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LIFE AND SCIENTIFIC PRIORITIES OF PROFESSOR VASYL PETRUK

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Petruk Vasyl Hrygorovych was born on April 19, 1958 in the village of Kropyvna, Khmelnytskyi district, Vinnytsia region. In 1975, he finished Stupenetska Secondary School with a gold medal and entered Ivanovo Chemical-Technological Institute, which he graduated from in 1980 with a degree in chemical technology of electrovacuum materials. His qualification is chemical engineer-technologist. He also graduated from military department. His military rank is the captain of the reserve.

Petruk V.H. began his career in 1980. From 1980 to 1983, he worked as an assistant at the Chemistry Department of the Ivanovo Energy Institute. After that he was transferred to the Vinnytsia Scientific – Production Association "Zhovten", where he worked till 1985 as a leading specialist at the technological bureau of the company's basic microelectronics department.

From 1985 to 1990 at Vinnytsia State Pedagogical Institute Petruk V. H. was engaged in scientific work. He worked in the position of a senior laboratory assistant, head of optics laboratories and junior researcher. Later he was enrolled as an assistant of the Department of Chemistry at Vinnytsia Polytechnic Institute (now Vinnytsia National Technical University (VNTU)) where he works at present.

In 1991 he defended his thesis for the degree of candidate of technical sciences. In 1993, he was awarded the academic title of associate professor, and in 1994, for a complex of research works, he became a corresponding member of the Ukrainian Technological Academy at the Department of Informatics Technology, Life Support Networks of the Population and Automation of Production. In 2002 he became Academician of the Ukrainian Academy of Economic Department of Cybernetics of Ecological Processes, in 2007 – Academician of the International Academy of Ecology and Life Safety at the Department of Ecology, in 2012 – Academician of the Academy of Ecological Sciences of Ukraine, in 2015 – the actual Academician of the Ukrainian National Academy of Natural Sciences. In 1998 Petruk V.H. defended his doctoral thesis. In 2001 he was awarded the academic title of professor and chief scientific officer of VNTU. Since 2000, he has been the Head of the Department of Chemistry and Environmental Safety, and since March 2007 – Director of the Institute of Ecology and Environmental Cybernetics of VNTU (renamed in 2015 as the Institute of Environmental Safety and Environmental Monitoring). Petruk V. H. is the Head of the Specialized Academic Council for the defense of doctoral theses in the field of 05.11.13 – Devices and Methods for Monitoring and Determining the Composition of Substances and 05.11.08 – Radio Measuring Devices, as well as a member of the Council for the specialty 21.06.01 – Environmental Safety. He is a member of the editorial board of six international scientific journals.

Petruk V. H. is the author of thirteen monographs, as well as more than 30 patents for inventions of Ukraine and the USSR author's certificates, 3 textbooks: "Introduction to the Specialty", "Organization and Methodology of Scientific Research", "Ecogeography and Ecotourism", more than 540 scientific works in the field of control, spectrophotometry of heterogeneous (dispersed) environments, new environmentally friendly technologies for neutralization and utilization of industrial and household waste, etc. He is a co-organizer of several and participant of more than 50 international scientific and scientific-practical symposia, conferences, seminars, in particular on environmental problems of Podilsk region and Ukraine. He is an organizer of six All-Ukrainian Congresses of Ecologists with international participants which caused a significant positive resonance for the development of the environmental industry of Vinnytsia, Podillia region and Ukraine as a whole.

In 2000, on his initiative, the specialty "Ecology and Environmental Protection" was opened in VNTU. He organized the Department of Ecology and Environmental Safety. Together with his department Prof. Petruk carries out training of bachelors, specialists and masters in this specialty. He has created and successfully leads the Institute of Environmental Safety and Environmental Monitoring of VNTU.

