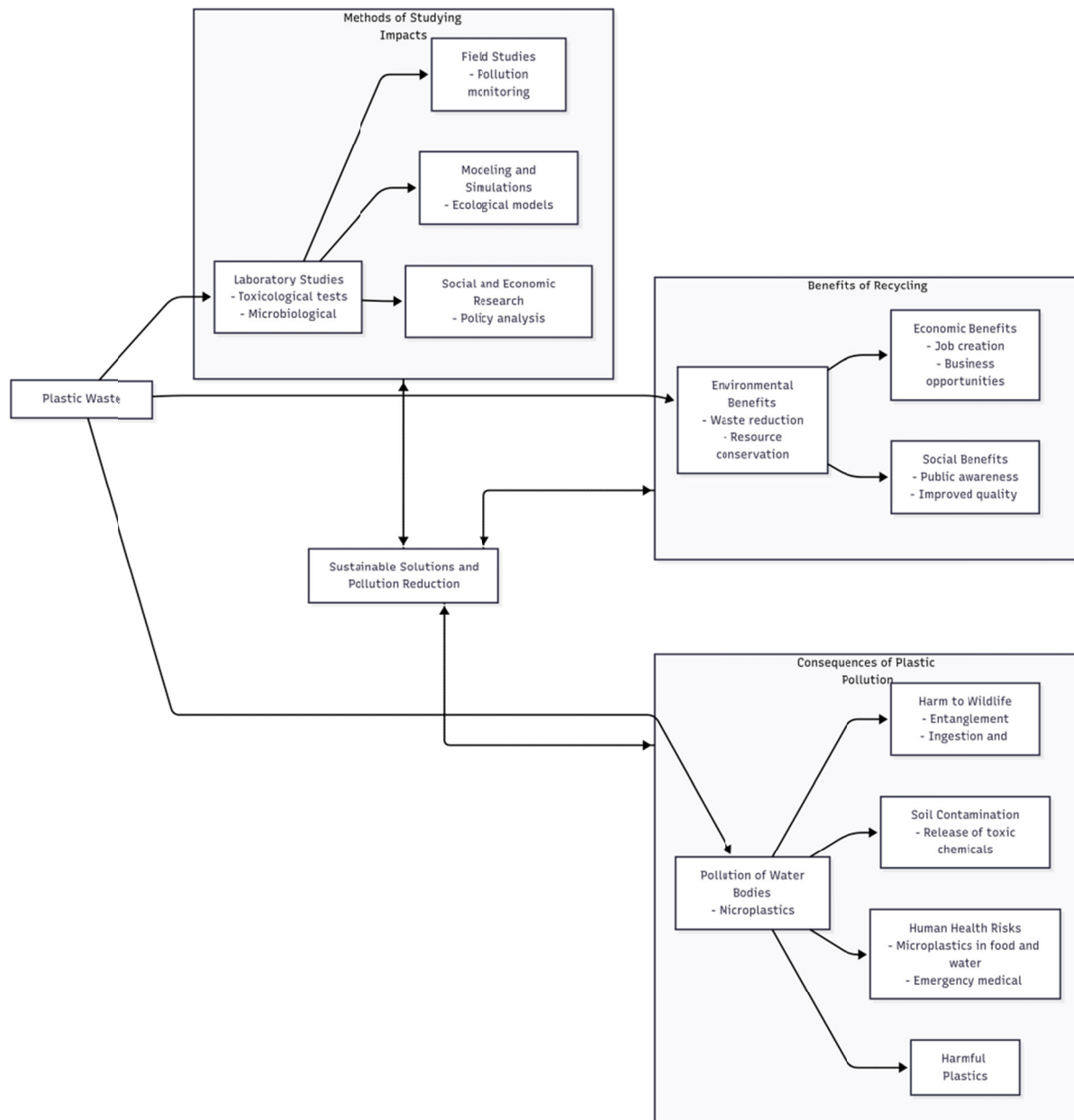
Fig. 1. Pollution Effects and Benefits of Plastic Recycling in a Sustainable Development System.

3. Theoretical Framework.

The pollution of water bodies and adjacent territories, along with plastic and other slowly decomposing waste, requires systematic control measures. The first objective of this study was to limit the pollution of water bodies and adjacent territories with plastic and other slowly decomposing waste.

In parallel with pollution reduction, the second objective of this study was to develop a pollution control system that integrates autonomous vessels for water-surface monitoring and aircraft for aerial surveillance. This combined approach allows for more comprehensive monitoring of territories and minimises blind spots when relying on a single type of observation.

The developed model for collecting information uses two main types of information collection with auxiliary independent means:

The first method of collecting and transmitting information is using an autonomous floating vehicle, which collects information directly from the water surface and coastline. The floating vehicle is amphibious, and at low water levels or in the presence of small obstacles, it can overcome them by moving along the bottom of the water body.

