UAVs to CBRN Threats monitoring

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Unmanned aerial vehicles (UAVs) play an increasingly important role in various areas of life, including in terms of protection and security. The possibilities of using the devices were analyzed in terms of weather conditions, construction, and used materials in CBRN (chemical, biological, radiological, nuclear) threat situations. It was found that, thanks to the use of appropriate sensors, cameras, and software of UAVs integrated with a given system, it is possible to obtain information on air quality at a given moment, which is very important for the safety of people and the environment. However, several elements, including the possibility of use in acidification conditions, requires refinement to changing crisis conditions.

unmanned aerial vehicles (UAV) CBRN threats industrial area air quality

1. Introduction

The area of unmanned aerial vehicles (UAVs) is a very dynamic and promising sector, which offers new possibilities and opportunities [1][2][3][4]. According to estimates, the drone technology market will reach USD 100 billion in 2020 [5][6][7]. Most of this market, estimated at 70%, covers military applications, and the value of the commercial market showing a faster growth rate is estimated at USD 13 billion in 2020. Moreover, PwC experts estimate that the total market of commercial applications in the world amounts to USD 127 billion. Whereas, the size of the industrial drone fleet in Europe and the United States is estimated by the consulting firm BCG at USD 50 billion dollars by 2050, with most of this value expected to be related to drone services and data collection [8][9]. Additionally, in Poland, the development of the drone market may be beneficial for the economy and may amount to PLN 310–910 mld, according to the Polish Economic Institute [10][11]. The value of the Polish drone market is currently estimated at PLN 140 million, and it is estimated that by 2026 it will increase to over PLN 3 mld [8][9].

It should also be noted that in the traditional monitoring system the points are scattered over a large area, sometimes even several kilometers apart. Thus, monitoring concerns the constant measurement of a selected type of pollutant at a given point. If drones are used, it is possible to continuously measure selected pollutants in a given area in a specific time unit. The obtained data make it possible to obtain information on the distribution of pollutants in a given area in a given time unit. This type of monitoring is important especially in crisis situations, such as fire, or in areas where economic activity is carried out with different emission levels, such as landfills, chemical industry.

2. Air Monitoring in Industrial Areas

Atmospheric air and its quality are of significant importance, because on the one hand it determines the functioning of living organisms and the occurrence of various processes, and on the other hand, it is a medium into which various substances are introduced during the emission process. The presence of compounds of different composition and the physical state determines the quality of the air and thereby affects the organisms that live in an area and affects processes. The sources of indoor pollution are practically every process that is carried out in a given area, including printing, photocopying, sanding, mixing, drilling, cutting, painting. Therefore, in industrial areas, depending on the type of technology used, processes and activities carried out, compounds that are catalysts of biochemical processes, often allergenic, toxic, and carcinogenic, are emitted including among others nitrogen, sulphur and carbon oxides, ammonia, ozone, heavy metals and their compounds, dusts of various grain sizes and structures, organic compounds such as benzene, acetylene, halogen derivatives, carbon tetrachloride, lead tetraethylide, dimethyl disulphide, phenol, PAHs, and benzo(a)pyrene.

3. Characteristics of Unmanned Aerial Vehicles

UAS (unmanned aerial systems), also known as drones or remotely piloted aircraft systems, are systems consisting of an unmanned aerial vehicle (UAV), a communication link, a ground control station (GCS), payload, software, and an operator. Thanks to the current technology, UAVs may be controlled from the ground, remotely, partially, or fully autonomous. UAVs are classified in various ways, including e.g., operational range, weight, or configuration. Currently, however, there is no one universal, recognized classification that would be universally used.

One of the essential elements in the selection of UAVs for work are parameters of the device and the skills of its operator, which determine the ability to perform specific, desired activities. Dedicated devices are used to conduct measurements, they have sets of sensors and equipment, as well as software often constituting a proprietary solution addressed to a given device such as FLIR VueLink™, DRIMS2, Atmon FL Ground Unit [12][13][14], for recording the results of their analysis and transmitting information and signals.