In 2001, under his scientific leadership and direct participation, a project of the Ministry of Ecology and Natural Resources of Ukraine was implemented to develop environmentally friendly technologies for the disposal of unsuitable pesticides and other toxic substances accumulated in Vinnytsia region; the regional program for the treatment of toxic waste, the specification for the design of a pilot industrial model of a mobile complex for reagent and thermal neutralization of unusable toxic wastes as well as studies on the state of organization of integrated management and handling of solid household waste in Vinnytsia and Vinnytsia region, implemented with EU support in the framework of the Tacis project "Assistance to Regional Development in Ukraine". By the order of the State Fund of Fundamental Research of Ministry of Education and Science of Ukraine, since 2005 International Ukraine-Belarus projects have been carried out in collaboration with the Institute of Physics named after B. I. Stepanov of the National Academy of Sciences of Belarus and other institutions. In 2011, under the leadership of Vasyl Petruk, a scientific project "Development of a Regional Environmental Monitoring Program of Vinnytsia Region" was implemented .

Since 1985 Vasyl Petruk has beem a responsible executor and supervisor of more than 21 projects. Under his scientific guidance 10 PhD and 1 doctoral dissertation have been defended, and several postgraduate students and applicants have prepared their Ph.D. and doctoral dissertations for the defense. As a scientific supervisor and developer of a unique device for the early diagnosis of skin melanoma, he is the winner of the All-Ukrainian Competition "Innovative Breakthrough 2012"., the winner of the All-Ukrainian Competition "Invention 2012" in the nomination "The Best Invention of 2012".

Professor Petruk is a member of the regional Board on Environmental Protection, a member of the working group of the Ministry of Education and Science of Ukraine to develop the State Standard for Environmental Education; an expert of the State Commission of Accreditation and Licensing of the Ministry of Education and Science for Ecological Specialties of Ukrainian Universities; a member of the Scientific and Methodological Council on Ecology of the Ministry of Education and Science, the Chairman of the Podilsk Regional Branch of the Ukrainian Technological Academy; a. member of the public board at the Vinnytsia Regional Council, a EU expert on integrated waste management; President of Vinnytsia Regional Ecological Youth Organization "Ecotopia of Podilia".

Vasyl Petruk pays considerable attention to improving his scientific, methodological and qualification level; in particular, he underwent advanced training at Shevchenko National University., majoring in General Chemistry, at the Interdisciplinary Institute at St. Petersburg Technical University, majoring in New Information Technologies in Environmental Education, Świętokrzyskie Technical University, Kielce (Poland) on the problems of modern water purification and water saving technologies of European countries, the Julich Research Center (Germany), etc.

Petruk V. H. is awarded with diplomas of the Ministry of Education and Science of Ukraine. Vinnytsia Regional Council and Regional State Administration, Department of Education and Science of Vinnytsia Regional State Administration, the medal of the Ukrainian Technological Academy "For Achievements", the Order of the Ministry of Natural Resources "For Merits" and. the badge of the Ministry of Education and Science "For Scientific and Educational Achievements." He is listed on the regional Honor Board in the nomination "Labour and Victory of Vinnytsia People". He is the winner of the regional Ivana Bohun Prize "Excellence in Education of Ukraine". He also has the honorary title of Ukraine "Honored Environmental Protection Officer of Ukraine".

Among a large number of works written by Vasyl Petruk, I want to highlight several international Ukraine-Belarusian projects in collaboration with the Institute of Physics named after B.I. Stepanov of the National Academy of Sciences of Belarus according to the order of the State Fund for Fundamental Research of Ukraine on the development of methods and means of spectrophotometry of biological tissues and humoral media. As a result of the implementation of these projects, biological tissues and humoral media were studied based on of radiation transfer theory, substantiating the advantages of using spectrophotometric methods for diagnosing biological objects. An interactive information-measuring system for spectrophotometry of biological tissues and humoral media was developed, block diagram of which is shown in Fig. 1.

