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Using Drones to Clean Continental Water Bodies

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***Abstract*— Pollution of continental water bodies has become increasingly widespread in recent decades. Plastic, construction, household and other waste is being dumped uncontrollably both near water bodies and directly into them. In addition to pollution, this often leads to more serious crisis and emergency situations such as floods, pollution of drinking and groundwater, landslides and others. This article proposes a new application of mid-range drones for monitoring pollution, the presence of unregulated landfills and transmitting information in real time. In this way, it will be possible to monitor large areas for the presence of illegally dumped waste with fewer resources. This will help to more effectively combat unregulated landfills and solve the problem in its infancy and save financial and human resources.**

Keywords*— *continental water bodies, drone, groundwater, landfill, pollution, waste, water resources.

I. Introduction

In recent decades, unmanned aerial vehicles have been increasingly widely used. They are relatively light, maneuverable, and their price is becoming lower and more affordable. These modern technical means are being used in more and more areas, including the military industry [1], [2]. This is also proven in the military operations that are taking place in Ukraine, the Gaza Strip, and other hot spots on our planet. But at the same time, various modifications of unmanned aerial vehicles are also required in the civilian sector of the economy, as well as in the field of services, cartography, and other areas of our lives [3], [4]. Drones, as a type of unmanned aerial vehicle, have many modern applications that significantly facilitate various aspects of our lives and work.

First of all, the use of drones in the delivery of goods can be put, for example, the companies Amazon and UPS use them for fast and efficient delivery of goods to customers. In this way, they significantly reduce delivery time.

It can be said that the use of drones in agriculture is also increasing significantly. There, drones help farmers monitor and analyse crop conditions, as well as spray fertilizers and pesticides. They are replacing the use of agricultural aviation for fertilization, but smaller farmers still use ground transportation equipment more often. But for larger farmers, the use of unmanned aerial vehicles is becoming a cheaper option and also more efficient [5], [6].

In recent years, there has been an increasing emphasis on environmental monitoring. Here, they are used to monitor natural resources, forest fires and pollution in areas that are difficult to access with conventional equipment, while at the same time providing a better view of the monitored component. This is also the purpose of this work, which shows the possibilities of using these aircraft to detect unregulated dumps in water bodies or in their immediate vicinity. With conventional means, detecting these pollutants is sometimes difficult, and their consequences can be very serious [7], [8]. This is especially true for non-degradable and plastic waste.

Drones can be used to search and rescue people in hard-to-reach areas, in the event of natural disasters, such as avalanches, earthquakes, floods and others. This method is especially valuable for mountain rescuers during the winter season.

Next, infrastructure inspections can be mentioned. They are used to inspect bridges, buildings and other infrastructure sites, which saves time and resources. This is especially important for hard-to-reach sites where it is not possible to examine certain nodes and details in detail [9], [10].

Filming and photography: Drones are popular in the film industry and photography for capturing unique aerial shots and are increasingly used to film films, series and short advertising videos.

Yes, drones can be used to monitor environmental pollution. They can be equipped with specialized sensors

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and cameras that can measure various pollution parameters, such as air, water and soil quality, the content of certain ingredients in them and others. When monitoring air, drones and in particular the equipment they carry can measure the concentration of pollutants such as carbon dioxide, nitrogen oxides and dust particles. When monitoring water, they can collect samples from water bodies and measure parameters such as pH, temperature, the presence of toxic, hazardous or other substances, the presence of amounts of non-degradable waste and others. When conducting soil monitoring, drones can analyse the condition of the soil and detect contamination with heavy metals and other harmful substances, using equipment located on them or transporting samples from the field.

Their use is particularly relevant in radiation monitoring [11], [12]. After natural disasters with the release of radioactive substances, drones can be used to detect and map radiation hotspots by surveying large areas and transmitting information in real time [13].

The use of unmanned aerial vehicles and equipment located on them allows for fast and efficient data collection, which helps to better manage and protect the environment. Thus, personnel do not enter the contaminated area, are not exposed to radioactive radiation, and very good results are obtained from the measuring equipment without danger to the population.

