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The Need to Create and Apply High-Precision Operational Remote Environmental Monitoring in the Face of Modern Challenges

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Abstract

The paper formulates new principles that should form the basis for the development and creation of new environmental monitoring based on heavy UAVs and high-altitude so-called pseudo-satellites capable of operating for a long time at altitudes of 25 - 30 km. In order to develop such principles, this paper analyzes the radioecological situation in the territories of Donetsk and Luhansk regions of Ukraine for rapid and high-quality environmental cleanup and rehabilitation of areas with detected critical levels of environmentally hazardous pollutants. In order to quickly obtain fundamentally new environmental information, it is necessary to conduct multi-parameter, high-precision integrated monitoring of the Earth's geospheres based on the latest methods and equipment for ground and remote environmental measurements, and new methods and technological means of clean, environmentally safe processing and final disposal. As the most appropriate technology, we propose mobile installations for plasma-chemical pyrolysis of medical waste directly at the place of its generation.

Keywords

Operational Environmental Remote Monitoring, Medical and Hazardous Waste, Plasma-Chemical Pyrolysis

1. Introduction

Today, many modern traditional measurement methods and tools have reached the limit of their information capabilities or have been completely exhausted and are ineffective for high-precision operational environmental monitoring with high resolution in the atmosphere-underlying earth surface system. In most cases, they are illustrative in nature. This primarily concerns remote monitoring. The challenge in war is the impossibility of systematic planned work with medical and other hazardous waste generated in the course of military operations. Accurate accounting of their location and quantity, as well as obtaining information on the morphological, physical, chemical and ecological state of the environment in their locations, requires operational high-precision monitoring.

Today, the main most dangerous environmental challenges are posed by military conflicts and wars, including military and terrorist operations involving nuclear power plants (NPPs) and direct nuclear and environmental blackmail and terror. Military actions in the territories of coal mines and other facilities related to coal mining and combustion in the coal industry also pose a danger of this level. Therefore, the hardware for remote sensing of environmental disaster areas has faced new, unconventional challenges and practical tasks of developing high-quality operational high-precision methods and hardware for the most accurate detection of the scale, structure, determinants of environmental crime, etc.

Environmental crimes have accompanied and continue to accompany all wars—Vietnam, Iraq, Yugoslavia, Georgia, Syria, Armenia, Ukraine. In Yugoslavia, hundreds of thousands of hectares of land remain unsuitable for agricultural use today. To ensure international trials of war environmental crimes, a proper documentary evidence base and, above all, monitoring hardware and analytical statistical calibrated data obtained through remote operational high-precision environmental monitoring based on calibrated measuring sensors combined with methods and means of high-speed automated processing and analysis of large arrays of environmental primary measurement data and obtaining final information is necessary. The main task is to identify obvious and hidden early signs of dangerous environmental patterns and trends of potential environmental disasters and the availability of means and technologies for appropriate rapid countermeasures.

An important function of environmental monitoring is also to ensure the automatic presentation of environmental information in accordance with regulatory requirements and unification of reporting, reduce the impact of human errors and risks of non-compliance, and ensure cybersecurity and confidentiality of environmental measurement data arrays in the process of their transmission. At the same time, the introduction of artificial intelligence, machine learning and analysis in the extreme environmental monitoring system will allow to quickly identify potential critical environmental anomalies, threats and risks and instantly analyze and respond to them, ensure the efficiency and reliability of the latest environmental technologies, fully automate the processing and presentation of final environmental information, and thus reduce routine operating costs and manage resources more efficiently, extend the working life of equipment, detect failures and various malfunctions before they become critical. At the same time, artificial intelligence and machine learning will also ensure faster and more informed decision-making critical to environmental challenges.

2. The Aim of the Work

The aim of the work is to create new principles of environmental monitoring based on heavy and high-altitude unmanned aerial vehicles.

3. Analysis of Recent Research

Analysis of the radioecological situation in the territories of Donetsk and Luhansk oblasts in the conditions of war. Today, large-scale hazardous complex environmental changes are taking place in the territories of military operations, including radioecological changes caused by the complex impact of flooding of coal mines and exposure of the population and the environment to coal radionuclides, radon emanations, Chornobyl radionuclides and radionuclides formed as a result of the so-called peaceful underground nuclear explosion "Kliwazh" at the Yunkom mine in Donetsk region. To this should be added radioactive products released into the environment in the processes of rock weathering and coal combustion containing natural radiotoxic nuclides in the industrial, municipal and private sectors. In addition, there are hundreds of radiation sources in Donetsk and Luhansk oblasts over which the State Nuclear Regulatory Inspectorate of Ukraine has lost control. In total, more than 120 tons of various natural radionuclides are released into the environment annually in Ukraine as a result of various industrial activities.