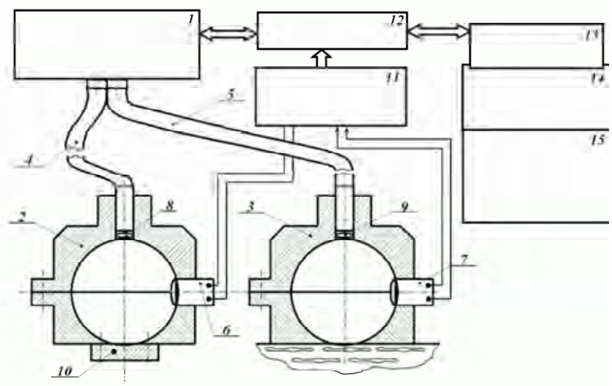

Fig. 1. Block diagram of an interactive information-measuring system for spectrophotometry of biotissues and humoral media

An interactive information-measuring system for spectrophotometry of biological tissues and humoral media consists of a source of monochromatic radiation (1), two photometric probes 2 and 3 (integration spheres) with identical parameters. The inner surface of each of the spheres is coated inside with a benchmark reflector based on barium sulfate. The inlets of the probes 2 and 3 are connected by optical fibers 4 and 5 with the source 1. Operating and inlet holes of the sphere are on the same axis, and the radiation receiver 6 (or 7) is installed perpendicular to it. At the entrance of the probe there is a quartz lens 8 (or 9), which provides the same diameter of the light beam in the operating hole. In probe 2 there is a plug 10, the surface of which is covered with the same substance as integration spheres 2 and 3. Receivers 6 and 7 are electrically connected with recording equipment 11. The device also includes microcontrollers 12 and 15, a personal computer 13 with software 14 for processing reflection spectra.

Methods of studying the spectra of biological objects and diagnostics of their pathologies were improved. The study was made on the features of the conversion of an optical signal during its passage or reflection through such bio-objects as the surface of normal and pathologically affected skin, as well as through the blood layer. A number of mathematical models has been developed that describe light scattering of multilayer biological tissues, as well as polydisperse biological media. They allow us to link the physiological properties of the object of study and optical-physical parameters that will be directly measured using information-measuring systems.

The developed information-measuring system was introduced for the diagnosis of patients with amputated limbs and those affected by systemic lupus erythematosus at the Research Institute for the Rehabilitation of Disabled Persons of Vinnytsia National Medical University named after Pirogov, as well as for the study of the samples of injured tissues and non-invasive diagnosis of patients with superficial injuries in the Vinnytsia Forensic Medical Examination Bureau.

Thanks to the research and the discoveries obtained at the department, the scientific school “Spectrophotometry of Natural Environments” functions under the leadership of Vasily Petruk.

Also noteworthy is the research work “Development of Methods and Means of Measuring Control of Optical Parameters of Heterogeneous Media based on Multispectral Images” performed under the guidance of Petruk V. H. The project proposes a promising scientific direction of creation of new means of control and diagnostics of the state of heterogeneous media on the basis of multispectral images that can be used for environmental monitoring, medical diagnostics and product quality control, practical implementation of which takes into account the uneven distribution of pigments and the structure of the near-surface layer, which makes it possible to increase the speed and reliability of control and the accuracy of diagnosis [2]. To process the obtained measurement results, an expert decision-making support system was developed, which made it possible to control the morphological state of the surface of inhomogeneous media with high probability to control the morphological state of the surface of inhomogeneous media and to distinguish objects with high accuracy.

The coordinates in the multispectral n-dimensional space are determined based on the spectral characteristics of radiation sources, filters, photomatrix and control object. When using multispectral cameras with light filters at the inputs of photomatrix elements, the system of equations for determining coordinates in the n-dimensional multispectral space will be:

$$\begin{cases} M_1 = \sum_{i=1}^{i_{\max}} P(l_i) s_1(l_i) R_d(l_i) \Delta l, \\ M_2 = \sum_{i=1}^{i_{\max}} P(l_i) s_2(l_i) R_d(l_i) \Delta l \\ \ldots \\ M_n = \sum_{i=1}^{i_{\max}} P(l_i) s_n(l_i) R_d(l_i) \Delta l. \end{cases} \quad (1)$$

where $P(l_i)$ – the spectral characteristic of the radiation source, $s_i(l_i)$ – is the spectral characteristic of the i-th channel of the multispectral camera, $R_d(l_i)$ – the spectral characteristic of the diffuse reflectance of the object of study

