# ASSESSMENT OF THE COMPLEX EFFECTS OF HAZARDOUS WASTE COMPONENTS IN AQUATIC ECOSYSTEMS

**Assoc. Prof., Ph.D. Serhii Kvaterniuk** [1]
**Prof., Dr. Sc. Volodymyr Pohrebennyk** [2]
**Assoc. Prof., Ph.D. Roman Petruk** [3]
**Prof., Dr. Sc. Vasyl Petruk** [4]
**Dr. Anna Kochanek** [5]
[1, 3, 4] Vinnytsia National Technical University, Ukraine
[2] Lviv Polytechnic National University, Ukraine
[2, 3] State Higher Technical School in Nowy Sacz, Poland

## ABSTRACT

During the operation of landfills for the storage of garbage, waste-processing complexes, or during transportation of waste, hazardous substances contained in the composition of the waste can be released into the water bodies. The work aims to ensure environmental safety in the field of hazardous waste management and improve the efficiency of assessing their integrated impact on water bodies using methods and means of multispectral environmental monitoring. The relevance of the topic is due to the need to ensure the environmental safety of water bodies by increasing the reliability of monitoring the parameters of water pollution and the ecological state of water bodies following the tasks of environmental monitoring, taking into account their optical and physical characteristics by improving multispectral methods and developing appropriate hardware and software. When solving the inverse problem, the parameters of phytoplankton in the near-surface layer of the aquatic environment are determined using multiple regression based on the resulting array of multispectral images of the surface of the water body. When using bioindication of the ecological state of water bodies by macrophytes using the method of multispectral environmental monitoring, it is possible to determine the concentration of the main chromophores in higher aquatic plants (chlorophyll a, chlorophyll b, carotenoids, etc.), the species composition of communities of higher aquatic plants, the relative sizes of damaged leaf areas. The assessment of the ecological status of water bodies is carried out based on the biodiversity indices obtained from the study of the species composition of phytoplankton or macrophytes. In several modern studies, the development of the synergetic theory of the management of complex natural-man-made systems is being carried out, which can be used to assess the ecological state of water bodies. At the same time, the properties of the ecosystem, its synergistic characteristics are manifested in the interaction with environmental factors. To assess the ecological status of water bodies using a synergistic approach, it is necessary to monitor the dynamics of populations of aquatic organisms, which will determine the phase portrait of the fluctuations in the dynamics of populations of aquatic organisms. In this context, it is possible to use the developed multispectral methods and means of control, which will allow determining the necessary characteristics of populations for

phytoplankton and higher aquatic plants in natural water bodies and model ecosystems. Research and improvement of measuring tools and new methods for monitoring the integral parameters of water pollution to improve the efficiency of environmental monitoring of water bodies and assessing the impact of anthropogenic factors on them has been conducted, which has allowed developing new concepts and methods for environmental protection and rational nature management.

***Keywords:*** *environmental safety, water body, multispectral monitoring, phytoplankton, macrophytes.*

## INTRODUCTION

One of the important components of monitoring and controlling water quality is a comprehensive assessment of the ecological status of surface water bodies subject to anthropogenic pollution. The most common methods used for these purposes is the calculation of the water pollution index and the environmental water quality index, the lack of effectiveness of which is associated with the use of a limited list of (mainly hydrochemical) indicators, does not allow for a thorough comprehensive assessment of the state of the abiotic and biotic components of the aquatic ecosystem. It is impossible to assess the state of an ecosystem only by physicochemical parameters, since its main characteristic, the state of hydrobionts, is not taken into account. Analytical control is complicated by the synergistic effect of most compounds. The reaction of hydrobionts depends not only on individual physicochemical factors, but also on their interaction.

In several modern studies [1], [2], [3], [4], the development of a synergetic theory of management of complex natural-man-made systems is carried out, which can be used to assess the ecological state of water bodies. At the same time, the properties of the ecosystem, its synergistic characteristics are manifested in the interaction with environmental factors. Ecosystems meet the requirements for systems that are self-organizing: non-closed, unstable, non-linear, dynamic hierarchy. Therefore, ecosystem approaches should be considered from the point of view of a synergistic concept using a systems approach to conduct a study of changes in their state. The formalization of bifurcation processes in the biosphere is inextricably linked with an understanding of the synergistic patterns of the evolutionary development of biota.