In the territories of military operations, radioecological hazard is especially critical as a result of artillery shelling, rocket and air bombardment.

Results of field radioecological measurements

Radon levels in different territories of Ukraine are higher than the levels defined by international standards, for example, in buildings constructed in regions with naturally increased radiation—in karst and mountainous regions, as well as in areas with increased tectonic and volcanic activity [1], the results of the study of the correlation between radon levels in residential premises and the risk of cancer are presented.

Field measurements of radon emanations in the territories of mine fields showed an excess of radon fluxes from 11 to 33 times, and in residential areas above mine workings from 6 to 17 times. At the same time, in stationary geological conditions, according to the conclusions of the Laboratory of Radiation Protection of the State Institution "O.M. Marzeev Institute of Public Health of the National Academy of Medical Sciences of Ukraine", D in [2] analyzed the correlation between radon levels in residential premises and the risk of cancer. The presence of ^{222}Rn in 4800 (out of more than 30,000 homes surveyed in Ukraine) was higher than the international reference level of 300 Bq/m^3. Estimated mortality from radon lung cancer in Ukraine reached more than 8000 citizens/year (21 citizens/day).

A description of existing methods of instrumental radon measurements and their effectiveness in the field is presented in [3].

The radioecological impact of radon on ecosystems and on surface and underground hydrosystems is also dangerous [4].

Thus, the research results show that in different regions of Ukraine there is a significant radon threat to public health, which also requires 4D instrumental monitoring, prevention and reduction of the level of this gas in residential premises.

Most of the soils above coal mine workings are classified as radon hazard class 2 and 3 according to NRBU-97, which requires enhanced environmental protection measures for buildings. At the same time, geogenic radon predominates in residential buildings. Based on the established patterns, the data obtained can be extrapolated to other coal regions.

Analysis of the dynamics of the incidence of malignant neoplasms in the Kryvyi Rih and Dnipro regions as a result of exposure to hazardous environmental factors [5] [6] shows a significant increase in the incidence in industrial areas, such as Kryvyi Rih, as a result of the impact of heavy metallurgy on people and the environment [7].

A close correlation was found between increased levels of heavy metal pollution and an increase in the number of cases of lung and digestive cancer. An analysis of the actual dynamics of the incidence of malignant neoplasms in 1993-2007 (per 100,000 population) in Ukraine as a whole and, in particular, in the Dnipropetrovs'k region and Kryvyi Rih shows that the risk of radon cancer is 25% - 35%. At the same time, the average number of malignant neoplasms (MN) increases by 2 times in summer seasons. The peak number of pulmonary malignancies is observed in the group of 65 - 69 years old men and 70 - 74 years old women. In men, 51% of pulmonary NETs are observed in the 65 - 74 age group and a very high percentage in the 55 - 64 age group—22%. In women in the age group 65 - 74 years, 41% of pulmonary diseases were detected, and in the group 55 - 64 years—19%. It was found that all categories of citizens, without exception, are exposed to radon risks, which indicates the environmental hazard of the problem.

The number of malignant tumors per 100,000 population in the Popasna district of Luhansk region for diseases that can occur when drinking drinking water with an excess of iron, copper, sulfates, coal and other radionuclides, and dry residue in mine water increased from 67 citizens in 2014 to 200 citizens in 2017.

According to fragmentary data, in the area of mine water contamination of drinking water in 2018-2019 in the Popasna district of Luhansk region, cancer mortality per 100 thousand people in the territory controlled by Ukraine amounted to 260 people, compared to 230 in 2018, *i.e.* 13%. Mortality from other diseases increased to 8% in 2018-2020. According to statistics in the Luhansk region, for every 10 years of living in certain geological complexes associated with high radon emissions, the development of lung cancer increased by 11%.

According to the World Health Organization (WHO), ≥80% of diseases are caused by poor-quality drinking water. If no precautions are taken, further consumption of water from the water intake areas of the Kamyshevakha, Bilenka, Siverskyi Donets and Don rivers will lead to a steady increase in the incidence of diseases by more than 3.5% against the background of already negative demographic processes.