An example of processing a multispectral image with the calculation of the relative sizes of its segments is shown in Fig. 2

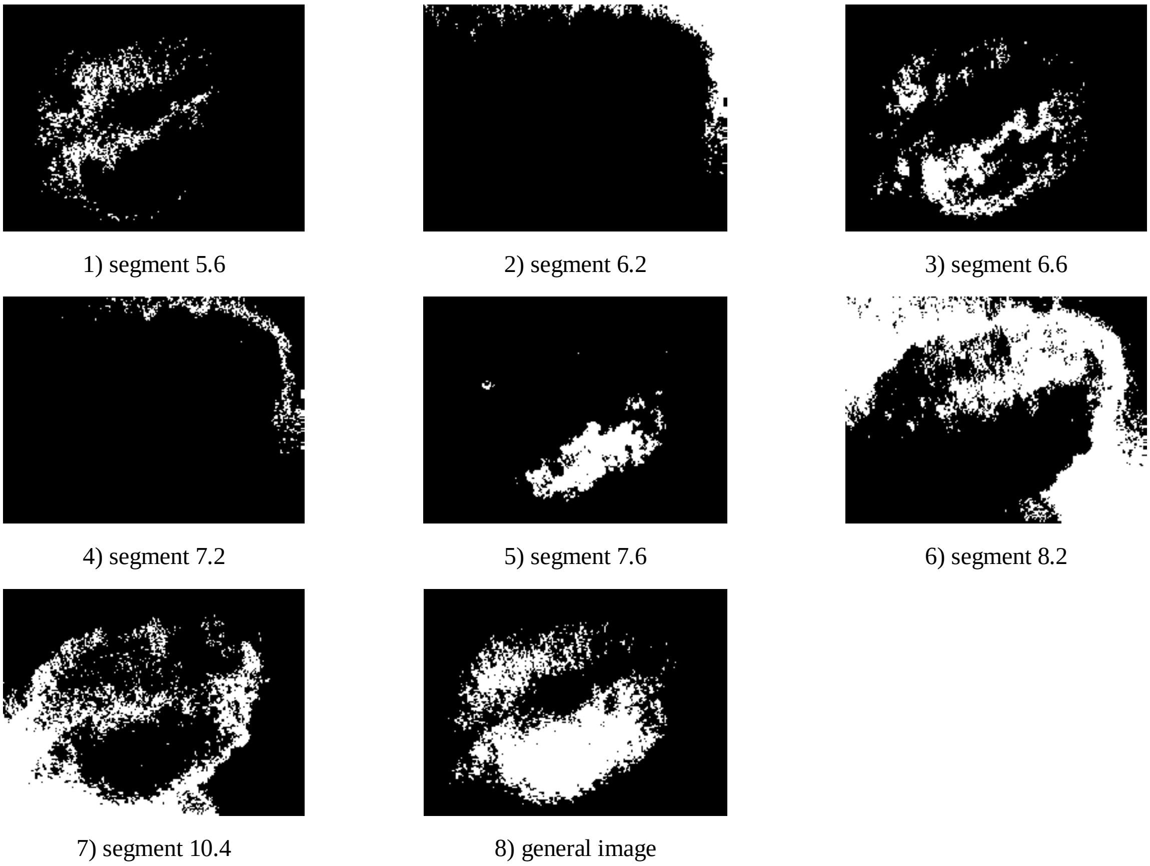

Fig. 2. An example of processing a multispectral image with the calculation of the relative sizes of its segments

During a comprehensive research project under the guidance of Petruk V. H., the work "Development of Optical Means and Improvement of Methods for Monitoring the Concentration of Phytoplankton in Water Bodies" was carried out. A promising scientific direction for creating new means of environmental monitoring of water bodies pollution was developed in the project. Implementation of these means in the work of specialized laboratories provides the ability to reliably control the content of biogenic substances in aquatic environments by using bioindication by phytoplankton and [3].