The reaction to seemingly insignificant environmental changes (the appearance of polutants, introductions, invasions, etc.) is characteristic primarily of the “living substance” of the biosphere of species of individuals, biocenoses. If the changes relate to certain boundary conditions that ensure the maintenance of the equilibrium of an ecosystem, then with time a substantial restructuring of its structure and functioning is possible, up to and including the destruction of the ecosystem itself. To assess the ecological status of water bodies using a synergistic approach, it is necessary to monitor the dynamics of populations of aquatic organisms, and it will be possible to determine the phase portrait of fluctuations in the dynamics of populations of aquatic organisms [5]. In this context, it is possible to use the developed multispectral methods and means of control, which will make it possible

to determine the necessary characteristics of populations for phytoplankton and higher aquatic plants in natural water bodies and model ecosystems [6].

## METHODS

The analysis of integrated assessment methods for technogenic pollution of natural water bodies confirmed that the control of integral indicators of water pollution, in accordance with Ukraine's international obligations and the need to harmonize water policy in Ukraine with European legislation, should be based on water ecotoxicity. At the same time, a comprehensive integrated assessment of the state of the aquatic ecosystem, taking into account various manifestations of the interaction of polluting chemicals, can be obtained using the biotest method. The system for assessing the deterministic environmental risk of hazardous substances uses the value of toxicity and the concentration of hazardous substances in aquatic environments, and the ratio of deterministic risk in TER (Toxicity exposure ratio):

$$TER_{i,j} = \frac{LC_{50\,j}\left(NOEC_j\right)}{C_i}, \quad (1)$$

where TERi,j – the ratio for the i-th substance when using the j-th test object; LC50 j – semi-lethal concentration for the j-th test object; NOECj– inactive concentration for j-th test object; Ci – concentration of i-th substances in the aquatic environment.

For further research, microalgae and higher aquatic plants were selected as test objects, and biomass concentration and the ratio between pigments were selected as test parameters.

The method has been improved and a tool for multispectral measurement of water pollution parameters has been developed, which, unlike the known ones, uses an indirect measurement of water pollution parameters using regression equations relating these parameters to the results of brightness measurements in each pixel of images obtained at specific wavelengths when used in the tool measuring control of CCD cameras, filters and radiation sources with known spectral characteristics. For indirect measurement of the parameter of water pollution based on the multispectral measurements in n spectral channels using 5th order polynomials. In fig. 1. presents a block diagram of a tool that implements the proposed method. The tool contains a circular diffuse illuminator 1, which serves to illuminate a sample of the aqueous medium, indicated by the position 6. The CCD camera 2 is optically connected to the lens 3, which is connected to the rearrangements by filter 4. In addition, the CCD camera 2 is connected to the control unit and image processing 5.

For multispectral monitoring of parameters of multilayer aqueous media, a CCD camera, a lens and a tunable filter device can be located deep in the aquatic environment and capture the multispectral images produced by optical radiation in each of the layers. The model of a multi-layered aquatic environment is the most universal and can be used for many tasks, in particular the environmental monitoring of water bodies using phytoplankton or macrophyte bioindication.

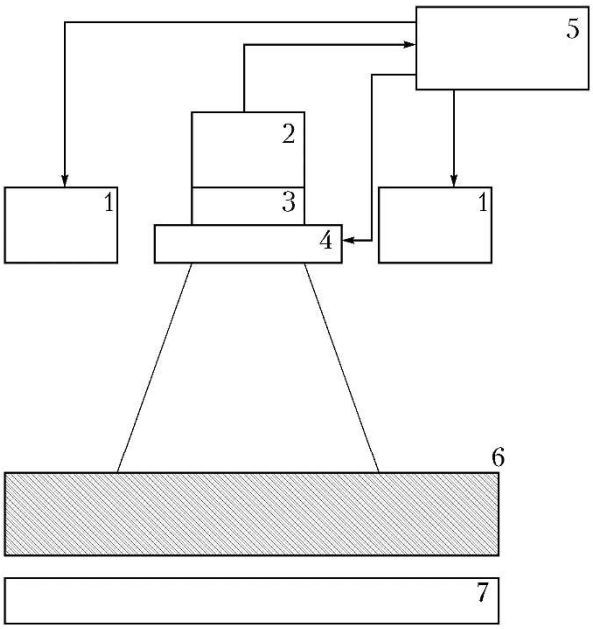
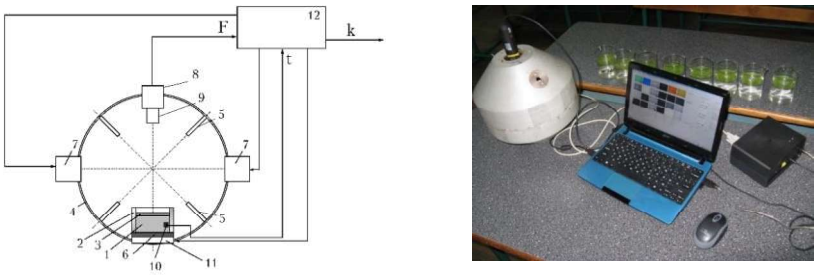