The second method involves independent flying vehicles, such as drones, which film and transmit information from the air. Both methods of collecting information envisage collecting information using video cameras and collecting information on a medium on the device itself. Simultaneously, the information will be transmitted to the information centre in the presence of a mobile network and a quality Internet connection.

Since unregulated landfills are made in hard-to-reach places, where there is usually no good Internet communication, it is envisaged that the information will be collected on a medium on the device itself and, if possible, transmitted. From the perspective of collecting information, the collected data can be downloaded from the device itself after monitoring is completed. Each type of monitoring has its own specifics for monitoring environmental pollution.

Combining several methods to obtain the most accurate and objective picture possible is good. Although still in its infancy, these technologies have already been applied to implement and manage several successful projects. In the municipality of Yambol (Bulgaria), drones are used to monitor unregulated waste disposal and the formation of landfills, according to Dolchinkov (2025). These drones are equipped with cameras and other sensors for effective monitoring purposes. However, there are no known cases of the successful implementation of similar projects in other municipalities.

However, the first successful applications will provide an impetus for these new methods to detect illegal landfills around water bodies. These technologies and methods allow for the rapid and effective detection of waste dumps, which helps manage waste better and protect the environment. With regular monitoring, such unregulated landfills can be detected early, and their growth can be prevented.

The benefits of regular environmental monitoring may be many, but the most important can be systematised as follows:

• Early detection of unregulated landfills and pollution.

• More effective waste management and nature conservation are needed.

• Saving time and resources through automated monitoring.

• Possibility of periodic control and rapid response to environmental changes.

When conducting the study, publicly accessible places will be used, and prohibited and restricted areas for which additional permission is requested will not be explored. If there is information about pollution in such areas, the necessary access permit will be requested, and an appropriate survey will be conducted. Other restrictions regarding territories are not allowed.

The survey mainly focused on plastic and other slowly decomposing products, and waste of other nature was reported as pollutants. However, this will not be the main objective of the survey. Plant waste will not be reported as it is not an environmental pollutant.

4. Results.

Based on the global experience of the last few decades of increasing use of plastic and other non-degradable products and the ever-increasing plastic waste, two main trends are required to limit environmental pollution. The first is to limit plastic products and packaging use in practical applications and the second is to create new plastics with a short service life before they degrade. Both directions, limiting the use of plastics and rapidly degradable plastics, have advantages and can contribute to reducing environmental pollution. The key aspects of each are as follows:

1. Limiting the use of plastics.

• Limiting the use of plastics leads to less waste that needs to be managed and recycled.

• Fewer plastic products in use means less pollution of the oceans, rivers, and soil. This will lead to a cleaner environment for future generations.

• Promoting using plastics that can be recycled and reused as raw materials to produce everyday, household, and economic products. Thus, this raw material can be used repeatedly and will not pollute the environment.

• Promoting reusable items and reducing plastic packaging can lead to more sustainable consumer habits. This can be achieved by issuing relevant regulatory documents, monitoring compliance, and encouraging and punishing the population as needed.

2. Use of plastics based on rapidly degradable components.

• This type of plastic can degrade more quickly in nature, which reduces the time during which it has a direct impact on the environment. Due to their shorter life, they do not have such an impact on soil and water.

• Raw materials that can be recycled and reused repeatedly are used to produce these plastics. They do not contain toxic ingredients, which is why they are much safer for living organisms' health and environmental protection.

• The use of rapidly degradable plastics can support the development of a circular economy (Angelov & Angelova, 2021; Brand Media Bulgaria, 2025), where materials are recycled and reused.

No clear preference can be given to either method for limiting environmental pollution because each method has its advantages and disadvantages, and no clear-cut answer can be given. The optimal solution will probably involve a combination of both strategies, and in each case, the weight of each proposed combination of the two methods must be weighed. The use of plastic is prevalent, but we should strive to limit its use and reduce the total amount of waste and pollution. In contrast, using biodegradable plastics and reusing raw materials in production can reduce the time plastics remain in the environment and have an economic effect by reducing the use of raw materials. Sustainable consumption habits for other types of packaging should be encouraged, and investments should be made in recycling, reuse, and waste management technologies.

Based on the experience gained in Bulgaria and around the world, numerous examples of biodegradable plastics can be cited, the use of which has become established and has shown its effectiveness:

• PLA (polylactic acid) is produced mainly from renewable resources, such as corn starch, and is used to produce packaging, disposable utensils, and other products. A positive quality is that it is compostable under the appropriate conditions.

• Polyhydroxyalkanoates (PHAs) are produced by bacterial fermentation of biological materials and are mainly used in medical products, systems, and packaging. They are biodegradable for short periods of degradation, and this process occurs naturally in the environment.

