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Building a System for Monitoring and Controlling Pollution of Water Bodies

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***Abstract*— Unregulated waste disposal is becoming increasingly widespread throughout our planet. Waste of various types is being dumped - plastic, glass, nylon, construction waste and others, which decompose very slowly and cause irreversible pollution and changes in the environment. These illegal dumps are particularly dangerous when they are located near water bodies or in the catchment area of drinking sources that supply settlements. The fight against these illegal dumps is still not at the required level and decisive measures are needed to limit them. The report presents a principle scheme for building a system for controlling the catchment areas of large sources of drinking water, which can be implemented very easily and quickly. This will help reduce environmental pollution near water bodies, groundwater and catchment areas of drinking sources. As a consequence, the risk of floods, landslides and other phenomena resulting from the impact of this waste will be reduced.**

Keywords*— *groundwater, monitoring, pollution, system, unregulated landfill, waste, water body.

I. Introduction

In recent decades, there has been an increase in the use of various types of plastic and plastic packaging, which have replaced the usual paper, glass or cloth packaging that was used until 50-60 years ago. Along with increased consumption, environmental pollution with this type of product has also increased. Numerous unregulated landfills have appeared around settlements and even in water bodies in the continental part of the planet. For these reasons, environmental protection and preserving ecological balance have been a hot topic for the last 40-50 years [1].

And while degradable waste does not pose such a danger, non-degradable waste causes serious consequences for the plant and animal world. This is due to the fact that in natural conditions they cannot decompose or the decomposition process takes thousands and tens of thousands of years. Plastic and plastic waste are some of the most dangerous non-degradable waste that humanity generates [2], [3]. Satellite images are available showing that in the Pacific Ocean there are several islands of plastic and other waste with a total area larger than the area of an average European country, for example. In the ocean waters, many developed economic countries dump part of their waste, and it is also a graveyard for space debris, which is obtained from the re-watering of decommissioned artificial space satellites. It cannot be mentioned with alarm that the amount of used and unrecycled plastic is increasing every year, and at a significant rate [4]. Many developed countries have exported their production facilities to underdeveloped countries, where the requirements for collecting plastic and nylon products that have gone out of circulation are significantly lower or absent altogether.

Despite the restrictions introduced on the use of plastic packaging, they are still extremely widely used. The pollution of the earth's surface with non-degradable waste is increasing every year and, for example, in Bulgaria this is visible everywhere around us – in settlements, in mountains and forests, along roads and railways and especially along streams and rivers. There is a lack of elementary culture in the disposal of waste and traveling around Bulgaria by car, bus, rail or even on foot we come across large amounts of waste, including plastic [5], [6], [7]. Almost every settlement has unregulated landfills and places littered with construction, plastic, household and other waste. Manufacturers of plastic products are obliged to buy back used plastic or nylon products, but almost nothing is done for their recycling and reuse.

II. Materials and Methods

The purpose of the development is to continue the author's research from previous publications and to build a model of a system for controlling water bodies and the territories around them to monitor these objects for the presence of pollution with non-degradable waste [5], [8], [9]. In this way, it will help to limit environmental pollution

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with this type of waste and illegal dumps will be discovered in a timely manner even in hard-to-reach areas in rugged and forested areas where there are flowing water masses [7], [8]. According to observations of specialists and the population, the greatest pollution is in water bodies, regardless of whether it is the world ocean or continental waters.

As mentioned in previous reports, the project is conditionally divided into two parts, initially paying attention to waste in water bodies on the continental part of the Earth, and in the second part, the main attention is paid to pollution of the world ocean. In both parts there are many places polluted by man, but each has its own specificity for monitoring, mapping and taking measures to reduce existing waste. Each pollution can also have its own specifics for its tracking and subsequent removal [1], [9]. Transboundary pollution is especially dangerous, where the polluter cannot always be identified, but the consequences of this can be determined. There are industrial enterprises that dump their waste on weekends or at night, when the controlling authorities are not working, and therefore one of the directions for limiting pollution is the use of sensors and cameras that operate continuously and can be traced back in time when, who and how caused the pollution of water bodies and the coast or dumped hazardous waste in an unregulated manner [10], [11].