*Fig. 1. Block diagram of the tool for multispectral measurement of parameters of water pollution*

The method has been improved and a tool for multispectral measuring control of pollution of aquatic environments has been developed with the help of the small duckweed (Lemna minor L.), which uses small duckweed plants, placed in model aquatic environments that can be kept for 7-14 days at a given temperature and illumination, while each day using the hardware and software control unit and processing of multispectral images determine the relative sizes of zones of the aquatic environment, which correspond to the leaves of duckweed without morphological changes (A), with morphological measurements (B) and clear water surface (C) and using analysis of multispectral images, which are obtained using a wideband CCD camera when illuminating the surface of aquatic environments with narrowband radiation sources at characteristic wavelengths of the duck chromophores, and the concentration of the pollutant in the sample determine using the regression results of experimental studies of the dependence of the relative sizes of zones of the aquatic environment on the concentration of pollutants based on the multispectral investigations of a number of samples with known concentrations.

The control device (Fig. 2) contains a model aqueous medium 1 in a quartz cuvette 2, a floating layer of the test object of small duckweed (Lemna minor L.) 3, an integrable sphere 4 covered with a diffusely reflecting coating based on barium sulfate, screens 5 and a substrate 6 s coated with an identical integrable sphere, radiation sources 7, television CCD camera 8, lens 9, temperature sensor 10, heating element 11 hardware and software control unit and multispectral image processing 12.




a) b)

*Fig. 2. Means of multispectral environmental monitoring of pollution of aquatic environments using small duckweed (Lemna minor L.): a) block diagram of control means; b) appearance of a prototype*

The method of multispectral measuring control of integral parameters of pollution using higher aquatic plants in a complex for wastewater treatment has been improved (Fig. 3). Wastewater treatment is carried out using a floating layer of higher aquatic plants, for example, eichhornia (Eichhornia crassipes). The temperature that is optimal for the development of a certain type of higher aquatic plants is maintained in the internal space of the bioreactor. Illumination is carried out by LED illuminators at characteristic pigment wavelengths. A CCD camera is placed in the upper part of the body; it forms an array of multispectral images of higher aquatic plants.

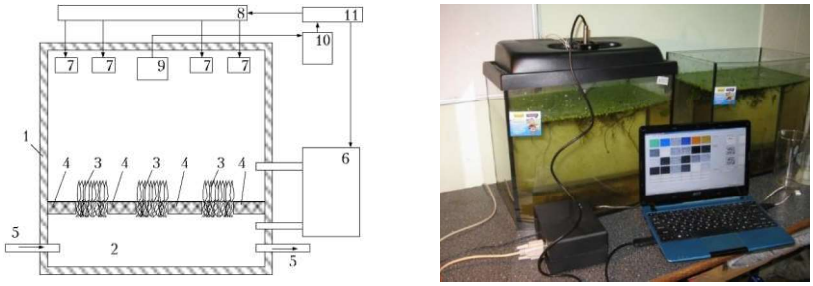



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*Fig. 3. Complex for wastewater treatment and multispectral monitoring of integrated pollution parameters using higher aquatic plants: a) block diagram of the complex, b) appearance of the prototype*

The control unit and processing of multispectral images on the basis of a personal computer allows evaluating the state of higher aquatic plants used to filter wastewater and control the integral parameters of their contamination using an expert system based on fuzzy logic or a neural network.

The complex contains the body of the bioreactor 1, is filled with water 2, the charm of higher aquatic plants 3 and the floating insulating material 4. To the body of the bioreactor is connected to the water supply pipelines for cleaning and removal of purified water 5, the thermal control system of the internal space and water 6. In

the case of the bioreactor placed LED illuminators 7 are connected to the pulsed control unit illuminators 8. Also in the body of the bioreactor is placed a CCD camera 9, which is connected to the input of the control unit and processing of multispectral images on the basis of a personal computer 10 which is connected via a microcontroller device 11 to a pulse control unit for illuminators 8 and the thermal control system of the inner space and water 6.

## RESULTS

When used as a test object green algae *Chlorella vulgaris* Beijer or *Scenedesmus quadricauda* (Turp) Breve it is necessary to establish differences between the growth rate of algae in the sample and culture medium (ISO 8692:2012). Multispectral methods and means measure the concentration of phytoplankton particles in cuvettes using a regression equation. The exposure time is 96 hours to determine the presence of acute toxic effects and 14 days to determine the presence of chronic toxic effects.