• Polybutylene succinate (PBS) is biodegradable and is used to produce packaging, stretch films, and agricultural films.

In Bulgaria, as in many countries in Europe and around the world, there has been growing interest in using biodegradable plastics since the beginning of the 21st century. Some companies and organisations have used these materials in their products and packaging for 10 years. For example, PLA plastics are used to produce biodegradable disposable cups and utensils, which are available in some stores and restaurants.

However, practice proves and imposes limited use of this type of raw material, as some of the components hinder its recycling and reuse of this raw material.

Therefore, in recent years, there has been a shift from plastic products to paper, pressed cardboard or wooden products, significantly reducing the pollution burden on the earth's surface.

Using plastics made with rapidly degradable components is an important step towards reducing environmental plastic pollution. The main categories of garbage in the world's oceans by type of product are shown in Figure 2. According to Eurostat (2024), in 2022, the EU produced 186.5 kg of packaging waste per capita, while in Bulgaria it was 78.8 kg per capita.
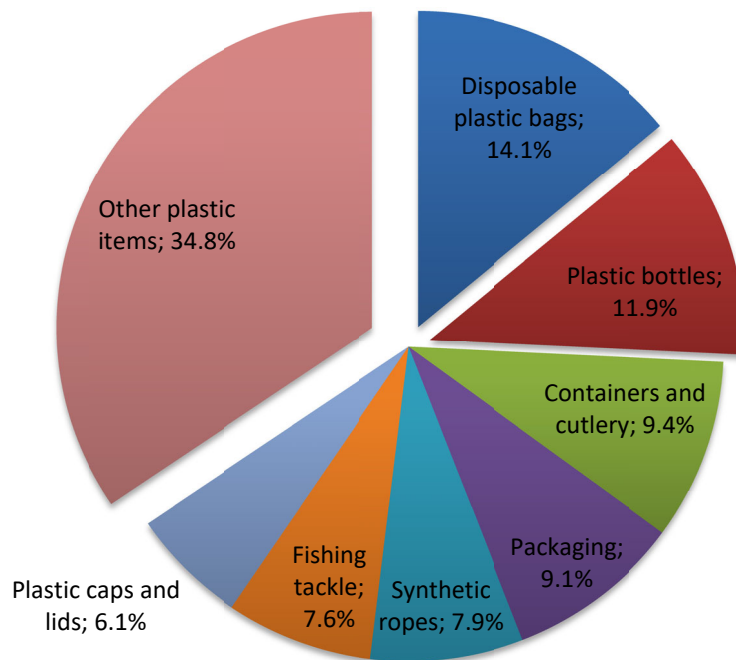
Fig. 2. Structure of plastic waste found in the oceans, % (2021).
Source: base on Carmen Morales-Caselles et al. (2021).

Many countries have adopted measures to reuse this raw material, and the recycling of plastic products is applied much more widely, with manufacturers being obliged to buy back the products and packaging produced. However, a regulatory framework that aligns with modern trends in societal development and environmental protection is needed to achieve better results. It is also important to change thinking and consciously use this type of production, and its recycling and secondary use. The advantages of polylactic acid (PLA) can be summarised in several directions.

• Environmentally friendly, because it is biodegradable and produced from renewable resources such as corn starch, bio-raw materials, and sugar cane.

• Easy to process because it has a low melting point (190–220°C), making it suitable for 3D printing and other applications.

• Minimal deformation because it cools quickly and evenly, reducing the risk of part deformation.

• Wide colour range of products, because they can be offered in many colours and special effects, such as metallic, transparent, or glow-in-the-dark.

Polyhydroxyalkanoates (PHAs) are plastics made from rapidly degradable components with specific advantages that make them widely used.

• PHA is environmentally sustainable because it degrades relatively quickly in our environment and does not harm plant.

• It is obtained by bacterial fermentation of plant materials and does not require expensive raw materials.

• PHA is biocompatible and is used in medical devices such as sutures, systems, packaging, and implants.

Polybutylene succinate (PBS) is another type of plastic that has its advantages for use, which can be summarised as follows:

• PBS is biodegradable and suitable for composting.

• It is suitable for various types of packaging for agricultural products and fertilisers because it has good mechanical properties.

• Biomass is the primary raw material for producing PBS, making it a preferred and inexpensive material.

Using these plastics based on biodegradable components can significantly reduce their negative environmental impact in the short and long term.The main disadvantages of PLA can be systematised as follows:

• It is sensitive to high temperatures because of its low melting point and deformation at higher temperatures, making it unsuitable for applications requiring heat resistance.

• The production of this type of plastic is more expensive than traditional plastics.

• PLA requires specific conditions for industrial composting.

Similarly, the main disadvantages of PHA can be formulated as follows:

• PHA production is expensive.

• PHA is more fragile and less resistant to mechanical stress than PS.