Mathematical models of the dynamics of phytoplanton populations in aquatic ecosystems using a system of recurrent equations were improved, which allowed to take into account the dependence of phytoplankton dependence on temperature, illumination, concentration of biogenic and toxic substances, and to simulate the change in the number of phytoplankton populations during water body pollution, as well as to evaluate the integral characteristics of pollution [1].

A new method of multispectral television measuring control of the ecological state of water bodies using phytoplankton parameters is proposed. It involves phytoplankton sampling, determining the species composition and the number of phytoplankton cells and comparing with the norm. Flow-through multispectral television measuring control of phytoplankton particles of continuous action includes comparing particle images in a flow measuring cell at characteristic phytoplankton pigment wavelengths using a microscope and a CCD television camera with images from a specific species phytoplankton particle database, determining the number of phytoplankton particles of each species, calculation of the Simpson and Shannon indices, which allowed to reliably assess the state of the water body ecosystem.

The basis of the method of multispectral television measuring control of the ecological state of water bodies by the parameters of phytoplankton is the task of increasing the reliability of the ecological monitoring of the state of natural water bodies by the parameters of phytoplankton. The task is fulfilled by the use of the method of multispectral television measuring control of the ecological status of water bodies by the parameters of phytoplankton, which involves phytoplankton sampling, determining the qualitative and quantitative composition of microalgae cells. The obtained data is compared with the normalized values. A flow-through multispectral television measuring analysis of phytoplankton particles of continuous action is conducted. The images of the particles in the flow measuring cell obtained at different wavelengths of the phytoplankton pigments using a microscope and a CCD television camera are compared with the images from phytoplankton particles database of certain species in a specialized processor in real time using the Bayes optimal classifier with solving functions based on the Mahalanobis distance. The absolute and relative numbers of phytoplankton particles of each of the species that are present in the sample are determined and the Simpson and Shannon indices are calculated and submitted to the indicator.

Fig. 3. presents a block diagram of the device for multispectral television measuring control of the ecological state of water bodies by phytoplankton parameters. The device contains a water sample with phytoplankton particles 1, a pump 2, a CCD television camera 3, a microscope 4, a flow measuring cell 5, a drain container 6, a database of phytoplankton particles 7, a specialized processor 8, an illuminator 9, Simpson and Shannon index calculation unit 10, an indicator 11.

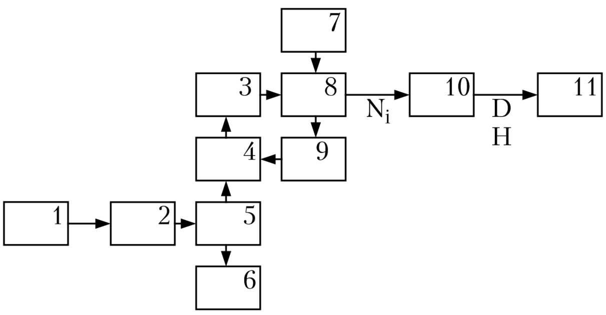

Fig. 3. Block diagram of the device for multispectral television measuring control of the ecological status of water bodies in terms of phytoplankton parameters

Mathematical models of aquatic environments with phytoplankton suspended particles have been improved, allowing to assess the ecological state of water bodies based on the measurement of the spectrophotometric characteristics of aquatic environments by remote methods, indicatrices and brightness bodies using the depth mode method and the concentration of phytoplankton particles in a flow-through measuring cell.

Optical tools and automated control and measurement systems for environmental monitoring have been developed and improved, allowing real-time monitoring of the ecological state of water bodies using phytoplankton bioindication, as well as integrated monitoring of pollution of water bodies with biogenic and toxic compounds and assessment of the integrated anthropogenic impact that will promote the implementation of effective environmental protection measures [4, 5].

A comparison of the results of sewage biotesting using phytoplankton culture and experimental studies of concentrations of pollutants was made. A correlation analysis was performed to identify relationships between concentrations of pollutants and the ratio of phytoplankton particle concentrations in the test and control samples. Correlations between some pollutant parameters and phytoplankton concentration, confirming the possibility of using the Scenedesmus subspicatus phytoplankton culture as bioindicators of wastewater contamination were revealed. The results of this work can be used in specialized environmental inspection laboratories for express control of wastewater parameters [7, 8]. The developed methods and means of medical diagnostics are implemented at the Basin Department of Water Resources of the Southern Bug River and at the Enerhoharant Ltd.