For the purpose of monitoring chemical hazards and threats in industrial areas, indispensable components include at least:

- thermometer—makes it possible to determine whether the ranges specified by the manufacturer are not exceeded and whether there is a risk, e.g., faster discharge of the batteries as a result of low temperature,
- pyrometer—enables remote point temperature measurement of an object, e.g., a tank,
- hygrometer—allows measurement of humidity and determining whether it does not exceed the level that may damage electronic systems or deteriorate radio communication,
- altimeter (e.g., barometric)—allows to compare the concentrations of substances at different heights,
- GNSS receiver—determines precise position of the UAV,
- transponder—enables detection and recognition of UAVs by other airspace users and air traffic services,
- navigation and warning lighting—enables safe flight at night,
- transmitters, radio signal receivers, antennas—they enable the control of UAVs on long distances.

4. Application of UAV for Air Quality Assessment

UAVs equipped with appropriate sensors are increasingly being successfully used in rescue operations. Visible light and infrared cameras are most often used during and after rescue operations. This was the case with the gas explosion and the fire of the gas pipeline in Murowana Goślina in 2018 [15] or the gas explosion in Janków Przygodzki in 2013 [16]. Current and constant monitoring of selected compounds and temperature, carried out by drones, allowed for taking appropriate measures, minimizing the further development of environmental contamination.

It should be noted that in the scientific literature there are relatively a few studies devoted to operational monitoring of threats in the chemical industry with the use of unmanned aerial vehicles. Restas A. distinguished two basic possibilities of its use [17]:

- to support preventive actions—during airborne inspections of hazardous materials transport and monitoring industrial facilities or installations,
- responding to accidents involving hazardous substances—reconnaissance in the event of an accidental leakage of hazardous substances.

The researcher draws attention to the advantages of using UAVs compared to the traditional operation of chemical rescue units—faster time of launching and delivering the image from the scene without exposing firefighters to danger. Traditional chemical reconnaissance means preparing measuring equipment, putting on protective clothing and a breathing apparatus along with starting the measuring devices, which obviously takes more time than the preparation and measurement flight of the UAV. Moreover, the protective clothing may obstruct movement or even prevent thorough reconnaissance [17]. It should be noted, however, that the effective and efficient use of UAV requires meeting several conditions at the same time. These include, among others: fast transmission of high-quality images from the camera, favorable weather conditions for flights, appropriate training, and qualifications of operators.

Particular difficulties may arise when it is necessary to use UAV inside facilities, such as rooms, tanks. Inside the facility there may be flammable dusts or flammable materials, pyrophoric compounds that react with water or oxygen, and toxic compounds. In such an environment the system may be damaged or contaminated. The need to decontaminate the UAV after use requires careful assessment and planning. In addition, remote devices may be out of the pilot’s line of sight and internal obstacles may present a difficult flight path. In such a situation, an action plan should be defined before starting operations in the event of a shutdown of the UAV inside the facility [18].

The possibility of using drones to minimize the threat to life and health due to the emission of harmful compounds into the atmosphere was also noticed by the Austin Powder company, which deals with explosives. The company aims to minimize the emissions of toxic NO_x that can be released into the atmosphere during mining operations. To this end, scientists at the Rochester Institute of Technology are developing ways to use drones to quantify the NO_x contamination produced by explosions. They plan to capture the volume of the NO_x cloud by placing multiple drones with synchronized cameras around the explosion, and fly the drone directly into the cloud left by the explosion to measure the gas concentration with special equipment [19].

Chemical companies are showing increasing interest in the use of drones to protect and counteract threats. Currently, drones are used primarily for taking photos, monitoring surfaces, however, due to the emerging technological solutions, research is being undertaken in the field of plant monitoring, for example to detect gas leaks [20]. The Defense Threat Reduction Agency (DTRA) is researching the placement of chemical weapons sensors on drones. One of the biggest challenges in developing this drone monitoring system is integrating the sensor software with the navigation electronics for drones so that if a suspicious relationship is detected with the drone it can be maneuvered into the cloud for optimal detection and data collection [20].

Drones can be used for individual detection, i.e., to measure a selected pollutant at a selected point, but they can also be used in an air quality monitoring system, in difficult, dangerous, health, and life-threatening areas or in standard conditions. Drones are used for ongoing monitoring works, including measurement and monitoring of pollutants emitted, especially in the autumn–winter–summer period. Due to the fight against smog, standard monitoring based on measurement points is insufficient. More and more often, the roads are used to measure smog pollution, including PM_{10} and $PM_{2.5}$. Ongoing monitoring of a given area, based on drones, is a tool to combat the improper process of heating houses or other activities contributing to the increased risk of smog.