• PHA production requires specific conditions and microorganisms.

The disadvantages of PBS are as follows:

• PBS is more expensive to produce than traditional plastics.

• PBS has a lower resistance to high temperatures.

• PBS production is not yet widespread in the country.

Despite these drawbacks, PLA, PHA, and PBS offer significant environmental benefits and can be an important part of efforts to reduce plastic pollution.

Based on the long-term practice of manufacturers and users, the following application areas for PLA, PHA, and PBS products have emerged over the years:

1. The following application areas have emerged for PLA.

• It produces food packaging, cups, containers, and foils.

• PLA is a popular material for 3D printing because of its easy processing and low melting point.

• It is used to produce medical implants and suture materials because it is biocompatible.

2. PHA materials have been applied in various fields.

• It is used to produce biocompatible implants, suture materials, and other medical devices.

• Suitable for producing biodegradable packaging and disposable utensils.

• Used for producing biodegradable foils for agriculture.

3. PBS can be used in the following areas.

• Used for producing biodegradable packaging, bottles, and containers.

• Suitable for producing foils for agriculture that degrade in soil.

• Used for producing disposable utensils and containers.

The use of plastic products has become widespread in various sectors of the economy over the past few decades. These products are most often used in the following branches of the economy and industries:

1. Food industry. Plastic products are often used to produce packaging, cups, and containers. These products can be single-use and reusable, and recycling policies must be implemented.

2. Medical industry. Here, the application is extensive and is most often used to produce implants, suture materials, systems, packaging of medicinal components, and other medical devices. Due to their specific nature, products can also be used as secondary raw materials when collected separately.

3. Agriculture. Here, the application is for the production of biodegradable films and packaging.

Many agricultural fertilisers, consumables, and products are stored in such packaging, and it is necessary to collect these packages separately, not throw them around the fields and warehouses, and use them a second time to obtain recycled raw materials.

4. 3D printing. Over the past 2 decades, this type of product manufacturing has found increasingly widespread application and is used to produce various parts and prototypes. The use here is at the highest pace and has great prospects.

In Bulgaria, there is a growing interest in using biodegradable plastics. Some companies and organisations have already applied these materials to their products and packaging. For example, PLA plastics produce biodegradable cups and disposable utensils in some stores and restaurants. Companies that use plastic products, especially those that produce products from such materials, organise the buyback of these products. These raw materials are reused, and environmental pollution is limited. These biodegradable plastics can significantly reduce their negative impact on the Environment.

"Extrapack" Ltd is a leading manufacturer of bags and packaging in Bulgaria. This innovative manufacturing company uses various types of modern polymers to produce numerous products.

"Megaport" Ltd from Veliko Tarnovo is one of the leaders in producing polymer and copolymer films, packaging, and materials, and has a wide range of manufactured products. The company continuously invests in plastic recycling technologies and sustainable practices.

These two companies are important for promoting sustainable practices and reducing plastic pollution in Bulgaria. Companies outside Bulgaria are good examples because their products are known in European countries. In Bulgaria, legislation on rapidly degradable plastics is in line with Directive (EU) 2019/904, which prohibits certain single-use plastic products and encourages the use of alternative materials.

This directive has been transposed into national legislation through the Ordinance on Reducing the Impact of Certain Plastic Products on the Environment (European Parliament and Council, 2019).

Bulgarian legislation strives to follow the requirements of international law, but current and adequate amendments to administrative regulations are not always adopted promptly in practice. This has led to a delay in these processes in Bulgaria and the later introduction of certain environmental regulations on the use of plastic products.

The separate collection of plastic packaging is enshrined in Bulgarian legislation. The Regulation on Packaging and Packaging Waste (European Commission, 2012) regulates the requirements for the separate collection, reuse, recycling, and recovery of packaging waste.

It includes measures to prevent waste generation and promote the reuse and recycling of waste. However, separate waste collection in Bulgaria is far from the norms in Europe and the world, and the population does not have the habits for this type of waste collection as in other parts of the world. In addition, Bulgaria generates significantly more waste per capita.

The legislation in this regard in European countries is at the necessary level, and in some countries, it is very high.

The European Strategy for Plastics in a Circular Economy, adopted in 2018, promotes using biodegradable and compostable plastics. Directive (EU) 2019/904 bans certain single-use plastic products and requires Member States to introduce measures to reduce plastic pollution.

The EU's new rules on reducing, reusing, and recycling packaging include targets for the separate collection of 90% of single-use plastic and metal beverage containers by 2029. Member States are also required to reduce the amount of plastic packaging waste and promote reuse. Many countries, such as Austria, the Czech Republic, Latvia, and Sweden, restrict plastic containers and bottles and encourage their return through deposits and other incentives.

