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LIFE AND SCIENTIFIC PRIORITIES OF PROFESSOR IHOR PETRUSHKA

Iryna Kazymyra

Lviv Polytechnic National University
12, S. Bandera Str., Lviv, 79013, Ukraine; iryna.y.kazymyra@lpnu.ua

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Ihor Petrushka, Professor, Doctor of Technical Sciences, is the Head of the Department of Environmental Safety and Nature Protection Activity at Lviv Polytechnic National University. In 2016 he became a member of the editorial board of the "Environmental Problems" scientific journal.

Ihor Petrushka was born on June 17, 1961, in Western Ukraine in the village of Dzvynyachka (Borshchiv district of Ternopil region). In 1983 he graduated from Lviv Polytechnic having received a diploma with honours and the qualification of an engineer-technologist in the specialty "Chemical technology of astringent substances". Then Ihor was directed to study at postgraduate courses in Lviv Polytechnic. In 1987, after completion the postgraduate studies, the promising young researcher became the head of the training laboratory of the Department of Processes and Apparatuses of Chemical Production.

In 1989 at Kyiv Polytechnic Institute Ihor Petrushka has defended his PhD thesis entitled "The carbonate non-gypsum portlandcement which is hardening at negative temperatures" in the specialty 05.17.08 "Technology of refractory and non-metallic silicate industries". Thus, his scientific and pedagogical activity had begun in 1990 when I. Petrushka worked as an Assistant of the Department of Processes and Apparatuses of Chemical Industries at Lviv Polytechnic National University. Along with this, he was actively engaged in scientific investigations in the field of environmental protection. In 2000 I. Petrushka received the Diploma of Associate Professor at the Department of Chemical Engineering and Industrial Ecology.

In the years of 2001–2012 Ihor Petrushka worked as an Associate Professor of the Department of Ecology and Environmental Protection at the Institute of Chemistry and Chemical Technology. In 2012, V. Chornovil Institute of Ecology, Nature Protection and Tourism has been established at Lviv Polytechnic National University. It was then that I. Petrushka was offered a proposal to perform the duties of the Head of the Department of Ecological Control and Audit and to fulfil the accreditation procedure of the specialty "Environmental control and audit", which was a new one for the University. Since 2014 the name of the Department was changed to "Environmental Safety and Nature Protection Activity", and from 2015 the department began the education process for the first set of students in specialty 183 "Environmental protection technologies".

In parallel with the teaching activities I. Petrushka had been working on the implementation of his Doctoral Thesis on "Scientific and methodological foundations of environmentally safe technologies for wastewater treatment by the sorbents of the mineral raw base of Ukraine" in the specialty 21.06.01 "Environmental safety". It was successfully defended in 2013 at Ivano-Frankivsk National Technical University of Oil and Gas. Professor Myroslav Malovanyy, Honoured Worker of Science and Technology of Ukraine, was the scientific consultant of Ihor Petrushka's Doctoral dissertation.

From 2013, according to the resolution of the Cabinet of Ministers of Ukraine of 9.08.2001 No. 978 "On Approval of the Regulation on the Accreditation of Higher Educational Institutions and Specialties in Higher Educational Institutions", Professor I. Petrushka was repeatedly appointed to be an expert conducting the accreditation examination of Masters' training in higher educational institutions of Ukraine.

During his work in a higher educational institution, DSC, Professor I. Petrushka showed himself to be an experienced teacher and an excellent scientific supervisor, who is actively working to train highly skilled scientific staff. To the professional features of a scientist, organizational and managerial activities must be added. He made every effort to create and manage a specialized academic council for the defence of PhD dissertations in the specialty 21.06.01 "Environmental safety". This academic council began operating at Lviv Polytechnic National University in 2015.

During the first period of its work 6 applicants successfully defended their PhD dissertations here. After the completion of the first term of the council functioning, the Ministry of Education and Science of Ukraine (the order No. 1413 of October 24, 2017) has approved a new composition of the specialized academic council K 35.052.22 with the right to accept and to conduct the defence of theses for obtaining the scientific degree of PhD (the candidate of technical sciences) in the specialty 21.06.01 "Environmental safety" for a period of three years.

At this moment Prof. Ihor Petrushka is a member of two specialized academic councils, in Lviv Polytechnic and in Ivano-Frankivsk Technical University, for the defense of candidate (PhD) and doctoral (DSC) dissertations in the specialty 21.06.01 "Ecological safety". He is also a member of the scientific and methodological sub-commission of the Ministry of Education and Science of Ukraine in specialty 183 "Environmental protection technologies", where the basic requirements for the training of the specialists in this specialty were formed and the professional competencies were developed in particular.