A large-scale study of low doses of household radon exposure in target groups of miners revealed an increase in lung cancer. The study of the impact of low household radon doses on the population, which is significantly lower than for miners, in 9 European countries revealed a significant increase in lung cancer. For non-smokers living in dwellings with a radon concentration of (0 - 400) Bq/m^3, the cancer risk is 0.4% - 0.7% for the age of 75, and for smokers—(10% - 16%). For example, in the Netherlands, the DALY index is (1000 - 14,000) DALYs, and for smokers this index is 3 times higher due to additional malignant lung tumors.

Radioecological experience of peaceful underground nuclear explosions. As a result of the underground peaceful nuclear explosion "Kliwazh" at the Yunkom mine, all refractory radionuclides are preserved in the melt of underground rocks in the hypocenter of the explosion, and volatile radionuclides such as Iodine-125, 129, 131; Cr-89, 90 and Xe-137 filled newly formed cracks in rock layers during the explosion. At the same time, Sr-90, Cs137 and other transuranic elements with a half-life T1/2 of less than 30 years pose a long-term radioecological hazard. At the same time, experimental studies of more than 180 hypocenters of underground peaceful nuclear explosions showed that all underground peaceful nuclear explosions form a specific burial ground in the hypocenter with radioactive substances inaccessible for extraction in the form of fission products; induced radioactivity; unreacted nuclear charge residue, rock melt and glassy slag.

In [8], the radioecological state of the territory around the hypocenter after the explosion was investigated. The results showed the possibility of penetration of radionuclides into underground aquifers, which requires special long-term monitoring of possible changes in migration and impact of radionuclides [9]. In these papers, the authors point out the need for continuous radioecological monitoring of groundwater that may be associated with the location of the Yunkom mine. After its flooding, the risks of migration of radioactive substances to drinking water intakes increase in case of violation of the natural sealing of the underground explosion chamber.

Thus, as a result of prolonged exposure of this underground burial site to the main radiation factor, which is water, liquid radioactive fluids are formed that migrate together with long-lived hazardous radionuclides over long distances and can reach drinking water intakes.

The nuclear charge at the Yunkom mine was detonated on September 16, 1979, and coal mining continued on September 17. The explosion was initiated by the military under the auspices of the Skochinsky Institute of Mining in Lyubertsy.

Six months later, in March 1980, a methane explosion occurred at the Yunkom mine, causing casualties. After that, abnormal radioactivity of 50 - 57 μR was observed in the village of Olkhovatka. A little later, an increased radiation background was observed in the more remote settlements of Khartsyzsk and Zuivka. And 8 years later (in 1989), there was an outbreak of cancer, including thyroid disease.

In 1990, as a result of Pu-239 and Am-241 leakage, the radiation level near the epicenter of the explosion was 60 Ci. In 2001, the Yunkom mine was closed, but the decision to pump mine water forever was recognized as not optimal, despite the fact that in the event of the destruction of the underground radioactive "capsule", radionuclides with water can come out of it to the surface and then the radiation level can reach 1000 μR/hour, while the norm is less than 30 μR/hour.

At the hypocenter of the explosion, the maximum temperature was 4000˚C - 5000˚C, and therefore about 15 tons of rock turned into steam with a pressure of Pmax = 150 - 200 atm, and 150 - 240 tons of rock melted. After the nuclear explosion, the temperature slowly, over many months/years, dropped from 5000˚C to 500˚C. The underground geologic spherical space was disturbed by the nuclear explosion within a radius of –0.7 km. At the bottom of this sphere, a lens of molten rock was formed in which the amount of newly formed hazardous radionuclides was 18 g (krypton, iodine, xenon, rubidium, cesium and other daughter radionuclides, including super toxic plutonium-239 with a half-life of 24,000 years. And each kilo ton of nuclear explosives produces—3.9 g of plutonium-239.

Thus, as a result of the mass closure of mines and intense hostilities in Donetsk and Luhansk oblasts, a new artificially created open and uncontrolled geological and geophysical ecological system with uncontrolled dynamic, chemical and radioecological parameters is being formed. The peculiarities and duration of equilibration of this system along with hazardous environmental consequences for the territory are currently unknown.

Radioecological remediation of these territories should take into account that contaminated areas with doses exceeding 50 mSv/year should be closed for human habitation and work, and areas with annual doses less than 5 mSv/year can be resuscitated for habitation and economic activity. At the same time, there is no radiation dose that does not pose a risk. Therefore, radon problems in coal regions require further fundamental study. At the same time, the impact of low doses of radiation manifests itself after many years. And even if the cancer situation in the area is not directly linked to the radiation background from natural radionuclides, the impact of natural radionuclides is definitely synergistically summed up, and often non-linearly, with other negative factors.

