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# AEROSPACE TECHNOLOGIES FOR ASSESSING SOIL CONTAMINATION

**Actuality.** Studies of soil pollution assessment are based on scientific principles that define a complex system of environmental safety management in the context of increased exposure to sources of secondary dust pollution of the atmosphere. To ensure environmental safety under conditions of high levels of dust pollution, it is necessary to apply and improve the relevant models. Among the many types of environmental pollution, dust pollution of the atmospheric air and the deposition of harmful substances on the soil are particularly dangerous. This pollution can take two forms: direct emissions from industrial enterprises (primary) or the formation of secondary pollution through physical and chemical processes in places where dust-like waste is stored. Fine waste after air purification with dimensions of less than 100 microns is particularly hazardous. In modern environmental monitoring and assessment of soil pollution, special attention is paid to remote methods that allow for more effective monitoring of the impact of human activity and solving environmental problems. The use of unmanned aerial vehicles is one such method that has positive results. **The purpose of the article** is to solve the scientific problem of improving aerospace methods based on unmanned aerial vehicles (UAVs) for monitoring and assessing the quality of soil pollution. **The object of the study** is the use of aerospace tools for monitoring and assessing the condition of soil cover. To achieve this goal, the following tasks have been defined: to study the current state and ways to improve the efficiency of UAVs in the system of environmental monitoring of soils; to develop models of environmental assessment; to analyze existing approaches to the use of aerospace assets for monitoring and assessing the state of soil cover. **Conclusions:** a methodological approach based on a modified method of the comprehensive assessment of the level of technogenic hazard of industrial facilities is proposed to assess the state of environmental safety in conditions of intense dust pollution of the atmospheric air.

**Keywords**: information technology; technogenic hazard; soil cover; dust pollution; atmospheric air; technical solutions; environmental safety; morbidity.

## Introduction

The scientific basis of soil pollution research is the need to determine the place of environmental hazards in the hierarchy of soil research. To ensure environmental safety in conditions of high levels of dust pollution, it is necessary to apply and improve the relevant models. At the current stage of soil research, five main areas of research are identified:

– production (for the production of products and raw materials for industry)

– preservation of the gene pool, reproduction of living beings;

– information (for scientific, cultural, educational and other information);

– engineering (for the creation and placement of engineering facilities, structures, roads, etc;)

– general environmental (global biochemical cycles, regulation of surface runoff, climate management and chemical element flows).

When conducting research to assess soil quality, it is necessary to distinguish between primary and secondary soil contamination and differentiate between sources of environmental hazards. Among the many types of environmental pollution, dust pollution of the air and the deposition of harmful dust on the soil cover pose a significant danger. This pollution can be caused both by direct emissions from industrial enterprises (primary) and secondary formation as a result of physical and chemical processes in places where dusty industrial waste is stored. Fine waste after air purification (<100 microns) is considered particularly hazardous [1].

The creation of new and improvement of existing methods for constructing cartographic models for assessing soil quality is possible only on the basis of the integrated use of aerospace and contact measurements.

## Analysis of recent studies and publications

Experimental studies on soil contamination are based on the use of expert assessment methods and information technology. Some laws of Ukraine, namely: "On Land Protection", "On Monitoring", "On State Control over Land Use and Protection", refer to the protection of lands that require special attention from the state, but are identified by the results of remote sensing. To determine the destructive processes of soil cover, it is necessary to have a database to update periodic information and build the dynamics of any processes. In order to make management decisions

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on land use and protection, a full package of various information should be available to managers of different levels, including local governments and control bodies. The scientometric analysis of the study area revealed many environmental problems that need to be addressed. An analysis of previous studies suggests that the impact of secondary dust pollution on the ecology of the region is of considerable interest to such scientists: O. Adamenko [1], Y. Adamenko, L. Arkhipova, O. Mandryk, O. Mashkov, M. Malovanyi, H. Rudko, O. Trofymchuk [2], V. Trisniuk, et al. [3, 4].

**The aim of the article** is to solve the scientific problem of improving aerospace methods based on an unmanned aerial vehicle for monitoring and determining the quality of soil pollution.

**The object of the study** is information technologies for comprehensive soil monitoring based on aerospace and contact methods.

To achieve this goal, the following tasks have been defined: to study the current state and ways to improve the efficiency of UAVs in the system of environmental soil monitoring; to develop models of environmental assessment; to analyze existing approaches to the use of aerospace tools for monitoring and assessing the state of soil cover.