It should be noted that there are also successful projects that demonstrate the effectiveness of drones in environmental monitoring:

1. The ICAERUS project is funded under the Horizon Europe program, this project supports innovative solutions with drones in agriculture and forestry. It involves partners from 8 countries and aims to explore the possibilities of using drones for environmental monitoring.

2. The SPADE project, also funded under Horizon Europe, this project promotes the use of drones and sustainable digital services in the crop, forestry and livestock sectors. The project brings together 21 partners from 10 countries.

These projects show how drones can be used for effective environmental monitoring and management.

Drones are also used in Bulgaria to monitor environmental pollution, albeit on a limited scale. For example, the Sofia Metropolitan Inspectorate uses drones to monitor air quality and to detect illegal waste burning. These drones are equipped with sensors and cameras that can detect pollutants and locate sources of pollution [14], [15].

II. MATERIALS AND METHODS

The use of this type of equipment is expanding extremely quickly and several leading companies can be mentioned that offer environmental monitoring services with drones. A long list could be made here, but we should first mention ZaiTechno, which offers radiation monitoring drones that can detect and map radiation hotspots and pollution. The company Copter.bg offers various drones and solutions for environmental monitoring, including aerial photography and mapping. There are other successful companies, but I believe that they will still expand and cover an increasingly larger perimeter of services.

Various methods and technologies can be used to monitor environmental pollution with drones. Here are some of them:

1. Drones can be equipped with air quality sensors that measure the concentration of pollutants such as carbon dioxide, nitrogen oxides and particulate matter. These sensors provide real-time data on air quality.

2. Thermal cameras can detect thermal anomalies that may be associated with pollution, such as chemical leaks or hot spots in industrial areas, chemical reactions taking place in unregulated conditions, and the release of large amounts of heat.

3. Multispectral and hyperspectral cameras can capture images in different spectral ranges, which allows for the detection of water and soil pollution, as well as vegetation analysis.

4. Water sensors can be deployed in drones and collect samples from water bodies and measure parameters such as pH, temperature and the presence of toxic substances. This is particularly useful for monitoring pollution in rivers, lakes, seas and other bodies of water.

5. After natural disasters or near nuclear facilities, drones can be equipped with radiation detectors to detect and map radiation hotspots. This is also a good way to periodically monitor the radiation situation.

6. Lidar technology uses laser beams to create three-dimensional maps of the terrain and can be used to detect changes in the landscape that may be associated with pollution.

This is just some of the methods used, and this allows for fast and efficient data collection, which helps to better manage and protect the environment. It is also possible to collect other types of data, which may be regional in nature, or to develop new detectors to study other environmental parameters [2], [15], [16].

One of these parameters is environmental pollution with non-degradable plastic, nylon and other waste in water bodies or in the catchment areas of drinking areas. This problem is of great importance for Bulgaria in connection with climate change, reduction of water resources and their inefficient use. Different types of drones and methods can be used to detect waste dumps near water bodies. Here are some of the most important ones, because it is impossible to list them all, and each case requires a specific solution [3], [17].

In this area of application of drones, the following can most often be used:

• Multicopters are maneuverable and can fly at low altitudes, which makes them suitable for detailed terrain photography and detection of waste dumps. They are

especially suitable for forested areas, mountain stream beds and overgrown and difficult-to-reach banks of water bodies.

• Fixed-wing drones can cover larger areas and are suitable for monitoring large areas around water bodies and above the water bodies themselves.

• Hybrid drones combine the advantages of multicopters and fixed-wing drones, which makes them effective for various tasks and they have the widest application.

There are different detection methods, the most common of which are:

• In visual photography, drones can be equipped with high-quality cameras that capture images and videos of the terrain. This data can be collected and analysed, thus monitoring the development of the area and serving for timely changes in the situation and detection of waste dumps.

• Thermal cameras can detect temperature anomalies that may be associated with waste dumps, especially if there is waste incineration. With the help of these cameras, the conception of fires can be detected and good preventive action can be taken to prevent large outbreaks of fires.

• Multispectral and hyperspectral cameras can capture images in different spectral ranges, which allows the detection of pollution and waste dumps.

• Lidar technology uses laser beams to create three-dimensional maps of the terrain and is very well used to detect changes in the surrounding environment and especially the formation of new waste dumps.