In the following scientific works of Vasily Petruk, the method of ecological monitoring of phytoplankton biomass concentration in the near-surface layer of natural aquatic media was improved when measuring in situ using a quadrocopter with a multispectral camera. An inverse optical problem was solved to determine phytoplankton biomass in natural aquatic environments by the results of multispectral measurements using eight-channel multispectral cameras of the CMS series (Silios Technologies) and the corresponding regression equations were obtained [6]:

$$\begin{aligned} B_{CMS\_C} &= 0{,}057154618 - 0{,}475979\mathrm{M}_{C\_7\_642} - \\ &- 0{,}472422\mathrm{M}_{C\_5\_563} - 0{,}287206\mathrm{M}_{C\_6\_600} + \\ &+ 0{,}345161\mathrm{M}_{C\_2\_461} - 0{,}343838\mathrm{M}_{C\_4\_536} + \\ &+ 0{,}237081\mathrm{M}_{C\_1\_430}, \end{aligned} \tag{2}$$

$$\begin{aligned} B_{CMS\_V} &= 0{,}058691384 - 0{,}196036\mathrm{M}_{V\_4\_669} - \\ &- 0{,}283101\mathrm{M}_{V\_6\_752} - 0{,}150405\mathrm{M}_{V\_8\_829} - \\ &- 0{,}131900\mathrm{M}_{V\_7\_795} - 0{,}122064\mathrm{M}_{V\_5\_719} - \\ &- 0{,}118101\mathrm{M}_{V\_3\_635}, \end{aligned} \tag{3}$$

$$\begin{aligned} B_{CMS\_S} &= 0{,}062431853 - 0{,}330180\mathrm{M}_{S\_5\_790} - \\ &- 0{,}283269\mathrm{M}_{S\_6\_827} - 0{,}170174\mathrm{M}_{S\_7\_871} - \\ &- 0{,}138106\mathrm{M}_{S\_3\_713} - 0{,}107677\mathrm{M}_{S\_4\_752} + \\ &+ 0{,}153303\mathrm{M}_{S\_1\_635} - 0{,}126370\mathrm{M}_{S\_2\_669}, \end{aligned} \tag{4}$$

where B_{CMS_C}, B_{CMS_V}, B_{CMS_S} – is the phytoplankton biomass determined using multispectral cameras CMS-C, CMS-V, CMS-S; $M_{i\_j\_k}$ – multispectral camera parameters of the i-th type, the j-th spectral channel, the k-th wavelength value in nm.

Comparing the values of the methodological error of phytoplankton biomass measurement for the cameras of this series, operating in different wavelength ranges, the smallest value was obtained for the camera operating in the range of 650–950 nm (CMS-S).

The random component of the measurement error is determined by the random components of the measurement error in each of the spectral channels, therefore the total random component of the error of indirect measurements will be determined by the random errors of the corresponding multispectral parameters, which fall into the general regression equation

$$d_{\text{instr.}} = \sqrt{\sum_{i=1}^{N} d^2_{rand.Mi} + 2\sum_{i=1}^{N}\sum_{j<i} R_{ij} d_{rand.Mi} d_{rand.Mj}}, \quad (5)$$

where $d_{rand.Mi}$, $d_{rand.Mj}$ – the random component of the error in the i-th and j-th channels; R_{ij} – коефіцієнт кореляції між мультиспектральними параметрами отримані після множинної регресії; N – загальна кількість каналів.

For the three-channel tool, the instrumental component of the error, taking into account the correlation coefficients between the results of measurements from different channels, was 0.303 %, for the four-channel tool it was 0.35 % and for the six-channel - 0.428 %. The optimal wavelengths of the spectral channels and their number in the indirect measurement of the biomass of phytoplankton in natural aquatic environments in situ are selected under the condition of ensuring the minimum total error.

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