## Analysis of the problem and methods of soil contamination detection

Soil contamination can occur both as a result of primary emissions from industrial enterprises and as a result of physical and chemical processes in places where dusty industrial waste is stored, especially fine dust removal waste. This secondary type of pollution is quite widespread, as there are currently no effective technologies for utilizing this waste. Failure to consider secondary soil contamination when monitoring environmental hazards can lead to underestimation of the environmental risk. In such cases, it is important to assess the impact of soil pollution sources in the formation of an industrial hazard. Typically, the technogenic hazard indicator is determined by the formula

$$T = K_T K_{KM} K_p \frac{\sum_{i=1}^{N} K_{ui} a_i M_i}{N} , \qquad (1)$$

where $T$ – is an indicator of technogenic hazard due to soil pollution;

$K_T$ – coefficient of regional economic activity;

$K_{KM}$ – coefficient of the number of citizens exposed to pollution;

$K_p$ – coefficient that takes into account the terrain;

$K_{ui}$ – coefficient depending on the characteristics of emission sources;

$a_i$ – air emission rate;

$M_i$ – annual weight of ingredients contained in emissions to soils, tons per year;

$N$ – the number of ingredients..

## Assessment of ecosystem dynamics under conditions of anthropogenic dust pollution of atmosphere air

A geodatabase has been created to assess changes in the ecosystems of the Carpathian region as a result of man-made dust pollution. It contains satellite images obtained from Landsat 7 satellites (shown in Figures 1 and 2), topographic maps, and digital elevation models with different levels of detail [5].

**Fig. 1.** Landsat 7 satellite image with a resolution of 30 m (10.05.2021)

**Fig. 2.** Landsat 7 satellite image with a resolution of 30 m (20.07.2021)

Since most anthropogenic phenomena and processes are multifactorial, it is impossible to take into account

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the degree of influence of each factor on the formation of the phenomenon. Therefore, a probabilistic approach based on the construction of interpretation and extrapolation models using monitoring results, such as observation series, and methods of mathematical statistics and probability theory, is effective for predicting environmental hazards. This approach makes it possible to take into account the multifactorial nature and uncertainty of the impact of individual factors on the result [6] (Fig. 3).

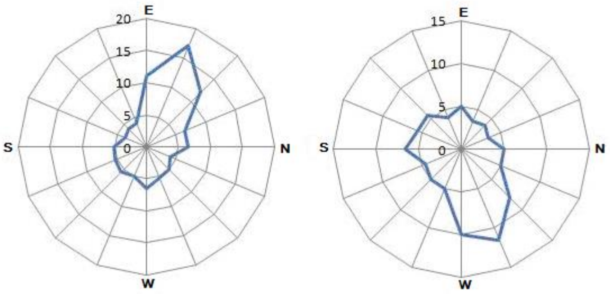


**Fig. 3**. Wind rose diagram of Burshtynska TPP

The wind rose and the probabilistic approach to predicting the environmental hazard of Burshtyn TPP are associated with the multifactorial nature of techno-natural phenomena and processes.

It is impossible to take into account the influence of each factor on the formation of the phenomenon, so it is advisable to use a probabilistic approach. This approach consists in building interpretation and extrapolation models based on monitoring data and methods of mathematical statistics and probability theory.

The wind rose is a tool for determining the directions of pollution spread, which can be used to improve the forecasting of environmental hazards from the Burshtyn TPP [7, 8].

In predicting maximum environmental performance, such as safety and pollution levels, a mathematical random variable model is often used as a simple and popular probabilistic approach. This model is the most effective. Sulphur dioxide in the atmosphere can react with water to become an acid, which is then likely to fall to the ground as rain. Today, sulphur dioxide emissions are the most acute problem, as they exceed European standards. Carbon monoxide, in turn, changes the greenhouse effect.

To promptly detect, localise, identify and monitor the anthropogenic and environmental impact of pollution on aquatic ecosystems and, as a result, on human activity, there is an effective method for building multi-criteria mapping models of the area in combination with remote sensing data analysis. This method, proposed by G. Krasovsky [2], makes it possible to determine the degree of combinatorial influence of the factors that cause a hazardous phenomenon. Contact methods for determining the areas affected by erosion processes involve a set of field and desk-based work. Field work involves surveying the territory, measuring habitat areas using GPS equipment, and taking samples of soil chemical composition. Desk-based work involves processing field data and forecasting the further development of these processes. The advantage of contact methods is the high accuracy of measurements of soil chemical composition and vegetation [9].