When used as a test object, small duckweed (*Lemna minor* L.) in the samples noted the preservation or change of the morphological signs of its listeks, in particular, discoloration (yellowing or blanching (chlorosis), complete discoloration (necrosis)) in research and control samples. Multispectral methods and means measure the relative surface area of the aquatic environment covered with duckweed plants without morphological changes, with changes and a clean surface of the aquatic environment.

Following the ISO 20079: 2005, the determination of the toxic effect index is carried out within 7 days.

Sampling, transportation and storage of samples was carried out in accordance with the current regulatory documents, in particular, the ISO 5667 series of standards.

Experimental studies of the toxicity of wastewater using biotesting, which allowed to evaluate their impact on the ecological state of water bodies. Using regression analysis in MathCAD, the sensitivity of test objects to the effects of pollutants was investigated.

In accordance with the UN Recommendation ST / SG / AC.10 / 30 / Rev.1 "Globally Harmonized Chemicals for Chemicals, a Globally Harmonized System of Classification and Labeling of Chemicals" develops a safety data sheet containing information regarding ecotoxicity for certain test objects. To biotest a chemical or mixture of chemicals, prepare an initial solution using distilled water. A study was made of the chemical composition of electronic waste products and their impact on the environment, in particular, samples of electroplating sludge samples. By X-ray fluorescence spectroscopy, it was established that the sample contains heavy metal oxides and hydroxides and falls under the 3rd hazard class. With the help of the developed tools, experimental studies have been carried out to control the toxicity of hazardous components of electroplating sludge in aqueous media using the multispectral method. The results of monitoring the toxicity of water with the presence of hazardous components of electroplating sludge

biotesting using the test object culture of chlorella alga (Chlorella vulgaris Beijer) and small duckweed (Lemna minor L.) using the developed means of multispectral monitoring are shown in Fig. 4. The proposed methods and the developed tools for multispectral environmental monitoring have made it possible to evaluate the complex effect of hazardous waste components on the ecological state of water bodies.

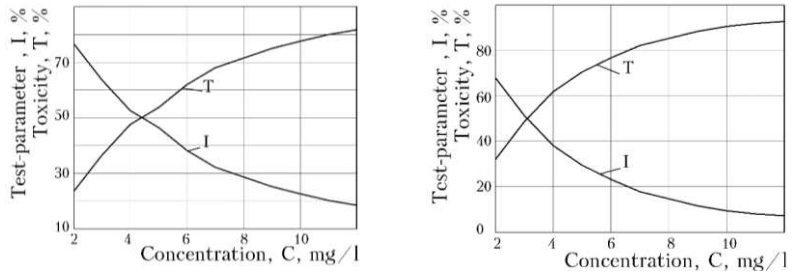


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*Fig. 4. Dependence of the test parameter and toxicity of water with the presence of hazardous components of electroplating sludge production by biotesting using a test object of culture: a) chlorella alga (Chlorella vulgaris Beijer) and b) small duckweed (Lemna minor L.)*

## CONCLUSION

As a result of analyzing the scientific problem, it was found out that when assessing the complex effect of pollutants on the ecological state of a water body using a synergistic approach, it is necessary to take into account the impact on biological indicators, in particular, the biomass and species composition of phytoplankton and higher aquatic plants. In addition, in accordance with the Water Framework Directive 2000/60 / EC, the control of integral indicators of water pollution should be based on their ecotoxicity, which is determined by means of biotesting and allows to take into account the synergistic interaction of pollutants. Based on the solution of the inverse problem of determining the parameters of water pollution and the ecological state of water bodies using their multispectral images, methods of multispectral environmental monitoring of surface waters are proposed. In particular, a method for multispectral monitoring of ecotoxicity, as an integral indicator of surface water pollution using indirect measurement of the concentration of microalgae particles, has been developed. In addition, the proposed method of multispectral control of pollution of surface water bodies, the essence of which, unlike the known, is to determine the relative size of the segments of the surface of the aquatic environment with higher aquatic plants (Lemna minor L.), which have morphological changes by analysis results of multispectral images obtained by a wideband digital camera when illuminating the surface of the aquatic environment with narrow-band radiation sources. Received the further development of the application of the method of multispectral control of integral parameters of pollution of wastewater using higher aquatic plants in the treatment complex. The developed methods and tools were used for multispectral environmental

measurement monitoring of the toxicity of hazardous components of solid household waste, which made it possible to increase the effectiveness of environmental monitoring of the environmental impact of landfills and waste-processing complexes. In addition, methods and means of multispectral environmental measurement control are used to control the toxicity of hazardous components of industrial wastes, which made it possible to evaluate their complex anthropogenic impact and promptly assess the toxicity of hazardous components of industrial wastes.

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