Many countries have adopted measures to limit the use of single-use plastics and promote biodegradable alternatives. For example, the UN is working on a global agreement to reduce plastic pollution and support the transition to a circular economy. This aims to limit the use of plastic products and reduce environmental pollution.

Many countries have introduced separate collection and recycling systems for plastic packaging. For example, Japan and South Korea have strict, separate waste collection and recycling laws, including for plastic packaging.

These global legislative measures are important for reducing plastic pollution and promoting sustainable practices.

In support of this, global initiatives on plastics, such as the Global Plastics Treaty, are being adopted. The negotiations for the Global Plastics Treaty, organised by the UN, aim to create a legally binding treaty to tackle the problem of plastic pollution worldwide. The main objectives are to reduce plastic production, improve waste management, and promote recycling as indicated by Nichev and Koynakov (2025).

The European Union has adopted a strategy for plastics in a circular economy that promotes the reuse and recycling of plastics.

The strategy includes measures to reduce plastic waste and promote sustainable practices in the country. The implementation of this strategy varies between countries that have adopted it. Not all countries have domestic legislation aligned with international law; thus, each country implements this strategy to a varying degree. In addition to international agreements, other events and initiatives that are not at the official state level are taking place globally. One such manifestation is the Ocean Foundation Plastics Initiative. This initiative promotes sustainable plastic production and consumption to achieve a circular economy.

Many countries and intergovernmental associations have legislation on plastic product use, collection and recycling. The countries with the strictest laws restricting the use of plastics are presented in Table 1, which provides a comparative overview of plastic waste regulations and recycling practices.

Table 1. Comparative Overview of Plastic Waste Regulations and Recycling Practices in Selected Countries.

Country	Key plastic regulation measures	Features/Comments
EU	Ban on some single-use plastic products. Requirements for recycling and reuse of packaging.	Some restrictions are excessive; in some countries the legislation is stricter than at the Union level.
Canada	Ban on single-use plastics (straws, cutlery, bags). Ambitious targets for recycling and reducing plastic waste.	The population has become accustomed to the separate collection of not only plastic, but also all types of secondary products.
Japan	Strict laws on separate collection and recycling of waste, including plastic packaging. Encouragement of the use of biodegradable plastic.	Cultural traditions promote high recycling rates and environmental protection.
South Korea	Ban on the use of plastic bags and bottles. Promote the use of traditional materials. Strict waste management and recycling measures.	The measures are popular with the population, but produce effective results for society

Global initiatives and strict laws are required to reduce plastic pollution and promote sustainable practices. Thus, good and lasting results are achieved through strict legislative measures, regulatory framework compliance, and implementation of material mechanisms.

Plastic pollution and waste seriously affect humans, nature, plants, animals, and water bodies.

The main impacts are as follows in Fig. 3. The negative results of nature conservation and the increase in pollution highlight the need to reduce the production and use of plastic products and to promote sustainable practices. Moreover, this should not happen with one-time cleaning of water bodies or soils, but with daily actions to prevent environmental changes.
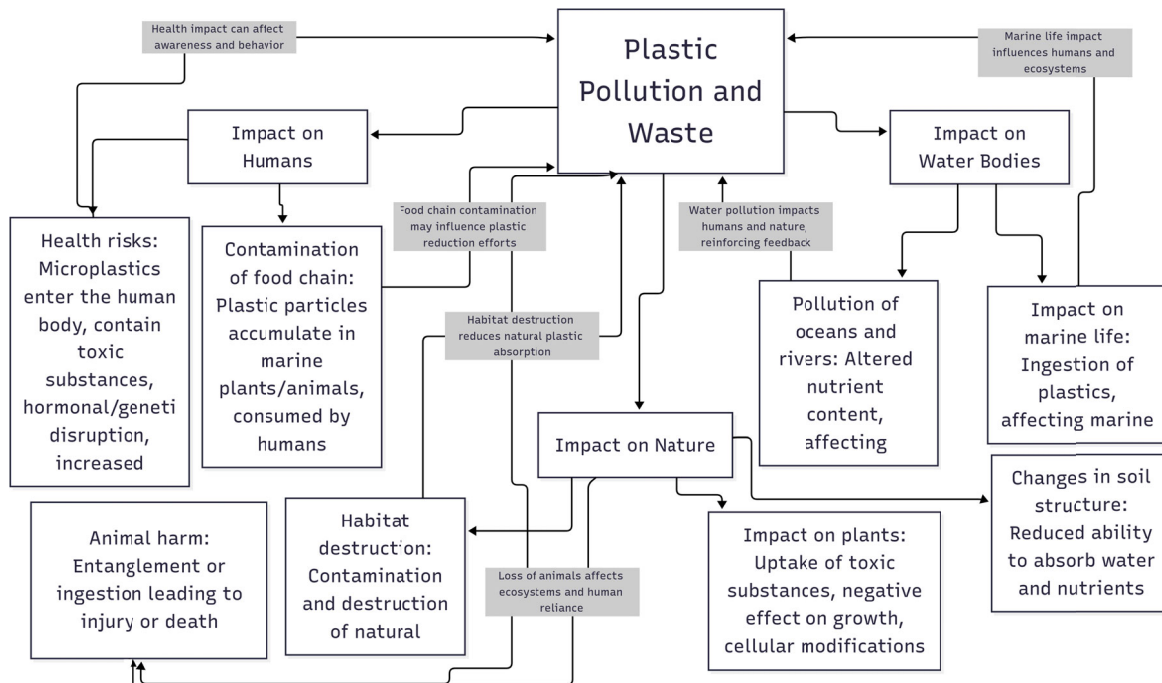
Fig. 3. Impacts of Plastic Pollution and Waste on Humans, Nature, and Water Bodies.