Thus, the creation of new and improvement of existing methods for building cartographic models of environmental assessment of agricultural land is possible only on the basis of the integrated use of aerospace and contact measurements, taking into account the variety of grain crop hybrids grown, the quality of agrochemical measures, meteorological conditions and the characteristics of the analysed area [10].

An analysis of methods for monitoring changes in the environmental state of the region showed that remote sensing data processing is the most efficient in terms of efficiency and retrospectivity of data, as well as in terms of labour and material costs. The results of multispectral imagery can be analysed semi-automatically by calculating the so-called vegetation indices. When they are calculated, new images of the area are created, where certain objects are highlighted by colour gradation. Out of the variety of vegetation indices, we selected the two most relevant to the subject of the research – the NDVI and NDWI indices.

The NDVI indicates the difference in vegetation levels for each field and is calculated using the formula

$$NDVI = \frac{NIR - RED}{NIR + RED}, \qquad (2)$$

where NIR is the reflection value in the near-infrared spectrum;

RED – the value of reflection in the red part of the spectrum.

The NDWI index indicates the level of surface moisture and is calculated by the formula

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR}, \qquad (3)$$

where NIR is the reflectance value in the near-infrared spectrum;

SWIR – reflectance value in the short-wave infrared spectrum.

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It is outlined that remote sensing methods have a number of features (time of survey, meteorological conditions, type of equipment, image resolution, etc.) in the context of determining the factors influencing the reflectivity of soils and vegetation and have been studied in detail. However, their main disadvantage is that in order to be confident in the results of remote sensing data processing, it is necessary to have at least some a priori information about the study area. After collecting, processing and analysing field and laboratory data from each site, soil contamination is calculated.

Building digital terrain models and creating cartographic models of surface slopes, combined with meteorological data, allows us to determine the impact of agricultural land on the aquatic ecosystem and soil pollution. Retrospective monitoring of the study areas based on remote sensing data reveals the effects of agricultural soil use on the ecological state of the region. In this way, a structural scheme for monitoring and assessing the impact of agricultural processes on the environmental safety of the territories was formed [11, 12]. Based on the results of remote sensing, the terrain is analysed and retrospective monitoring of land use for agricultural production is carried out.

The use of unmanned aerial vehicles has many advantages, including fast and accurate information about the state of the environment in a given area, the ability to reach hard-to-reach areas, and the ability to modify UAV onboard systems depending on the monitoring task. Modern UAVs have many capabilities, such as photo and video surveillance in the visible spectrum, as well as thermal and radar imaging. In addition, an approach has been developed to formulate a time or economic criterion to determine whether UAVs can be used at minimal cost to perform environmental tasks. An additional advantage of using UAVs for environmental control is the ability to respond quickly to the detection of pollution and take timely measures to eliminate it. The use of UAVs also reduces the risk for people who carry out observations in hazardous conditions, such as in pollution zones where exposure to toxic substances is possible. The use of UAVs in environmental control is an important element of the strategy for preserving the natural environment and improving environmental safety. In solving the problems of monitoring geo-environmental systems using unmanned aerial vehicles, the landscape approach is key. It considers the image of the earth's surface obtained with the help of technology as a complex geo-environmental system where all elements are closely connected and interact with each other. The landscape is seen as a result of natural and human activity, while it retains traces of different stages of development, which makes it possible to assess the importance of the landscape for the study of geo-environmental systems in both spatial and temporal aspects.

Contact methods provide information on the current agrochemical state of air, soil and water, as well as check the adequacy of remote sensing data processing results. Internet services provide information on the legal regime of land use for agricultural activities, as well as the legal framework for regulating the environmental condition of the area. This information makes it possible to build thematic mapping models and develop protection measures against harmful substances to ensure a sustainable environmental state of the region and maintain the level of agricultural production of grain crops. In addition, the information obtained reveals areas where there is an increased risk of erosion processes, and therefore the need for constant monitoring. The end result of data processing, analysis and interpretation is geomodels of the studied areas with a corresponding database that can be filled with new information or serve as a basis for making management decisions on the development of the region's environmental status [13].