Fig. 1. Waste along the Iskar River, 02.2021

The background of this development begins with a major pollution incident 6 years ago on the Iskar River in the Iskar Gorge, near the town of Svoge. As it was later found, there are a number of other such pollution incidents that sometimes become known, but are more often hidden from the general public. For more than a week, activities were carried out to clean the water surface next to the wall of the Prokopanik Hydroelectric Power Plant in the Iskar River from the accumulated miscellaneous waste, the area of which was more than 12 acres. Additional equipment was provided at the expense of taxpayers to prevent interruption of the process while trucks transported the removed garbage to the Kostinbrod regional landfill near Sofia. The main goal is to prevent part of the garbage from passing through the facilities of the Hydroelectric Power Plant, so as not to pollute the riverbed towards Svoge and further north. The heavy rains and the torrential downpours that followed on January 11 and 12, 2019, collected all the discarded waste from the ravines of the Sofia Field. The garbage is mainly the result of unconscious human activity, but there are also those that are the result of conscious and deliberate work. Work needs to be done in several directions, first of all, changing consciousness, along with the control and sanctions system, and no less important factor is the prevention policy. In the presence of facilities such as hydroelectric power plants, there should be barrier filters for collecting waste before them, along the river.

It was this pollution that sparked the interest in creating systems for monitoring pollution in or around water bodies and limiting environmental pollution. To create these systems, initial information collection was used, mainly for Bulgaria, but information from other countries was also analyzed. The first pilot projects in the municipalities of Sofia, Burgas and Yambol were also studied, where pollution control systems using drones and other unmanned aerial vehicles are being tested [2], [9], [12], [13]. This information was systematized and analyzed, and based on the results obtained, the main tasks that need to be solved when building the systems were identified. Various methods for environmental monitoring were discussed and a mixed control system is proposed using autonomous vessels and autonomous aerial vehicles to achieve optimal monitoring of water areas and adjacent territories to obtain a complete picture of the surface. It is striking that preventive and comprehensive measures with subsequent control are not taken, but decisions are made piecemeal and instead of improving the situation, the situation is getting worse. Uncleaned riverbeds and the presence of a lot of non-degradable waste in and around them leads to silting of the water body bed, the formation of artificial dams and floods when the water level in the water bodies rises [3], [14]. Over the last 4-5 years, there have been numerous floods in Bulgaria and around the world, the causes being uncleaned water catchment areas and the presence of plastic and nylon waste, which are lighter than water and float on the surface, contributing to the formation of barriers in the path of water flows [1], [15], [16].

Fig. 2. Riverbed pollution

After the waters recede after heavy rains, snowmelt or spring floods, in normal conditions, heaps of waste, especially plastic and nylon, remain on the banks of water bodies and the vegetation around them. An unpleasant sight is the riverbeds in the summer, when after the flowing of the violent spring waters and the increased level of the rivers, they return to their normal beds and we see "flags" of polyethylene bags, foil and other items left on the branches of trees on the banks on the surrounding vegetation. Very often, you can even notice "landed" plastic bottles, tubes and even more voluminous objects, which cause an unpleasant sight. And the initiatives to clean the riverbeds in April and September cannot compensate for the pollution during the rest of the year [3],

[17]. Reporting the activity with photos of the cleaned waste instead of with actually collected waste, which is in abundance, is very negative. Similar initiatives are organized annually in different parts of Bulgaria, but the media hype does not yield results, and real daily activities are needed - a little, but without interruption. and in other areas throughout the year. But we cannot clean up everything that we have polluted the other 364 days of the year in 1 day. It would be much better if we did not pollute 365 days a year, then there would be nothing to clean in this 1 day to clean the river, lake or dam and a person would feel pleasant in nature [2], [18].

If you go along the banks of many streams and rivers, you will see that there are many unregulated dumps in the riverbeds and thousands of waste channels connected to the river networks. As a result of the "cleaning" of the riverbeds, long-standing trees are cut down and bushes are obtained instead of them, and thus the condition of the riverbeds worsens. As a result, instead of improving the permeability of the waterbed after 2-3 years, it is significantly overgrown with shrubby vegetation and when the river level rises, the flow of water masses is hindered. At the same time, numerous plastic bags and other waste that people have illegally thrown away near the river are retained on the branches of this low and medium vegetation. In recent years, we have witnessed many such pollutions, some of which are shown in Figures 1 and 2.

The goal of the project, which was generated at the first stage in the gatherings of the "Curious" club at the National Military University "Vasil Levski", is to make a prototype of a floating device that can move autonomously along the riverbed and photograph and study the terrain of the riverbed and the surrounding area for the presence of waste and channels that flow into the river. At a later stage, the idea of using drones or other autonomous unmanned aerial vehicles to photograph water areas and the territories around them from the air was born. In this way, these devices will complement each other and it will be difficult to leave a place unphotographed that the filming equipment does not have access to. The devices will record and transmit information to a central point. The information will be collected and a characterization of the riverbeds along the entire length of the river and its adjacent tributaries will be made, based on the information collected, maps of the rivers, landfills and waste pipes will be made. This is extremely important given the current levels of dams in Bulgaria, which are filled below the sanitary 67% of their volume and provide quality drinking water to the population. This information will be very valuable, because the state authorities do not know or do not care about such landfills and there are many waste channels built and discharged that are not regulated, legal and do not have elementary treatment facilities [5], [9], [19]. The devices will be small in size, which will allow them to pass through small streams, and an all-terrain vehicle function may also be offered, so that it can pass through fords even when the water level drops.