An example is the Aviation Atmosphere Monitoring System by Pelixar S.A., which is used, inter alia, to detect sources of emissions resulting from the combustion of forbidden substances, to determine the size of the smog cloud, the directions of its movement, the place of its condensation and the prediction of the phenomenon. Depending on the version, the Pelixar LMA drone is equipped with a module for remote reading and recording of parameters: suspended $PM_{2.5}$ and PM_{10} dust, thermometer, hygrometer, GPS position, video camera with 10x optical zoom, video transmission in FHD resolution. The concept of measuring pollutants that generate smog, including the location of the emission source, based on drones, has been introduced in cities such as Gdynia and Elbląg (Poland) [21].

An interesting solution is also Scentroid DR1000, which can be used for sampling and analyzing the surrounding air up to 150 m above ground level. It gives the opportunity to monitor more than 30 different pollutants, including H_2S, CH_4, CO_2, SO_2, VOCs, and particulate matter (PM_{10}, $PM_{2.5}$, and PM_1). The Scentroid DR1000 laboratory drone also allows to safely collect air samples required for laboratory analysis, which is important especially in places that are inaccessible or difficult to access, or in places that threaten the operator’s health and life [22].

One of the applications of UAVs in the area of CBRN (chemical, biological, radiological, and nuclear) threats is the measurement of radioactive radiation. The method was successfully used during the accident at the Fukushima nuclear power plant. The unmanned helicopter during programmed autonomous flights was used to map the radiation distribution and illustrate the movement of the radioactive cloud. It also made it possible to measure radiation in areas that are difficult to access for units with portable meters. Marturano et al. [23] simulated complex scenarios that took into account increased levels of radioactivity as occurred during the Chernobyl and Fukushima nuclear power plants failures. In subsequent emergencies of this type, an accurate mapping of the radioactive cloud can provide invaluable input for mathematical models determining the dispersion of radioactivity in time and space. This information can be a valuable input to predictive models and decision support systems, providing valuable guidance on the safe intervention of first responders or the subsequent need to evacuate affected regions.

The prospects for the development and use of UAVs in rescue and fire prevention are very promising. In the future, UAVs will probably complement the functionalities of fire trucks used in the fire brigade, which have the possibility of wireless transmission of the current image of the scene of the event, as well as the transmission of additional information, data, and measurements.

Mass use of UAVs is related to obtaining full autonomy by the UAV and its equipment, so that the Commander can independently use the UAV platform, adapted to the rescue needs [24]. It should also be added that the research carried out at the Scientific and Research Centre for Fire Protection—National Research Institute (CNBOP-PIB, Józefów, Poland), as part of the project "Controlling an autonomous drone using goggles (monocular)" [25]—showed that the main requirements concern, inter alia, weather conditions in the scope of operating temperature from - 30 to + 65 °C, wind speed, flight possibilities during rainfall, as well as functional ones, such as resistance to water, interference, dust, selected chemicals, flight time.

5. Conclusions

For the development of the mass use of UAVs, projects and technologies related to the automation of operation, control, and continuing airworthiness are important. Paradoxically, apart from the legislation, for the rapid development of UAVs applications, standardization work and the development of product standards are necessary. For rescue applications, there is great potential in combining technologies. An example is the already mentioned project [25] implementation period 2018–2021, under which a dedicated form of drone control using the operator's eyesight is being developed for the purposes of operational activities of the Border Guard. Such research allows revealing new needs and possibilities of available new technologies and their combination. They also allow for the verification of already possible practical applications and those requiring further technology development, e.g., UAV. However, it is important to be aware that the use of each new technology is associated, on the one hand, with new possibilities and functionalities and, on the other hand, with new needs, challenges, and threats. (e.g., drone fall, loss of control, communication, collision, damage, danger, etc.).

The presented research results also indicate the possibility of using the system of permanent air quality control in specific places, such as landfills, due to the high mobility of the system and the possibility of quick and easy location of areas where additional personal protection or areas at risk of explosion is required. The cited research results and the conducted analysis may also constitute the basis and some inspiration for further activities, research, experiments and, finally, implementation of solutions dedicated to air quality assessment and their use in practice. These studies may reveal further needs for the practical application of such measurements. Among them, it is justified to mention that there is the need for dedicated guidelines about tactics of using UAVs to monitor selected CBRN threats and support for rescue and firefighting operations.

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