Remote sensing makes it possible to detect erosion processes in soils, as they have a significant impact on optical properties. This is because erosion reduces the amount of humus and clay in soils, which leads to an increase in the brightness of their surface. This phenomenon is amplified when lighter rocks come to the surface after the upper soil layers are washed away. Erodibility is an important soil characteristic that can be detected on satellite imagery, and it can help monitor soil conditions and avoid negative impacts of economic activities. Soil erosion can be caused by either water erosion or wind deflation. One of the main factors of water erosion is surface water runoff. The flow regime depends on various factors, such as rainfall, topography, soil properties, vegetation cover, land use and many other factors.

Linear erosion forms, such as gullies and ravines, can be tracked on satellite images. These forms appear on images with a spatial resolution of 1 to 2 m as clearly defined contours with a jagged shape. On images with a spatial resolution of more than 10 m, gullies are usually not visible, but networks of gullies with elongated wavy tree-like shapes are clearly visible. The bottoms and slopes of gullies are usually occupied by natural vegetation, which is denser and more moisture-loving in the lower parts of the slopes and along the bottoms.

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Specialists of the Institute of Telecommunications and Global Information Space of the National Academy of Sciences of Ukraine have developed a clustering algorithm that allows for clearer detection of gully structures on satellite images in combination with digital elevation model (DEM) data. Remote sensing is a powerful tool for obtaining information about different areas, especially for objects that are inaccessible or difficult to reach. For example, the study of gully structures, forms and soil types in Boryspil, Kyiv region, and Pancheve village, Novoukrainskyi district. Pancheve in Novoukrainsky district of Kirovograd region can be used for detailed cartography, land use, industrial planning and other purposes.

To analyse and process the results obtained, the modelling tools of the ERDAS Imagine package were used, which performs various image processing operations, including classification and clustering. The developed clustering algorithm makes it possible to determine the similarity of objects in the image and to distinguish them from others. Thus, the results of the study may be relevant for various purposes, such as land management, environmental protection, transport infrastructure planning, construction and industrial development planning, etc.

This indicates that land resources have been exploited for decades without taking into account natural factors and the principles of sustainable development. As a result, serious problems have arisen: natural ecosystems have been destroyed, their biodiversity has decreased, the environment has been polluted and the climate has changed. Such processes are typical for many regions of the world where soil degradation is occurring, especially on land used for growing crops. The deterioration of the humus condition of soils leads to a decrease in their fertility and bioproductivity. This ultimately reduces the quality of crops and increases dependence on chemical fertilisers and pesticides. In addition, soil degradation can lead to a decline in biodiversity, in particular through the loss of natural habitats for various plant and animal species. This can have a negative impact on ecosystem services, which ensure the environmental sustainability and resilience of geosystems. Therefore, it is important to ensure sustainable and environmentally sound development of agricultural areas, taking into account the impact on natural resources and ecosystems.

It is important to pay attention to the use of land resources, taking into account their natural characteristics and potential. It is necessary to develop land use with a view to sustainable development and preservation of ecological balance. To this end, it is important to use scientifically sound methods and principles of soil, water and forest conservation, and to reduce the environmental impact of industry and other activities. It is also important to create special protection zones for natural complexes and ensure their effective functioning. The deductive approach to landscape research is to study individual characteristics of landscape systems to understand their organisation as holistic entities. The use of remote sensing and multidimensional spatial analysis allows us to identify patterns of landscape structure and genetic relationships between individual landscape elements.

Some landscapes may have similar or even identical spectral characteristics that make it impossible to distinguish them on images. This can be caused, for example, by sparse and small plant communities, soil cover, moisture, and other factors. To solve these problems, complex analysis methods are usually used, including additional information from other sources and manual work by interpreters. Targeted use of industrial and agricultural waste can help improve the ecological state of the pedosphere. For example, using organic waste as fertiliser can reduce dependence on chemical fertilisers and improve soil quality. Using industrial waste to build roads and other structures will reduce the negative impact on the environment and reduce the need for the extraction of new materials. It is also necessary to take into account the impact of human activity on natural ecosystems and implement measures to preserve them, such as gr een plantations, restoration of river ecosystems, creation of nature reserves, etc.

The classified image clearly shows linear objects such as dirt roads, roads and railways, forest clearings and clearings with power lines. They are particularly visible where they cross forests due to their light tone. The most visible are dirt roads built on the highest ground, with their lithological base being sands. But within settlements, they often disappear, as they have identical or similar brightness to other elements that form the settlement. Due to their special internal organisation, settlements can be clearly identified against a less structured background. The rectangular shape of buildings and gardens and the network of roads leading to or crossing them play a significant role in this.