Scientific direction of Professor Ihor Petrushka is "Development and creation of environmentally safe technologies of adsorption purification of contaminated liquid media using natural disperse sorbents". The results of the scientific work include over 210 scientific papers, reports and presentations at more than 100 international scientific conferences, publication of 3 textbooks, 2 manuals and 5 monographs on the "Environmental protection", registration of 5 patents for invention and 2 copyright certificates. Many years of scientific activity is summarized by the study of methods of intensification of sorption processes in environmental technologies aimed at rational use of natural resources.

On the basis of experimental studies of contaminated liquid systems, structural peculiarities, properties and methods of modification of natural disperse materials, a schematic diagram of use of natural and modified disperse sorbents for purification of liquid systems contaminated by pollutants of the 2^{nd}–4^{th} class of danger [1] has been proposed (see Fig. 1). When constructing this scheme a mathematical model of prediction of the absorption intensity of the pollutants from liquid media was developed for each of the variants of use taking into account the kinetic and hydrodynamic conditions of the process.

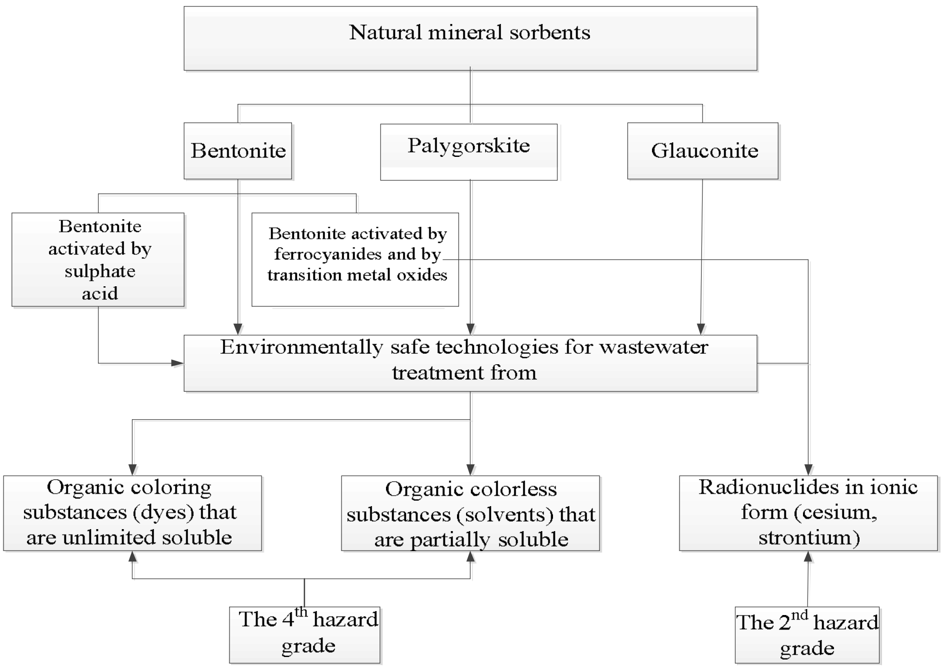

Fig. 1. Classification of natural and modified sorbents according their use in technologies of wastewater treatment from contaminants of the 2^{nd} – 4^{th} hazard grade

Prof. I. Petrushka proposed the method of comparison of experimental values with the theoretical ones in the case of an internal diffusion sorption process on the basis of effective internal diffusion coefficients. It is based on the generally accepted methods for adsorption processes and consists in the fact that adsorption occurs in the volume of a liquid which in a mass ratio significantly exceeds the solid content phase (sorbent). This means that at the initial moment of time the concentration of pollutant in the liquid changes slightly. Accordingly, at the beginning of the process, it can be assumed that it is a constant on the surface of the adsorbent grain, and the mathematical problem is written as a problem of diffusion with boundary conditions of the first kind.

The solution of this problem for the intra-diffusion process of adsorption at the initial ($\tau = 0$; $C_0 = 0$) and the limiting conditions of the first kind, with the assumption that the shape of the particles is spherical, is the equation that determines the change in concentration for the sorption of the component in the apparatus with the stirrer component in the liquid phase over time:

$$\frac{c_1}{c_0} = 1 - \frac{1}{1+a}\left[1 - \sum_{n=1}^{\infty} \frac{6a\,(1+a)\exp\left(-m_n^2 t\right)}{9 + 9a + a^2 m_n^2}\right], \quad (1)$$

where C_0 – the initial concentration of the component in solution, g/dm^3; C_1 – concentration of the component at a certain time, g/dm^3; m_n – positive roots of the characteristic equation; α – coefficient of filling of pores.