Where access to vessels is limited, information will be collected from the air using drones. There will also be navigation for management and tracking of the location for detection if necessary and the ability to autonomously return to the starting point in the absence of a communication network. At the same time, the watercraft or air devices will store and transmit information about the condition of the areas they have inspected. After completing their mission, an operator will download the collected information from memory and it will be processed by a team. It is planned that the autonomous vehicles will have a module for online transmission of information. In this way, the operator can, if necessary, use the autonomous device to conduct a more detailed examination of a specific terrain and locate available non-degradable waste and its origin. In this way, a detailed analysis of the location and type of waste can be achieved, and measures can be identified for their removal or limiting disposal. If necessary, a prolonged inspection of the terrain can be carried out with a view to identifying the violators and their administrative punishment [6], [20].

Fig. 3. Collection of plastic waste in the Varna Bay [2]

III. Results and discussion

In many countries around the world, restrictions and bans have been introduced in some industries on the use of plastic and plastic containers, bottles, tubes and other products. There is a legislative order in place in which countries must comply with the requirements and stop the production of plastic and nylon items described in the regulations. In some countries such as Austria, the Czech Republic, Greece, Germany, France and others, the use of plastic products has already been significantly limited, but in countries such as Bulgaria, these measures have lagged behind and practically nothing is being taken or is being taken to a very limited extent. Usually, the last moment is waited for the bans to come into effect and reasons are found to extend the period of entry into force of the specific regulatory act. Going this way, things will not happen, strict measures and appropriate penalties are needed for non-compliance. The next measure that will be proposed is to install nets on all drainpipes in water bodies to collect large waste found in the flowing water. Such developments have already been made in Australia and other countries around the world. Large nets can also be placed at the inlets of streams where large amounts of waste have been detected. These nets will be equipped with overflow-type devices that will signal when their capacity is filled. The waste is then removed, sorted and recycled. This will help limit the spread of waste in our surrounding nature [7], [21]. The effect will be double - reducing waste and environmental

pollution and collecting raw materials for recycling, which will be used in the production of secondary products. In the summer of 2020, the Australian authorities installed a new water filtration and waste collection system. This system is incredibly simple and useful. Both the government and citizens have already seen the benefits of its use and its effectiveness. It consists of a simple net placed at the outlet of a drainage pipe, which helps to capture large waste and protect the environment from pollution. These pipes discharge running water from residential areas into natural water bodies, and the waste from these places can be in huge quantities, which is extremely harmful to the environment. In addition, this garbage is usually washed away by heavy tropical rains, which drag it into the drainage systems. In this way, waste that has fallen into the water streams of the streets and neighbourhoods after heavy tropical rains is collected.

Fig. 4. Plastic waste collection in Australia [6]

The Australian authorities initially started by installing 2 nets and were amazed by the results – their new filtration system was able to collect more than 360 kilograms of bulky waste over a period of several weeks. This had an extraordinary effect on society and led to a reduction in pollution in water bodies. So, a decision was made to install these facilities and minimize pollution of nature and water in particular. Although installation and maintenance cost money, the overall system is quite cost-effective, as the authorities save significant costs for maintaining the state of the environment. For example, one of the main advantages is that they save on the cost of manual labor, which previously had to be paid to people to collect all this waste from large areas [6].

The designed device will also carry out subsequent control to monitor the change in pollution. When conducting the study, information will be collected over a certain period of time, half a year, one year or more, and a comparison and analysis of the distribution of waste in the studied water bodies will be made. The collected and processed information will be transmitted to the competent state authorities, and they have the authority to impose sanctions on violators and to grant or revoke relevant permits. After a certain period of time, more frequent control can be carried out at the most critical points, and even a transition to continuous monitoring of the situation and the disposal of non-degradable waste can be made. In this way, in the club, by implementing extracurricular employment for cadets and students, we stimulate the development of their habits, skills and creative solutions [4], [22].