Although in its infancy, these technologies have already found application in the implementation and management of several successful projects. In the municipality of Yambol, drones are used to monitor illegal waste disposal and the formation of landfills. These drones are equipped with cameras and other sensors that allow for effective monitoring [7], [18]. So far, there are no known cases of successful implementation of similar projects in other municipalities, but the first successful applications will give impetus to the use of these new methods for detecting illegal landfills around water bodies [19].

These technologies and methods allow for the quick and effective detection of waste dumps, which helps to better manage and protect the environment. In this way, with regular monitoring, such illegal landfills can be detected at an early stage and their expansion prevented.

After researching different types of unmanned aerial vehicles, their characteristics and the task at hand, several specific drones are proposed as the best options. For detecting waste dumps in or near water bodies, some of the most suitable drones are:

1. DJI Matrice 300 RTK is a drone that is known for its stability and ability to carry various sensors and cameras, including thermal and multispectral cameras.

2. SenseFly eBee X is a drone that has fixed wings and is suitable for covering large areas and can be equipped with various sensors for environmental monitoring.

3. Parrot Anafi USA is a drone that is equipped with thermal and optical cameras, making it suitable for detecting waste dumps and monitoring pollution.

The methods for detecting contaminated areas in water bodies and adjacent areas are diverse and sometimes even specific to the specific case [20]. But they can be systematized into several main categories:

1. Visual imaging uses high-quality cameras to capture images and videos of the terrain, which can be analysed to detect waste dumps. The image can be stored on a carrier that is located on the drone or the information can be transmitted using electromagnetic waves with a certain frequency.

2. Thermal imaging cameras are used to detect temperature anomalies associated with waste dumps, especially if there is waste incineration and heat energy is released.

3. Multispectral and hyperspectral cameras are used to capture images in different spectral ranges to detect pollution and waste dumps.

4. Lidar technology is used to create three-dimensional maps of the terrain where non-degradable waste may be located.

These drones and methods allow for efficient and rapid detection of waste dumps, which helps to better manage and protect the environment. Regular site surveys can detect the creation of such landfills at an early stage and timely preventive measures can be taken. This way, the disposal of plastic, nylon and other hard-to-degrade waste can be significantly limited.

III. Results and discussion

Detecting unregulated dumping sites for persistent substances is a difficult, and sometimes almost impossible, way to limit environmental pollution. The use of unmanned aerial vehicles greatly facilitates this task. To make drones more effective for environmental monitoring, various sensors and components can be added, the most commonly used sensors being:

1. Air quality sensors measure the concentration of pollutants such as carbon dioxide, nitrogen oxides, particulate matter, and other components of the ambient air.

2. Water sensors can collect samples from water bodies and measure parameters such as pH, temperature, and the presence of toxic, poisonous, or other substances.

3. Radiation detectors detect and map radiation hot spots, which is useful after natural disasters or near nuclear facilities.

4. Thermal cameras use infrared sensors to detect thermal anomalies, which is useful for detecting waste dumps and pollution.

5. Multispectral and hyperspectral cameras capture images in different spectral ranges, which allows for analysis of vegetation, water and soil.

In addition to sensors for obtaining reliable, real and timely information, other components are also used to supplement, process, transmit or enrich the information received. As such, GPS modules are very often used, which serve for accurate positioning and navigation of both the drone itself and the monitored objects. Another example is the use of the LIDAR system, which is used to obtain high-quality images of the environment in all projections and monitor the state of nature in and around water bodies. Various communication systems and channels are used to transmit data in real time to ground stations or mobile devices. In this way, the collected information is transmitted to the control centre, where it is summarized and analysed. This is achieved by using appropriate data analysis software. It serves to process and visualize the collected data, which facilitates analysis and decision-making [21].

The use of various sensors and components makes drones more efficient and versatile for various environmental monitoring tasks. In this way, we can obtain a large volume of quality information with specific data and the development of this data over time in a short time [22].

Thermal cameras are one of the most commonly used components for environmental monitoring and they work on the principle of capturing infrared radiation emitted by objects depending on their temperature. They convert this radiation into electrical signals that are used to create a visual image called a thermogram. The principle by which thermal cameras detect water bodies contaminated with plastic waste can be explained in several ways, each of which is correct and complements the others. The first explanation is the presence of temperature differences. Plastic waste and water have different temperature characteristics. Thermal cameras can detect these differences and visualize them as thermal images. Plastic waste usually appears as colder or warmer objects compared to water during different seasons of the year and is not at the same temperature as water.