4. Summary of the Main Material

Environmental hazards of military medical and biological waste accumulation. The widespread use of disposable medical materials, the volume and rate of generation of hazardous medical waste are critically increasing. At the same time, the only environmentally friendly technologies capable of processing and disposing of hazardous medical waste at temperatures above 1150˚C - 1350˚C are high-temperature plasma-arc technologies [10].

These technologies can become a comprehensive solution for the processing and final utilization of medical waste with the conversion of the organic component of waste into combustible energy synthesis gas. The latter can be used for the plant's own needs to save electricity from external sources. At the same time, the high temperature and powerful UV radiation of the plasma jet completely destroy dangerous bacteria and other microorganisms. Due to these environmental benefits, plasma technology can significantly simplify a significant part of the processes in a complex and overloaded organizational system of hazardous medical waste management [11].

Plasma technologies and manufacturing of construction and other materials [12].

Coal ash and slag dumps of thermal power plants and boiler houses have a huge promising construction potential for the restoration of Donbas. The use of plasma-chemical technology for processing ash dumps of thermal power plants (TPPs) is a technology for obtaining valuable construction materials. However, coal ash and slag, along with valuable materials, contain radioactive and toxic substances that are environmentally hazardous to the public and the environment. Plasma processing by decomposition and change of the structure of ash and slag waste materials is carried out at temperatures above 3000˚C, which makes it possible to decompose the hardly soluble and hazardous components of ash.

High temperatures activate and modify chemical reactions to separate or convert hazardous compounds into less harmful or useful products. Plasma chemical treatment produces useful mineral concentrates and various metals such as aluminum, silicon, iron, and others, as well as strong, chemically resistant construction slag.

One of the leading European projects in the field of plasma-chemical pyrolysis is the work of Polish research institutes together with foreign partners (in particular, Germany and France) to integrate this technology for the treatment of various hazardous wastes, including medical waste. For example, Polish institutes can adapt technologies similar to those already successfully used in other countries to create high-temperature plants based on a plasma torch or arc plasma torch.

Among the research projects, we can mention the work of Mateusz Wnukowski [13], which is studying plasma reactors for the pyrolysis of methane and the production of useful by-products such as hydrogen and carbon black. Although there are no large-scale plasma plants for municipal or medical waste in Poland yet, pilot projects are currently being tested that show promising results for further application.

Plasma-chemical processes also reduce the toxicity of materials by neutralizing heavy metals and other toxins, which is very important and allows minimizing the environmental impact of waste dumps when they are processed to produce metals and building materials. Plasma methods also make it possible to reduce the amount of waste to be buried in an environmentally efficient manner. Thus, plasma-chemical technologies can not only process ash dumps at thermal power plants for their industrial use in new production processes, but also improve the environmental situation around them.

Main principles of development and construction of new operational environmental monitoring using modern heavy UAVs

International environmental law and its legal definitions clearly define that everything that war does to the population, to the environment, and to living and plant objects of fauna and flora is ecocide. In fact, it is an environmental weapon of mass destruction of the population and the environment. But the evidence base of ecocide for the ICC, from the perspective of international experts, is a very difficult job. Military environmental crimes are committed in dangerous and inaccessible areas. Therefore, it is extremely difficult to quickly take direct samples in the occupied or war-torn territories. The main limitation in collecting factual evidence is the transience and latency of hazardous environmental processes. Therefore, reliable environmental operational hardware and analytical data are needed to form the evidence base. It is impossible to implement this approach without the creation of modern high-precision remote operational monitoring using modern aerial vehicles in the "underlying surface-atmosphere of the Earth" system with the possibility of hardware vision of underground anthropogenic and natural geological and geophysical structures.

It is also obvious that the economic restoration of the territories of the Ukrainian Donbas also requires long-term environmental monitoring, the creation of which should also be among the priorities of Ukraine's post-war reconstruction. In this case, the main source of environmental information should be objective instrumental statistical environmental data, taking into account their possible latent nature, on each specific vital object/element for making future informed management decisions. Only objective mapping, geophysical and environmental information can serve as the basis for this. The same information is also needed in international environmental courts to assess the dangerous consequences that arise and may arise as a result of war crimes committed by the aggressor on the territory of Ukraine. The environmental consequences in the areas of radioecological disaster are real new deaths, illnesses, deformations of consciousness and mental abilities, and reactions of the population.