The problem of the accumulation of non-degradable and plastic waste in ocean waters should not be ignored. Every year, over 14 billion tons of waste are dumped into the waters of the World Ocean, the majority of which is plastic and nylon. Many world experts have gone so far in their studies that they predict that if pollution continues at the same pace, in 30 years there will be more waste than life in the oceans. More and more animals are dying as a result of eating plastic or nylon waste in the sea waters or getting entangled in these piles of floating waste and dying in them. And this is tantamount to an ecological disaster and a disruption of the ecological balance in the world.

The reason why this type of waste occupies the largest share is that the material is cheap, easy to shape into various products and at the same time, it is very light and relatively durable [12], [23]. However, it is the latter factor that makes it extremely harmful to the environment. It is recyclable, but not in all its forms. At the same time, when burned, it releases many gases that are harmful to the atmosphere [2], [5]. When it enters nature, its decomposition takes an extremely long time. One of the most important directions in the fight against waste from plastics, nylons and other organic compounds is to increase the share of recycling. A partial solution to the problem is the use of rapidly degradable plastic and nylon components. But the most important thing is not to throw away unnecessary, difficult-to-degrade materials into nature, because they disrupt the ecological balance.

According to various sources, there are about 180 million tons of plastic and nylon waste in the world's oceans, and every year between 4.8 and 12.7 million tons of additional plastic waste enter the seas and oceans. And this is without collecting or recycling the existing waste. According to data from the European Parliament, over 730 tons of plastic waste enter the Mediterranean Sea alone annually. The area of floating islands in the Pacific Ocean alone is larger than the territory of a country like Bulgaria. And this is as of today, and we can imagine what it will be like in 20 or 30 years if adequate measures are not taken. Plastic and nylon do not only mean uglier beaches, even in places untouched by man. Marine animals can get entangled in larger floating pieces or get confused and swallow smaller particles. Plastic also releases toxic substances that enter the digestive system of fish. From there, it can reach humans through the food chain [9]. The effect on human health is unknown, at least for now, because no relevant studies have been conducted, but it is certain that the harm is significant.

Waste also brings economic losses to the chemical, oil refining and other sectors of the economy and people connected to the sea, but also to manufacturers. Only 5% of the value of plastic packaging finds reuse in the economy, the rest is simply wasted. Despite the measures taken to limit the use and increase the recycling of these materials, they are not yet leading to the desired result. The need for more recycling and to prevent more plastic from entering the oceans is obvious [8], [23]. If the entire amount of plastic or nylon is collected and recycled, this will provide a resource for the chemical industry for more than

8 years and save raw materials, which will be replaced with recycled plastics and nylon.

Fig. 5. Plastic waste in ocean waters [16]

In 2022, the National Military University "Vasil Levski" purchased a telescope and an adjacent dome. Now, after completing another public procurement, we are about to build our own astronomical station, from where we will be able not only to carry out relevant observations, but also to use databases with space and satellite photos and images of the surface of our planet. In cooperation with fellow teachers and astronomers from related universities such as Sofia University, N. Y. Vaptsarov Naval Academy, Georgi Benkovski Naval Academy, and the Stara Zagora Observatory, we will begin joint activities of our club with related clubs in the field of astronomy, and in particular, work on projects and programs of the EU, NASA, and others [10], [24]. One of our priorities will be the observation and mapping of both space debris and debris in sea and ocean areas that cannot be hidden when observed from space. With this, we will contribute, albeit a little, to a better future for the planet.

Fig. 6. Coexistence of plastic waste with the animal world [16]

The team now plans to refine the technology so that it can more accurately detect floating debris in murky coastal waters and large rivers. The idea is to combine this method with drones to track plastic pollution and assist cleanup operations. Scientists are categorical that the only way to clean up our polluted oceans is to drastically reduce the amount of plastic we produce. Based on the information collected and analyzed, a schematic diagram of a system for collecting information on pollution in and around water bodies was developed. The developed basic device consists of a device that moves on water, powered by a self-propelled autonomous engine device, and collects information from the water surface and the adjacent coastline. At low water levels, the device can move along the bottom of the water body with the help of an all-terrain chassis powered by the same engine. The device transmits the collected information and also stores it with itself, because there may be no continuous connection due to movement in rugged and difficult-to-pass areas. After the study is completed, the collected information is downloaded from the device's memory and stored on a large and powerful medium. The information is analysed and summarized, and the terrain is mapped based on the data, allowing data to be superimposed and information to be obtained about the dynamics of processes and the results of previous studies to be obtained.