It should be noted that due to the complex colour scheme, the detail of the settlements in the classified image is much higher than in the panchromatic satellite image. Colour combination is also an identifying feature of the natural conditions and location of the territory.

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While the colours of peat bogs, forests, and meadows dominate on the interfluve, and the colours that reflect different degrees of humusification of arable land are much less common, the ratio of cover and, therefore, their brightness is somewhat different on the birch terraces of the Dniester River. In the second case, additional deciphering features of settlements are the large size of the surrounding agricultural land, while in the interfluves it is smaller. Thus, satellite imagery is a useful tool for determining landscape features of a territory, but it cannot be relied upon entirely for landscape mapping.

The boundaries of plant communities on the images may not coincide with the boundaries of landforms, which complicates the process of delineating tracts. In addition, the images may contain patches of developed areas covering several landscape systems. This makes it difficult to identify them in black and white images. Deciduous and coniferous forests can be shown in the same tone in panchromatic images, which also makes it difficult to distinguish them if they are located side by side.

The advantage of classified images is the ability to use digital processing techniques to automate the process of extracting image elements and classifying them. For example, machine learning algorithms can be used to identify soil types, which is faster and more accurate than a human expert. In addition, digital methods allow for the rapid processing of large amounts of data, which results in faster and more efficient mapping.

The colour scheme and detail of image elements on classified maps can make it difficult to understand and perceive the landscape. For example, if the colour of a satellite image is uniform, different elements on a classified map may stand out, which is likely to change the perception and understanding of the boundaries of the territory. For example, identifying areas with shallow groundwater using remote sensing is a rather difficult task. However, some features may indicate the presence of such zones, as mentioned above, such as increased topsoil moisture and moisture-loving vegetation.

Soil moisture can be determined using different spectral ranges. For example, in the optical range, measurements are made by determining the coefficients of spectral brightness and reflectivity of dry and wet soils, as well as the polarisation of reflected light. In addition, increased soil moisture can be detected in the infrared and microwave ranges by measuring the radiance temperature of the soil throughout the day. However, it should be noted that these methods do not directly indicate the occurrence of groundwater, but only provide indirect indications of the presence of high soil moisture. Therefore, a combination of several methods and detailed geological and hydrogeological information about the study area may be required to more accurately identify areas with shallow groundwater.

In addition, the variation of brightness values can lead to a sharp difference in the display of trace elements, which can make it difficult to perceive individual details on maps. Therefore, when constructing landscape boundaries, it is necessary to take into account not only classified maps, but also additional information about the landscape, in particular, orientation to the terrain, taking into account its physical and natural features. However, it should be noted that image classification has its limitations and drawbacks. For example, when using colour classification, errors can occur due to the similarity of colours of different objects.

Also, when processing large amounts of data, errors may occur due to incomplete or incorrect information, as well as the lack of a priori information about objects in images. Therefore, it is important to follow the correct methods of data processing and analysis, as well as to take into account possible errors and limitations when interpreting the results. These methods have their drawbacks. First and foremost, it is the insufficient study of moisture and the complexity of its interpretation.

Radar surveying methods determine the areas of waterlogging and the depth of groundwater occurrence using the complex permittivity of soils. However, given the lack of a priori information, it is difficult to adapt them to forecast the development of flooding processes. The method of cosmobioindication developed by G. Krasovsky makes it possible to control waterlogged areas by determining the state of vegetation cover by vegetation indices according to the degree of waterlogging. However, the application of this method is limited to uncultivated wetlands and ponds. Remote methods help to accurately determine the contours of flooded areas based on indicative signs and conduct operational monitoring. However, these methods have insufficient accuracy in determining the depth of groundwater.

Anthropogenic soil erosion is a complex phenomenon caused by both natural and economic factors. A set of measures to protect soils from erosion and rational land management can help maintain landscape balance in the face of complex terrain and diverse soil cover. The study of erosion processes and the formation of eroded soils is important for the development and implementation of effective erosion control systems and the rational use

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of eroded land. This allows us to get a complete picture of the condition and characteristics of eroded areas, identify their potential opportunities and limitations, and develop scientifically sound recommendations for the restoration and protection of these lands. Such research is an important element of the soil conservation strategy, as it allows for optimal use of resources and increased soil productivity. They also help to identify effective measures to combat soil erosion and prevent its further spread. The hydrothermal coefficient (HTC) is used to estimate the moisture availability of plants during the growing season and is calculated using the following formula:

$$HTC = \frac{(Tav + 10)}{(Cav + 10)}\ , \qquad (4)$$

where Tav is the average air temperature during the growing season (usually from March to October), and Ccp is the average precipitation during the same period.