The latency factors of environmental processes are not obvious, transient, and therefore the consequences of criminally committed hazardous environmental phenomena and processes often become apparent only in case of mass diseases or death of people and all other species of living or plant life. Therefore, for the instrumental recording and accumulation of statistical environmental data, permanent operational environmental monitoring should be based on new universal principles of ground and aerospace environmental control of the geospheres. At the same time, the monitoring instrument complex should have maximum economic and strategic feasibility in order to fully meet the country's needs for complete high-precision environmental data.

https://www.bbc.com/news/technology-62123819

Figure 1. Zephyr S Airbus solar-powered high-altitude UAV pseudo-satellite suitable for remote environmental monitoring of natural and anthropogenic objects: wingspan—25 m, weight—about 75 kg, maximum flight altitude—up to 23,200 m, continuous flight duration—up to 3 months.

https://www.military.com/equipment/mq-9-reaper

Figure 2. Heavy universal unmanned aerial vehicle UAV MQ-9 with sensor sensors installed on a stabilized sighting platform with a powerful zoom, laser and infrared thermal imager, all-weather SAR radar with a synthesized aperture for high-precision remote environmental sensing, which can be used to map radiation fields in the "atomosphere" system—the underlying surface of the earth.

One of the options is to create such a complex on the basis of modern unmanned aerial vehicles (UAVs), for example, on UAVs such as Zephyr S Airbus with a flight altitude of up to 23,200 m, or Skyd weller Aero with a flight altitude of up to 14,000 m and a payload of up to 400 kg. Autonomous continuous flight of these UAVs in a given area can last up to 3 months (**Figure 1**).

Another variant of the carrier for placing the entire environmental monitoring equipment complex on it can be a heavy universal UAV MQ-9 made in the USA (**Figure 2**).

On the special stabilized instrument platforms of these UAVs, which are essentially pseudo-satellites with low flight trajectories at altitudes of up to about 30 km, as well as on heavy UAVs, it is possible to install portable optical sensors with a powerful zoom that are well-developed today in terms of engineering and physics. thermal imagers, lasers, synthetic aperture radars for all-weather vision, and special spectropolarimeters for measuring all 4 Stokes parameters for all types of hazardous atmospheric aerosol [12].

Such a toolkit will allow for high-precision measurements of environmental and other parameters of various objects, phenomena and processes both in the "underlying surface—Earth's atmosphere" system and on geological and geophysical horizons below the underlying surface itself, including radiation objects, fields and sources of radiation, including military ones. Such a fundamentally new monitoring complex based on modern UAVs, which will have no analogues, is capable of providing relevant environmental and other institutions with fundamentally new operational high-precision environmental information both during war and post-war environmental revitalization of territories, including data packages for scientific substantiation of critical limits of environmental assimilation of environmentally hazardous geospheric pollutants. Particular attention should be paid to identifying the accumulation of hazardous medical waste in the frontline areas and radioecological mapping of Donbas territories and radioecological burial grounds. The latency factors of environmental processes have a hidden fluid character, and therefore the consequences of hazardous environmental phenomena and processes, including war crimes, often become apparent only in the event of mass death or mass diseases of living and plant organisms.

5. Conclusions

For the instrumental recording and accumulation of statistical environmental data, operational environmental monitoring should be based on fundamentally new means of ground and aerospace environmental instrumental control of the geospheres with maximum strategic feasibility. Such highly effective international environmental aerial monitoring can be created on the basis of modern high-tech heavy unmanned aerial vehicles and high-altitude pseudo-satellites, which will solve the following remote tasks:

- Conduct remote all-weather sensing using synthetic aperture radar with high geographic resolution;
- Detect locations of ground and underground storage (at positions, in warehouses) and transportation of nuclear materials and facilities based on electroresonance methods;
- Map the total content and vertical profile of atmospheric aerosol concentrations, their chemical and phase nature, as well as geometric characteristics and spatial orientation of aerosol particles using spectropolarimeters capable of measuring all 4 Stokes parameters;
- Will carry out mapping for environmentally friendly and safe processing and

final disposal of hazardous medical military waste directly at the site of its generation the best are mobile plasma arc technologies in the form of installations for plasma-chemical pyrolysis at temperatures 1150˚C - 1350˚C.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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