When building the astronomical observatory, the same observation will be possible through satellite systems and monitoring of areas potentially threatened by pollution. The general information will be analysed and submitted to the relevant state control authorities. The developed pollution control system will be summarized and a principle model of the system will be developed, which will be patented at a later stage of development. The conceptual design is only the first stage of the overall construction project and there is hope that at a subsequent forum, when finding funding, it will be possible to move to the next stage of implementing the idea [25], [26].

As a result of the study and the possible implementation of monitoring and mapping of water bodies, it is expected that environmental pollution will be reduced and contaminated areas and their pollutants will be detected in a timely manner. This will lead to both an economic and environmental impact for society, an impact that will be calculated upon final completion of the prototype.

The idea is extremely inspiring and aimed at a truly significant global problem - pollution from plastic and other waste. This is an example of initiative that can have a real impact on the environment and quality of life.

1. The autonomous vessel sounds like an innovative solution for collecting pollution data. The technology could prove to be key for monitoring areas that are difficult to access and will provide important information for taking adequate measures.

2. The emphasized need for individual action is also very important. Even small changes in everyday life can start a large movement to limit plastic. This is a message that needs to be spread and supported.

3. Presenting the development to government institutions and companies is the right approach to finding funding. This idea has the potential to attract attention and support if it is communicated clearly and with data on its effectiveness.

Prototyping a riverbed waste monitoring prototype is a challenge, but it’s also an exciting opportunity to apply innovative technologies. Here are some of the ones you could use:

1. IoT devices (Internet of Things): Small sensors that measure pollutants, water level, temperature, and other parameters. Connectivity via Wi-Fi, Bluetooth, or GSM for real-time data transmission.

2. Water drones: Small autonomous or semi-autonomous GPS-enabled floating drones that can navigate riverbeds and collect data. Use lightweight and durable materials such as carbon fiber for the construction.

3. Machine vision and artificial intelligence: Integrate high-resolution cameras and AI algorithms to recognize waste, such as plastic or other pollutants. These algorithms can help automatically identify and classify waste.

4. Energy autonomy: Install solar panels or other renewable energy sources to power the device. Energy-efficient electronics that allow for longer operating times.

5. Communication technologies: LoRa (Long Range) for long-distance communication in areas without internet. 5G for fast data transmission in areas with coverage.

6. Modularity: Creating a design that allows for easy replacement or addition of sensors and other components for future development.

7. GIS systems (Geographic Information Systems): For visualization and analysis of collected data on mapping platforms.

You should start with a basic functional prototype that includes the basic elements such as sensors, GPS and communication. You can gradually add additional functions.

IV. CONCLUSIONS

Over the past 5 years, researchers at the university have collected data on the pollution of water bodies and adjacent terrain. A thorough analysis of these data and the results obtained showed the need to develop a system for monitoring and collecting information on pollution, including in hard-to-reach areas. Based on the assessment, 4 models were proposed for monitoring the spread of plastic and other non-degradable waste. After analysing their effectiveness and costs, an option was selected to create a conceptual scheme that includes the use of a light floating vehicle with the ability to move autonomously, even in reduced water resources. Although the results are not expected easily, it is important to take the first step towards improving our planet in order to create a better world.

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

The idea and prototype of the device for tracking waste in riverbeds are yet to be developed. Much work remains to be done, but the first steps have already been taken. Work continues on building the specific segments of the system with the aim of presenting it at the next conference. It is hoped that this development will attract the interest of state institutions and the private sector in order to secure funding for the completion of the project.

On the topic of water pollution and the need for its monitoring and control, some more significant conclusions can be drawn:

1. Environmental impact: Water pollution significantly affects biodiversity, leading to habitat loss and a decrease in populations of aquatic organisms. This is a serious problem that requires urgent measures.

2. The role of technology: Modern technologies such as autonomous systems and IoT devices play a key role in improving pollution monitoring and management. The integration of sensors, GPS and AI can significantly increase the efficiency of information collection systems.

3. Global nature of the problem: Plastic waste in riverbeds is only part of the overall pollution, which has a global dimension. International cooperation and the exchange of good practices are important to address this problem.

4. Education and awareness: Engaging the population in information campaigns to reduce plastic use and be environmentally responsible is crucial. Small changes in everyday life can have a significant impact.

5. Economic aspect: Pollution affects industries such as tourism, fisheries and water supply, leading to economic losses. Investments in sustainable technologies can contribute to long-term economic benefits.

6. Need for financing: In order to implement innovative solutions such as autonomous floating monitoring vehicles, resources are needed, which can be provided through public-private partnerships and support from government institutions.

7. A step towards sustainability: The implementation of a project to control and collect information on pollution represents a significant step towards sustainable management of water resources and environmental protection.

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