Thermal cameras can also detect thermal anomalies that may be associated with the presence of plastic waste. For example, large accumulations of plastic can change the thermal profile of a body of water, and hence this temperature difference can manifest.

Thermal cameras create infrared images that show the temperature differences between the water and the plastic waste. These images can be analysed to detect pollution. Experienced analysts can easily detect the presence of plastic waste in bodies of water from thermal camera images alone.

The most common use is in monitoring bodies of water and examples of use such as monitoring rivers and lakes. Thermal cameras can be used for regular monitoring of bodies of water to detect and map plastic waste.

Another example is in detecting pollution in marine areas. They can be used to detect plastic waste in coastal and marine areas, where pollution is more difficult to monitor with traditional methods.

These technologies allow for rapid and effective detection of pollution with regular monitoring, which helps to better manage and protect the environment.

Other types of cameras for detecting plastic waste in water bodies are:

1. Multispectral cameras capture images in different spectral ranges, allowing the detection of plastic waste and other pollutants in water. They are particularly useful for analysing vegetation and water bodies.

2. Hyperspectral cameras provide more detailed spectral data than multispectral cameras and can detect specific types of plastics and other pollutants in water.

3. High-quality RGB cameras can capture detailed images of water bodies, which can then be analysed for the presence of plastic waste. They are useful for visual inspections and monitoring.

4. Satellites equipped with different types of cameras and sensors can provide data over large areas of water and detect accumulations of plastic waste in oceans and coastal areas. Artificial intelligence can help analyse these images and detect pollution.

These technologies and methods allow for effective and rapid detection of pollution, which helps to better manage and protect the environment. Collecting all the information on a carrier on the drone carries significant risks of information loss, and therefore continuous transmission of information from the drone to the control centre is preferred, and different types of communication networks can be used:

1. Radio communication is the most commonly used method of data transmission is via radio. Drones use different frequency ranges (for example, 2.4 GHz or 5.8 GHz) to communicate with the ground station.

2. Some drones use mobile networks such as 4G or 5G networks for real-time data transmission. This is particularly useful in urban environments or areas with good mobile coverage.

3. For drones operating in remote or difficult-to-reach areas, satellite communication is a reliable method of data transmission. However, this method is more expensive and requires specialized equipment.

4. In some cases, drones can use Wi-Fi networks for data transmission, especially when operating near infrastructure with an available Wi-Fi signal.

This type of aircraft has great advantages in detecting unregulated landfills and pollution of water bodies with plastic, nylon and other difficult-to-degrade waste. However, there are areas in these areas where the signal strength for controlling the drones is absent or very weak. This is especially important for rugged forested areas, mountainous areas or areas remote from settlements. When

operating in such hard-to-reach areas with reduced visibility or limited signal, other techniques are used to control the aircraft, transmit information from them and other details of the flight and transmit information [4], [23].

The most common are autonomous flights, in which drones can be programmed for autonomous flights along preset routes. This reduces the dependence on constant connection with the operator and makes it possible to complete the task even in the absence of any type of connection.

Using RTK (Real-Time Kinematic) GPS is the next most commonly used method. This technology provides high positioning accuracy and is useful in areas with limited signal, such as mountainous areas and rugged terrain. In areas with limited signal, where regular flights and data collection are carried out, repeaters can be used to amplify and transmit the signal between the drone and the ground station or operator. These repeaters can be stationary or mobile depending on the frequency of flights, terrain and other factors affecting the flight.

Thermal and infrared cameras are another type of alternative to classical methods, which are also used in collecting information about the pollution of water bodies. In conditions of reduced visibility, thermal and infrared cameras can help navigate the aircraft and detect objects in low visibility.

For real-time data transmission from remote and hard-to-reach areas, satellite communication is a reliable method, although it is more expensive. As technology advances, this method is used more and more often and its price has decreased over the years. One of the main advantages of this method is that it can be used practically almost anywhere on the planet and the quality of the transmitted information is at a high level.