If the process approaches the equilibrium, the final concentration of the component in the solution has the following form:

$$\frac{c_{1к}}{c_0} = \frac{a}{1+a}. \quad (2)$$

The parameter τ is a dimensionless quantity that is analogous to the Fourier number $Fo_д = \frac{D_{вн} \cdot t}{R^2}$ and takes into account the physical and sorption parameters:

$$t = \frac{D_{вн}\, t}{R^2} * \frac{e_p}{1-e_p} * \frac{C_0}{r_S\, q_0}, \quad (3)$$

where t – sorption time, sec; $D_{вн}$ – coefficient of internal diffusion, m^2/sec; R – particle radius, m; ρ_s – density of solid porous phase, kg/m^3; ε_p – the porosity of the particle.

Obviously, the high value of the time corresponds to the low values of the exponent, therefore, from a certain time, we can neglect the roots of the characteristic equation. Equation (1) can be submitted as a straightforward dependence:

$$\ln\left(\frac{C_1}{C_0} - \frac{a}{1+a}\right) = \ln B - m^2 t. \quad (4)$$

From the tangent of the angle of inclination of the straight line, one can determine the effective coefficient of internal diffusion $D_{вн}$:

$$D_{вн} = \frac{tg\,a\; R^2}{m_1^2} * \frac{1-e_p}{e_p} * \frac{r_S\, q_0}{C_0}. \quad (5)$$

The obtained results of experimental studies allow to determine effective coefficients of internal diffusion of sorption of pollutants by natural sorbents in natural and modified forms and to estimate the intensity of the adsorption process [1, 2].

To determine the parameters of the exterior diffusion process of adsorption of the pollutant by natural and modified sorbents, Prof. I. Petrushka proposed a model based on the theory of local isotropic turbulence for apparatus with mechanical mixing devices in the dissolution of solid particles whose sizes exceed the thickness of the diffusion boundary layer, according to which the theoretical coefficient of mass deducing is calculated:

$$b_p = 0{,}267 \cdot (e_0 \cdot n)^{\frac{1}{4}} \cdot Sc^{-\frac{3}{4}}, \quad (6)$$

where e_o – specific dissipation energy; n – kinematic viscosity of the liquid, m^2/sec; $Sc = \frac{n}{D}$ – Schmidt number; D – coefficient of diffusion of pollutant in solution, m^2/sec.

The diffusion coefficient of the contaminant in the solution was calculated using the dependence of Wilkie and Chang. The mixing capacity was determined according to the dependence:

$$N = K_N \cdot r \cdot n^3 \cdot d_м^5, \quad (7)$$

where K_N – coefficient of mixing, which depends on Reynolds number; ρ – liquid density, kg/m^3; $d_м$ – diameter of the mixer, m; n – the number of revolutions of the mixer, 1/sec.

The specific value of dissipation energy per unit of mass of liquid (ε_0) was determined by the following dependence:

$$e_0 = \frac{N}{r \cdot V}. \quad (8)$$

According to the research of L. Braginsky, V. Bogachev, and V. Barabash, for small diameter vehicles without reflecting partitions, due to the radial separation of solid particles, an increase of the coefficient of mass deductibility is observed in comparison with the calculated by equation (6). Taking into account the correction coefficient k_β, whose magnitude depends on the radial heterogeneity of the particle distribution, depending on the size of the apparatus (the coefficient k_β increases with the decrease in the size of the apparatus), the theoretical values of β are closer to the experimental ones [3, 4].

The proposed mathematical models of the adsorption process based on the calculation of external and internal diffusion parameters makes it possible to determine the limiting stage of adsorption, which in its turn makes it possible to increase the degree of absorption of contaminants from waste water.

The environmental safety of handling of liquid radioactive wastes (LRW) was also investigated. In order to increase the ecological safety of handling of LRW saturated with cesium and strontium ions, the modification of the surface of montmorillonite natural minerals of the Yazivsky sulphur deposit with ferrocyanides and transition metal hydroxides was done and the results are given. In the process of modification there is a destruction of calcium and magnesium carbonates. This is confirmed by the disappearance of the characteristic peaks of the carbonate component at 874 and 710 cm^{-1}.