The primary sources of pollution of water resources with plastic and other waste, both in Bulgaria and worldwide, can be grouped into the following main areas:

1. Continental water bodies.

• Untreated and polluted industrial waters are significant sources of pollution in these water bodies.

• Agrochemical pollution also plays a significant role. Plastic products in agriculture, such as irrigation pipes and fertiliser containers, and their disposal after use near fields contribute to soil and water pollution. Therefore, strict control of these products and their buyback and recycling is necessary. There are significant reserves for reducing and limiting the pollution of water bodies, some of which are used for irrigation or drinking.

• Improper waste management is an important factor. The disposal of plastic waste in unregulated places leads to the pollution of groundwater and rivers.

2. Oceans.

• Plastic waste reaches oceans through rivers. Most plastic waste in oceans comes from rivers that carry waste from the interior of continents to coastal waters.

• Large maritime traffic also affects the presence of plastic waste in oceans. To pay lower fees, vessels dump much of the waste into the open sea. Plastic waste from ships and fishing gear, such as nets and buoys, contributes significantly to ocean pollution.

• Very often, the work of people and businesses on the coasts of seas is also among the primary pollutants of marine waters, along with plastic and other waste. Tourism and coastal industries increase the amount of plastic waste in seas and oceans. The culture and behaviour of local people and vacationers have an impact here.

Plastic waste accumulates in high concentrations in ocean gyres, such as the Great Pacific Garbage Patch, where vast amounts of plastic accumulate in the ocean. The area of these patches is larger than the territory of a country such as Bulgaria. Marine animals are exposed to large amounts of plastic waste in the oceans, which break down into microparticles.

These accumulated plastic and other waste islands highlight the need for effective plastic waste management and pollution reduction. Pollution is not uniform within Bulgaria or across the globe.

The regions most affected by plastic waste pollution in Bulgaria can be systematised as follows:

1. Bulgaria's Black Sea coast is among the regions most affected by plastic pollution worldwide. Studies have shown that the areas around Varna, Cape Kaliakra, and the mouth of the Kamchia River are particularly polluted with microplastics and other plastic waste. This is contributed to by the unregulated dumping of waste along our coast, sea currents, and numerous wastes from military and civilian activities in Ukraine, which reach coast through rivers flowing into the Black Sea and currents.

2. Danube and Maritsa are affected by plastic pollution owing to improper waste management and pollution from agriculture. There are also dams of local importance, which significantly reduced their volume during the drought period and increased the concentration of plastic waste. This is also contributed to by the many unregulated landfills near water bodies and weak control by authorities.

The most affected regions in the world can be summarised as follows:

1. The Great Pacific Garbage Patch is one of the world's largest accumulations of plastic waste, located in the northern Pacific Ocean. Vast amounts of plastic, carried by ocean currents, are collected here. Because it is located in neutral waters, no country has taken the initiative to clean up this area. However, if no measures are taken, this stain will increase over the years. In this case, it will inevitably begin to affect certain economic interests, and measures will be taken to limit and seize it.

2. The Mediterranean Sea is one of the most affected by plastic pollution worldwide. This is justified by its location and the fact that it is a practically closed inland sea. Plastic waste originates from coastal countries and tourist activities.

3. The Baltic Sea is heavily polluted with plastic waste from industrial and agricultural activities in the region. This is again related to its location and closed nature.

4. The Ganges River in India, one of the most polluted rivers in the world, is overflowing with plastic waste, which is one of the reasons for the high incidence of illness and death in the region.

These bodies of water are particularly vulnerable to plastic pollution and toxic waste and require action to reduce waste and protect the environment. As a result of the implemented projects in Bulgaria on environmental protection and waste management, the following results were obtained:

1. Increase separate waste collection, plastic waste recycling, and reuse of raw materials obtained from recycling. Mass media campaigns aimed at raising awareness of plastic pollution, significantly reducing the use of single-use plastics and supporting sustainable practices.