These methods and technologies allow for effective operation of drones even in hard-to-reach areas and under adverse conditions. This is one of the reasons for the increasing use of unmanned aerial vehicles in various areas of our lives, including for monitoring environmental pollution with non-degradable waste. In practice, the use of drones in military operations in Ukraine proves the capabilities of drones in all areas, including military affairs.

Ensuring the safety of drone flights is essential. With the use of more and more drones, the thesis of their safe use is also required, including legal regulation of these flights. With the development of aircraft, systems for safe flying with them and with other participants in aviation are also developing [24].

With the increase in the number of drones and the flights they perform, collision avoidance systems are also improving. Many drones are equipped with obstacle avoidance sensors that use ultrasound, infrared rays or lidar to detect and avoid obstacles during flight. In this way, they change the trajectory of their flight and avoid collisions with obstacles or other aircraft.

With the increasingly widespread use of drones, geofencing is also required. This is a technology that restricts drone flights in certain areas, such as airports, military bases and other sensitive sites. Geofencing helps prevent incidents and airspace violations, such as the one that occurred at Sofia Airport 2 months ago, when a drone violated the airspace of the airport complex and disrupted air traffic for hours.

Many drones have an automatic return-to-home function that is activated when the signal is lost or the battery is low. This ensures that the drone will return safely to the take-off point without the need for navigation. This is an autonomous function that limits the possibility of losing the drone in the airspace over a certain territory.

Training and certification also play an exceptional role in the normal operation of these aircraft. Drone pilots must undergo training and obtain certificates for drone control, especially for professional and commercial flights. People who operate drones for monitoring must be well trained and have a certificate to operate the specific type of aircraft.

Working in adverse weather conditions is also key. To monitor pollution of water bodies and adjacent areas, favourable weather conditions should be used whenever possible. In adverse weather conditions, flights should only be carried out in extreme cases and, if possible, they should be cancelled for more favourable conditions [25].

Choosing the right drone is especially important when working in adverse conditions. For operations in adverse weather conditions, it is important to choose a drone that is resistant to wind and rain. Larger and more stable drones are better suited to such conditions. It is also a good idea for the aircraft to have additional flight control systems.

Thermal and infrared cameras can be very helpful for navigation and detection of objects in reduced visibility, such as fog or darkness. For each flight, the cameras should be selected according to the type of activity the drone will perform and the weather conditions of the flight.

For real-time data transmission in low visibility and bad weather conditions, satellite communication is a reliable method, although it is more expensive.

Drones can be programmed to fly autonomously along preset routes, which reduces the dependence on constant communication with the operator and is not affected by weather conditions [26], [27].

These measures and technologies help ensure flight safety and the effective operation of drones even in adverse weather conditions. However, legal regulation of the use of drones is also necessary, because at some point chaos will occur in the airspace and then regulation will be more difficult [28], [29], [30].

Based on a study, the most suitable drones for monitoring pollution of water bodies and adjacent areas in bad weather can be indicated:

1. DJI Matrice 300 RTK is a drone known for its stability and resistance to wind and rain. It is equipped with

multiple sensors for avoiding obstacles and can operate in severe weather conditions.

2. DJI Mavic 2 Enterprise Dual is a drone equipped with a thermal camera and is resistant to wind and rain. It is suitable for rescue operations and monitoring in bad weather conditions.

3. Parrot Anafi USA is also a drone resistant to wind and rain and is equipped with thermal and optical cameras, which makes it suitable for operation in harsh conditions3

When flying in bad weather conditions such as fog, heavy rain or snowfall, safe flight conditions must also be observed above all and flights should not be carried out if possible. For example, flying in fog is difficult due to reduced visibility and drones with thermal and infrared cameras can help navigate in such conditions. Many drones are not waterproof and can be damaged by heavy rain. For flying in the rain, it is important to use drones that are specially designed for such conditions. The requirements for flying in snow are similar, because it can be dangerous due to reduced visibility and the risk of freezing of drone components. Drones with cold-resistant components and thermal cameras can help operate in such conditions.

In the process of conducting the study, it was found that in Bulgaria, in addition to the municipality of Yambol, the Sofia municipality and the Municipality of Burgas use marine drones and artificial intelligence to detect potential risks of pollution of habitats in the Black Sea. This initiative is part of a project in support of the blue transformation of the Black Sea basin. These are still the first tests for the use of drones in this area, but it always starts small.