Identification of experimental data on adsorption of radionuclides with existing theoretical sorption isotherms was performed. It is established that the process of sorption extraction of Cs and Sr by modified clay minerals is best described by three-parameter models of Redlich-Peterson and Langmuir-Freindlich, which testifies the presence of active centers of different chemical nature in sorbents. The influence of background electrolytes, competing ions, products of equipment corrosion and surfactant content on the sorption extraction of Cs-137 and Sr-90 has been revealed. The technological scheme of decontamination of liquid radioactive waste by sorption method with the use of modified clay minerals is proposed.

The conducted by Ihor Petrushka studies of chemical modification have proved that:

– on the surface of montmorillonite the destruction of the carbonate component and the formation of phases of ferrocyanides of iron (III), copper (II), copper (II) – potassium, as well as titanium hydroxide (IV), state (IV) and stibium (V) occurs;

– modified samples are characterized by a developed surface, which makes it possible to predict the external diffusion sorption mechanism.

Therefore, considering the nature and properties of the contaminant, one can choose the optimal method for modifying natural sorbents to intensify the sorption processes of purification of contaminated liquid media. Taking into account the received experimental data and the developed mathematical models Professor Ihor Petrushka has proposed the optimal methods of modifying bentonite-containing clay minerals depending on the type of pollutant in a liquid medium (shown in Fig. 2).

The theoretical bases of modelling of processes of purification of contaminated liquid media by adsorption on natural sorbents were considered by Professor I. Petrushka in his scientific investigations. It was revealed that for most adsorption systems, the form of the Langmuir isotherm, which belongs to type 1 according to the classification proposed by Brunower, Deming, Deming and Teller (BDDT), is inherent. A characteristic feature of this type of adsorption isotherm is that a certain concentration of a component in a solution equilibrium concentration in the solid phase reaches a value which can be considered as actually constant.

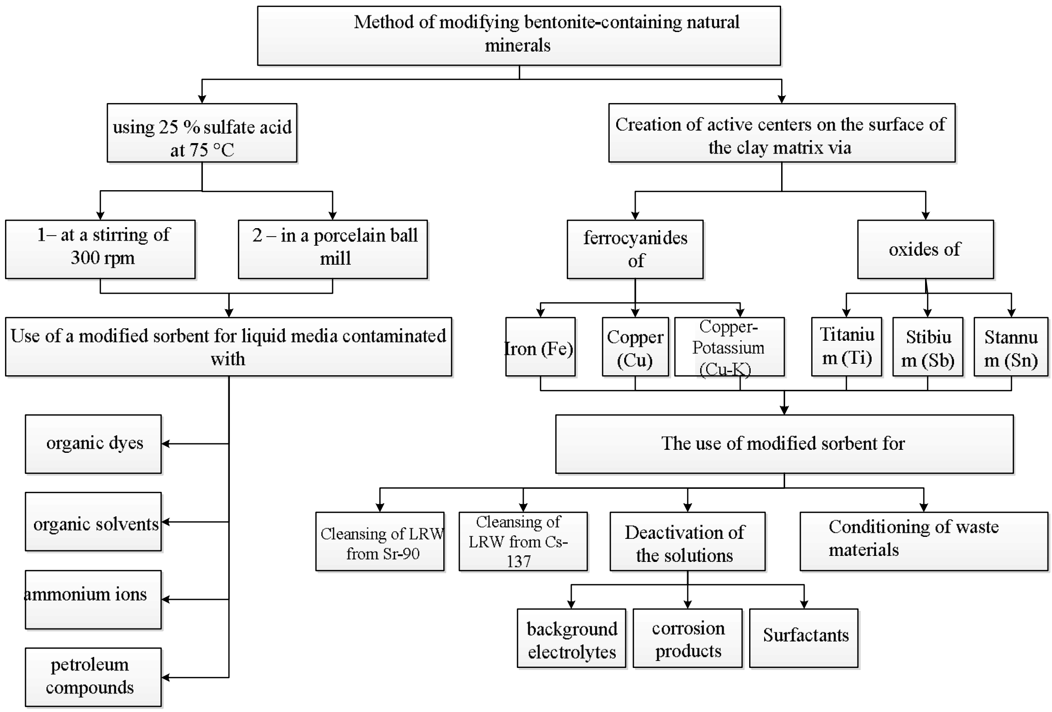

Fig. 2. Optimal methods of modification of bentonite-containing clay minerals for the use in environmental technologies

Consequently the sphere of scientific interests of Professor Ihor Petrushka is associated with the development and improvement of environmentally safe technologies for the protection of liquid media. This is a promising and relevant direction of scientific research, especially if one considers the goals of sustainable development (including pure water) and takes into account the problems of the development of science in particular.

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