The HTC value is expressed as a percentage. The higher the HTC value, the greater the potential for plant productivity and soil erosion protection. For example, in regions with an HTC of more than 1.5, greenbelts are installed to protect against soil erosion. This is an effective method. Air humidity and winds have a significant impact on the intensity of erosion and on the evaporation of soil moisture, which can lead to a decrease in soil moisture turnover and an increase in the risk of erosion. In addition, strong winds can redistribute snow over the territory and lead to uneven freezing of the soil, which can increase the intensity of erosion. Taking these factors into account is important when designing erosion protection measures. Relief is an important factor that determines the nature of erosion processes. The example of the Holohori-Kremenets Ridge shows how a steep and high escarpment can increase the erosion activity of the river network and cause dismemberment of the relief. On the other hand, the mature denudation pattern that characterizes most of the area may reduce the intensity of erosion processes, as it has already passed the stages of active denudation and river valley formation. However, the topography is not the only factor that determines erosion processes in the region. The terrain can also be affected by climatic conditions, land use, and other factors. It is worth noting that, in addition to satellite imagery, geographic information technologies include other tools, such as geographic information systems (GIS). GIS can be used to process and analyze various geoinformation data, including satellite images, and create digital maps of various parameters of objects. Such maps can help to establish the relationship between various factors affecting erosion processes and identify the most vulnerable areas of the earth's surface. In addition, GIS can be used to predict the development of erosion processes based on mathematical models, as well as to develop and evaluate the effectiveness of erosion prevention measures.

The methodology for identifying patterns of landscape structure based on multidimensional spatial analysis using the theory of nonlinear oscillations allows us to study the influence of various factors on landscape formation and determine their interrelationships. The results obtained can be used for genetic interpretation of landscape habitats and understanding of the processes taking place in them.

Thus, it is important to take into account a systems approach in environmental research, as environmental problems are complex interactive systems that contain not only biological but also social and economic components. For example, morbidity and mortality rates can be caused not only by environmental factors, but also by social factors, such as living standards, access to medical care, etc. However, environmental factors can be one of the main causes affecting human health and the ecosystem as a whole. Therefore, to address environmental and health issues, it is important to conduct comprehensive research that takes into account various factors and the interrelationships between them.

To determine the impact of the hazard on the health of the local population, we identified areas of agricultural development with high dust concentrations located near industrial enterprises, the main sources of secondary air pollution [14]. The size of these zones was determined by calculating emission dispersion using the EOL software package.

The use of geoinformation technologies, in particular GIS and remote sensing, provides more accurate and complete information on the state of the environment and the development of environmental problems. This allows for more informed decision-making in the environmental sphere, reducing the risks of negative impact on the environment and public health.

Environmental forecasting based on geoinformation data helps to identify potential negative consequences of the development of settlements depending on various factors, such as air, water and soil pollution, ecosystem destruction, etc. Such analysis allows us to develop effective measures to reduce the negative impact on the environment, improve the health of technologically

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polluted areas and create more comfortable living conditions for the population. An important component of the successful solution of environmental problems is ensuring access to quality and reliable information for making informed decisions.

Based on the results of the study, it was determined that in the areas of direct impact of sources of secondary dust pollution, the impact of environmental hazards on the incidence of diseases among the population is increasing. The system of environmental safety management in a region with a high level of secondary dust air pollution involves a comprehensive system of technical and technological factors operating under conditions of intensive exposure to pollution sources. This system is based on the principles developed after a comprehensive analysis and synthesis of the results of previous theoretical and practical studies on environmental safety management at the regional level [15].

The effectiveness of departmental surveillance systems in relation to the defined tasks can be assessed within the framework of the following proposed assessments:

– spatial and temporal resolution of the network (minimum size and variability of the observed objects);

– parametric composition of observations (adequacy, necessity and sufficiency of the number of measured indicators to characterise the state of the monitored objects);

– efficiency of the observation network, i.e. the time of sending standard and extreme information to the consumer (this relative indicator is compared with the time of preparing a management decision, since for each type of object this time period may differ depending on the characteristic period of its variability);

– the degree of informatisation of the monitoring network (automation of collection, storage, processing and sending of monitoring data to the consumer);

– compliance with the goal set by the monitoring entity (target orientation to a specific type of management decision).