2. Legislative changes are important steps towards reducing plastic pollution. These include introducing regulations to reduce the impact of plastic products and increasing producer responsibility.

3. The introduced programs for separate collection and subsequent waste recycling had a positive effect. These have led to an increase in the share of recycled plastic waste and reduced pollution levels. Companies that produce plastic and polyethene products buy back these products and use as secondary raw materials.

At the same time, Bulgaria has joined several major international cooperation projects, the most significant of which are:

1. The Global Plastics Treaty, through which the UN seeks to create a legally binding treaty to tackle plastic pollution, was adopted. Negotiations at this stage include the participation of the scientific community and member states, with the main goal of reducing the production of plastic products and improving waste management practices.

2. The EcosySTEM project focuses on environmental challenges, including waste management and biodiversity conservation. In view of the ongoing military operations in Ukraine, this project is highly relevant. Unfortunately, many of these activities cannot be implemented now, negatively impacting the continental and Martian surfaces.

3. The CIRCLE association is an initiative launched by USAID, Unilever, and EY to support the fight against plastic waste through public-private cooperation. This is a example of cooperation between state and government bodies and companies.

By joining these measures and projects and implementing activities under them, important steps are taken to reduce plastic pollution and promote sustainable practices in Bulgaria and globally. However, these are only a few of the initiatives.

The following steps for Bulgaria can be formulated in several main directions, but the most important are as follows:

1. Strengthening legislation based on the continued implementation and improvement of legislation to reduce pollution with plastic and polyethene waste, including expanding bans on single-use plastic products and promoting biodegradable materials.

2. Raising awareness, including conducting educational campaigns and initiatives to raise public awareness about the harms of plastic pollution, is of key importance. In this way, we strive to reduce the use of plastic products and waste from their use. This should be implemented as a national policy, using various strategies to raise public awareness and encourage the right decision and behaviour.

3. It is also important to promote the implementation of innovation and manage investments in using sustainable technologies and environmentally friendly materials that replace traditional plastic products. Particular attention should be paid to the reuse of raw materials and the secondary processing of used products and packaging, thus saving valuable raw materials and reducing costs.

4. Separate collection programs should be expanded by increasing the scope and effectiveness of separate collection and recycling programs for plastic waste. Special attention should be paid to the younger generation and habit-building in this area.

Globally, international projects will play an increasingly important role, and Bulgaria is involved in many such initiatives, some of which are as follows:

1. The EcosySTEM project brings together organisations from countries in the Black Sea region and aims to integrate environmental education with STEM. The project addresses key environmental challenges, including waste management and biodiversity conservation in our surrounding environment.

2. BlackNETs is a program that focuses on the problem of abandoned, lost, or scrapped fishing vessels and gear in the Black Sea. The goal is to develop effective strategies for managing and protecting marine animals and habitats in the Black Sea.

3. The Bulgarian-Swiss Cooperation Program aims to introduce an innovative model for reducing plastic waste in the marine environment from land-based sources using Switzerland's experience in protecting alpine nature.

These steps and projects are important for reducing plastic pollution and promoting sustainable practices in Bulgaria and worldwide. However, it is essential to implement the measures taken and achieve a real result, not fictitious or documentary, but real. A major problem in reporting these project activities is not the actual implementation but the documentary development, which is not always applicable in the specific situation and region.

The following innovations have been implemented in Bulgaria to reduce plastic pollution:

• DMD ECO WORLD: This company produces and offers compostable alternatives to single-use plastic. Their products are 100% climate neutral and comply with EU standard 13432. They use innovative technologies to produce compostable packaging that can reduce waste by over 30%.

• LAM'ON: The Bulgarian startup LAM'ON develops biodegradable polylactic acid (PLA) films that are suitable for laminating paper and cardboard. These films are environmentally friendly alternatives to traditional laminating materials.

The effectiveness of separate plastic waste collection in Bulgaria can be considered in two ways: documented and implemented. Although Bulgaria has a separate waste collection system, it is ineffective. The main problems include insufficient separate collection containers, a lack of guidelines for proper waste separation, and distrust of the recycling system.

Bulgaria ranks second in the EU regarding plastic packaging waste, with 65% of plastic waste recycled in 2017. This is significantly above the EU average (42%) and shows progress in recycling plastic waste.

However, there are doubts about the correctness of the data and the real values, rather than those reported in documents. It is a widespread practice for separate collection containers to be collected by the same waste collector, and it is clear what the efficiency is and where this waste goes.

Promoting circular economy business models that include the reuse and recycling of materials is particularly important. This can be achieved in many ways, such as implementing incentives for companies that use recycled materials, raw materials from recycled products, or offering reusable products from environmentally friendly materials.