In Europe, the Copernicus Marine Service is one of the monitoring systems that uses unmanned aerial vehicles. In the countries of the old continent, various techniques are used for monitoring plastic waste, including numerical modeling, on-site monitoring and satellite monitoring. These methods help to track the movement of plastic waste and assess its quantity. The prospect is to monitor more and more water bodies and the space around them for the presence of non-degradable waste, and a significant part of the monitoring will be carried out with drones.

Different technologies are used around the world to detect plastic waste in the oceans. For example, ocean current modelling and satellite observation are key methods for tracking plastic waste and assessing its impact on marine ecosystems. Using satellite images, islands of plastic waste in the oceans and seas can be easily detected. In coastal areas, especially in the Pacific region with lush tropical vegetation, the use of drones for monitoring the coastal zone is of utmost importance and is increasingly being used [31], [32].

Some of the more significant successful examples and projects include:

The LIFE-funded HESOFF project uses drones to remotely image forests and assess their health. This project shows how drones can help conserve biodiversity and manage forest resources.

WWF projects use drones to monitor forests and wildlife in different parts of the world. These projects demonstrate how drones can be effective tools for environmental protection and combating climate change.

These technologies and methods allow for effective detection and monitoring of plastic waste pollution, which helps to better manage and protect the environment.

IV. CONCLUSIONS

The future of drones in environmental protection looks promising, as they are expected to play an increasingly important role in various aspects of environmental monitoring and management. Based on the study conducted, the analysis of the results achieved so far in the use of drones for detecting plastic waste, and the assessment of the future use of these progressive technologies, some conclusions and recommendations can be drawn for the development of the use of these techniques and technologies. Here are some key trends and technologies that will shape the future of drones in this area based on this study:

1. With the development of artificial intelligence and machine learning, drones will become increasingly autonomous, which will allow them to perform complex tasks without the need for constant human control. It will be necessary for a person to set the parameters of the task and control its execution, and the activities themselves will be performed by autonomous drones

2. Drones will be connected and integrated with IoT (Internet of Things), with networks of sensors and other devices, which will allow for the collection and analysis of data in real time for better environmental management. This will allow for larger databases to be collected, which will make research more accurate and forecasts better.

3. The development of new and more sensitive sensors and cameras will allow for more precise detection and monitoring of pollution and other environmental problems. Less time and resources will be needed to assess the situation and make an adequate decision.

4. Drones will increasingly use renewable energy sources, such as stand-alone solar panels, to reduce their carbon footprint and be more environmentally friendly.

As prospects for the use of drones in the foreseeable future, the following can be mentioned:

1. Drones will continue to play a key role in the detection and monitoring of air, water and soil pollution. They will be an indispensable tool for detecting pollution of water bodies and their adjacent territory by plastic waste.

2. They will be used to track wildlife populations and detect illegal activities such as poaching. They will help to expand biodiversity and preserve the purity of the environment.

3. Drones will help to quickly assess damage after natural disasters and plan restoration activities. They will help to locate injured people and rescue them.

These trends and technologies show that drones will continue to be an important tool in efforts to protect the environment and sustainably manage natural resources.

In Bulgaria, work is underway to increase the use of drones in state, municipal and private structures, and they are also used in a number of projects, and emphasis will be placed on several of them:

A project for the blue transformation of the Black Sea basin has the Municipality of Burgas as the main beneficiary. Municipal administration employees are using marine drones and artificial intelligence to detect potential risks of pollution of habitats in the Black Sea. This project is part of a larger initiative to protect the marine environment and is about to be expanded.

The HESOFF project, which is funded under the LIFE program and monitors the environment, including water bodies. This project involves remote sensing of forests with unmanned aerial vehicles to assess the health of forests, the state of water bodies in them and the protection of biodiversity.

These projects show how Bulgaria strives for sustainable development and environmental protection through innovation and new technologies, including the use of unmanned aerial vehicles. Based on the research conducted, the analysis of the results obtained and the identified prospects for the use of drones in environmental monitoring, and in particular of water bodies and adjacent terrains, we can summarize that a wider use of drones in environmental protection is imminent.

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