This means that the implementation of the management solution will reduce the amount of waste transported to storage sites by 2500–3000 tonnes per year. This reduction in waste will lead to a decrease in the level of man-made dust pollution in the study area [16]. The use of various on-board equipment on UAVs makes it possible to improve the monitoring system for assessing the risks of man-made pollution [17]. It is also possible to monitor, model and predict the state of the environment in a given region.

These are very interesting research results that demonstrate the potential of using the latest technologies to solve environmental problems. In particular, the environmental safety management system created for the hazards associated with secondary dust air pollution can help to effectively control and reduce the level of environmental pollution.

The developed technical solutions for eliminating hazard sources by involving fine dust waste in the manufacturing process of targeted products indicate the possibility of using this waste as secondary raw materials. Thus, the implementation of these technical solutions can reduce the negative impact of the industry on the environment. This will help ensure environmentally friendly production and preserve natural resources

## Conclusions

The study found that dust pollution can pose an environmental hazard. The necessity of distinguishing between primary and secondary sources of danger in accordance with the main technological process of production is proved. A methodological approach to assessing environmental safety in conditions of intense dust pollution is proposed. The creation of new and improvement of existing methods for building cartographic models of environmental soil assessment is considered. This approach is based on the use of the method of comprehensive assessment of the level of technogenic hazard of industrial facilities and time series analysis. It has been established that manifestations of environmental hazards affect the morbidity of the population directly exposed to sources of secondary dust pollution of the atmospheric air.

In further research, it is advisable to analyse the state and trends in the development of methods, technologies and mathematical apparatus for the creation and application of systems for detecting and polluting soils using UAVs and other aerospace vehicles; to improve methods for detecting soil pollution using UAVs and satellite imagery.

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# АЕРОКОСМІЧНІ ТЕХНОЛОГІЇ ВИЗНАЧЕННЯ ОЦІНКИ ЗАБРУДНЕННЯ ҐРУНТІВ

**Актуальність.** Дослідження оцінки забруднення ґрунтів оновані на наукових принципах, що визначають складну систему управління екологічною безпекою в умовах посиленої дії джерел вторинного пилового забруднення атмосферного повітря. Для забезпечення екологічної безпеки в умовах високого рівня пилового забруднення необхідно застосовувати та вдосконалювати відповідні моделі. Серед багатьох видів засмічення довкілля особливо небезпечним є пилове забруднення атмосферного повітря та осідання шкідливих речовин на ґрунті. Це забруднення може мати дві форми: пряме викидання забруднень від промислових підприємств (первинне) або формування вторинних забруднень через фізико-хімічні процеси в місцях зберігання пилоподібних відходів. Тонкодисперсні відходи після очищення повітря з розмірами менше ніж 100 мкм є особливо небезпечними. У сучасному екологічному спостереженні та оцінюванні забруднення ґрунтів особливу увагу звертають на дистанційні методи, що дають змогу ефективніше відслідковувати вплив людської діяльності та вирішувати екологічні проблеми. Використання безпілотних літальних апаратів є одним із таких методів, що має позитивні результати. **Мета статті** – розв’язання наукової проблеми вдосконалення аерокосмічних методів на основі безпілотного літального апарата (БПЛА) з метою моніторингу та оцінювання якості забруднення ґрунтів. **Об’єктом дослідження** є застосування аерокосмічних засобів для моніторингу та оцінювання стану ґрунтового покриву. Для реалізації цієї мети визначено такі **завдання:** дослідити сучасний стан і шляхи підвищення ефективності роботи БПЛА в системі екологічного моніторингу ґрунтів; розробити моделі екологічної оцінки; проаналізувати наявні підходи щодо застосування аерокосмічних засобів для моніторингу та оцінювання стану ґрунтового покриву. **Висновки:** для оцінювання стану екологічної безпеки в умовах інтенсивного пилового забруднення атмосферного повітря запропоновано методичний підхід, оснований на модифікованому методі комплексного оцінювання рівня техногенної небезпеки промислових об’єктів.

**Ключові слова:** інформаційні технології; техногенна небезпека; ґрунтовий покрив; пилове забруднення; атмосферне повітря; технічні рішення; екологічна безпека; захворюваність населення.

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