Along with the positive results reported worldwide, we should not miss the bad examples and disregard these problems. In a number of regions of the world, there are problems with pollution, especially with products made of plastic and nylon, with the worst situation in the following countries:

1. First, it can be pointed out that India is among the countries with the highest levels of plastic waste pollution. The lack of organised garbage collection in certain areas of the country and the uncontrolled burning of plastic materials cause significant problems and pollute the already polluted nature in this part of the world to a great extent.

2. Nigeria also suffers from severe plastic pollution, with much waste not being collected and burned openly.

3. Indonesia is one of the countries with the highest oceanic plastic pollution. The lack of effective waste management systems is a significant issue.

4. The Philippines is the largest net exporter of plastic waste and is often associated with oceanic plastic pollution.

It is worth noting that these countries are also taking measures to curb pollution, and they can be systematised as follows:

1. India.
• In India, which has significant environmental problems, a national cleanliness campaign, the Swachh Bharat Abhiyan (Clean India), was launched to improve waste management and reduce pollution.

• Bans on single-use plastics have been introduced, with some states introducing a complete ban on plastic bags and other single-use items.

2. Nigeria.
• In Nigeria, waste management programs have been established at the state level, which aim to improve waste collection and recycling systems for plastic, nylon and other slow-degrading waste.

• The government is striving to organise national educational campaigns to limit pollution and protect our environment. A good example is the media campaigns conducted to raise awareness about the harms of plastic waste pollution. Efforts are also being made to limit the use of plastic products

3. Indonesia.
• Indonesia has problems with coastal pollution and has adopted a long-term national action plan to reduce plastic pollution. Measures have been developed to improve waste management and promote recycling of used packaging, bottles and other products.

• It is one of the countries in the region that has become aware of the problem and is participating in many international projects to tackle plastic pollution, including UN initiatives.

4. Philippines.
• Pollution has reached high levels here; therefore, bans on single-use plastics have been implemented. In some regions of the Philippines, plastic bags and other single-use items have even been banned.

• The Philippines has adopted measures at the national level to improve its recycling and waste management systems.

These measures are important steps towards reducing plastic pollution and protecting the environment in these countries. However, these measures cannot be applied only in certain countries and should work together, as the effect will vary.

5. Conclusions.

Plastic waste pollution is a global problem that one country cannot tackle alone. Over the past five years, data on the pollution of water bodies and adjacent terrain have been collected.

The analysis of these data showed the need to develop a system for monitoring and collecting information on pollution, including in areas that are difficult to access. Four models for monitoring the spread of plastic and other non-degradable waste were developed based on the assessment. After analysing their effectiveness and costs, an option was chosen to create a conceptual scheme that included using a light floating vehicle with the ability to move autonomously, even with reduced water resources.

An autonomous aerial vehicle will be used for monitoring, transmitting information, and aerial photography.

Although the proposal is not revolutionary, we do not need to wait for revolutionary changes to deal with the vast amounts of plastic waste around us. Everyone can make a small contribution to ensuring a better life for everyone by limiting the use of plastic in their daily lives.

The idea and creation of a device prototype for tracking waste in riverbeds has yet to be developed. Although much work remains, the first steps have already been taken. The study continues to build the specific segments of the system to present at future conferences. This development will attract the interest of government institutions and the private sector to secure funding for the completion of the project.

Regarding water pollution and the need for monitoring and control, more significant conclusions can be drawn:

1. Water pollution significantly affects biodiversity, leading to habitat loss and a decrease in the populations of aquatic organisms. This is a serious environmental problem that requires urgent action.

2. The use of modern technologies such as autonomous systems and IoT devices is key to improving the monitoring of waste collection, the secondary use of materials for the production of plastic products, and the tracking of illegal dumps and pollution.

The combined and judicious use of various types of sensors, GPS and artificial intelligence can improve the efficiency of systems for information collection, analysis of the data obtained and controlled decision-making.

3. Plastic waste in continental water bodies is only part of the total pollution, which has a global dimension. International cooperation and the exchange of good practices are important for addressing this problem.

4. Involving the population in information campaigns to reduce the use of plastic and promote a responsible attitude towards the environment is crucial. Small, ongoing changes in daily life can significantly impact the future and are not merely momentary effects.

5. Resources are needed to implement new ideas and implement them in practice, such as the proposed system of autonomous floating and flying monitoring devices. These can be provided through public-private partnerships and support from state institutions, as there are such examples in several municipalities in Bulgaria.

6. The implementation of a project for collecting and transmitting information on pollution and subsequent control of these unregulated landfills is an important step towards sustainable management of water resources and environmental protection. This is a hot topic in Bulgaria due to several consecutive years with higher annual temperatures, reduced rainfall, and a drop in the level of surface and groundwater. Only in this way can quality water resources be preserved, which are also a guarantee of national security.

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