NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL SCIENCES OF UKRAINE

«APPROVED»

Dean of Agrobiological Faculty

_____ **Oksana L. Tonkha**

«____»_____2023

CONSIDERED AND APPROVED

at a Meeting of the Analytical, Bioinorganic Chemistry and Water Quality Department

Protocol № 9, the 10th of May, 2023

Head of a Department

_____ **Volodymyr A. Kopilevich**

PROGRAM
Academic Course
"BIOGEOCHEMICAL CYCLES OF METALS-MICRONUTRIENTS"

1. Level of higher education: third (educational and scientific)
2. Area of Knowledge: 10 Natural Sciences
3. Speciality: 102 Chemistry
4. Educational-research program: Chemistry
5. Guarantor of the program Volodymyr A. Kopilevich
6. Program developer: Olha O. Kravchenko, Docent, Candidate of Biological Sci

Kyiv - 2023

1. ACADEMIC COURSE DESCRIPTION
BIOGEOCHEMICAL CYCLES OF METALS-MICRONUTRIENTS

(name)

Field of knowledge, specialty, educational level		
Field of knowledge	10 Natural Sciences	
Educational-scientific level	The third	
Educational level	PhD	
Speciality	102 Chemistry	
Educational-scientific program	Chemistry	
Characteristics of the educational program		
Type	Elective	
The total number of academic hours	150	
Number of ECTS credits	5	
Number of content modules	3	
Course work (project)	No	
Workshop	No	
Forms of control	Exam	
Indicators of academic discipline for full-time and part-time forms of training course		
	Full-time	**Part-time**
Year of study (course)	1	1
Semester	3	3
Lectures, hours	20	10
Laboratory training, hours	20	10
Independent study, hours	110	120
Individual tasks	-	-
Number of weekly in-class academic hours for full-time forms of training	4	5

2. GOAL, OBJECTIVES, AND COMPETENCES OF THE COURSE

Biogeochemistry of metal-microelements is the study of biological controls on the trace metals chemistry of the environment and geochemical regulation of their ecological structure and function. Additionally, it will utilize the scientific literature from peer-reviewed journals to explore specific case studies on the micronutrients global biogeochemistry (e.g., precipitation, deposition, soil solution

exchange, etc.). Trace elements play a critical role in biosphere functioning. Although the concentration, distribution, and bioavailability of trace metals have changed with environmental evolution, their distribution and migration processes are relatively stable. The advent of clean techniques together with advances in analytical procedures and instrumentation, have led to a significant improvement in our understanding of trace metal-micronutrient biogeochemistry due to their activity as ferment active centres etc. The study of the biological, geological and chemical factors that influence the movement of metal-micronutrients through living systems across space and time is the main idea of an educational activity. Processes can be studies at the microbial, ecosystem and global scales. Scales are becoming increasingly integrated.

Biogeochemistry of metal-microelements is the professional-oriented subject. It is a discipline of the elective choice of PhD training in Chemistry.

The program shows types of migrations, biological circulation and biogeochemical cycles of metal-microelements and their role in the life of plants and animals. The principles of metal biogeochemical zoning are defined, the practical aspects of metal-microelement biogeochemistry as a science, its importance for environmental protection at the current stage of human development are revealed. The principles of mathematical modelling of chemical and physicochemical processes in the cycle of such chemical elements are presented.

The objectives of studying the discipline are to give graduate students knowledge about the cycle of trace metals and their impact on living nature, which would contribute to the understanding of the chemical aspects of environmental protection measures, the organization of the environmentally friendly products and the provision of safe sanitary and hygienic living conditions.

Course goals:

To study:

- General notions and laws of biogeochemistry;
- Biogeochemical cycles of main nutrients and pollutants;
- Student must can to do:
- To take a samples of water, soil, air;
- To prepare a sample to chemical analysis;
- To make a few analyses of main nutrients and pollutants of drinking water et al.

The objects of research (tasks) are:

- To study the laws of chemical composition of biosphere as the results of biogenic and a-biogenic processes;
- To explain the matter pass ways and migration of the chemical elements in the environment;

– To estimate of the environmental pollution, prognosis and simulating of pollutants behaviour in biosphere;

– To establish the principles of biogeochemical zoning and reasons of biogeochemical anomalies resulted as endemic non-infection diseases;

– To study the theories of life origin and the possibilities to create “the artificial life” (nowadays data);

– To create the quantitative models of biogeochemical cycles of the macronutrients, micronutrients, toxic elements;

– To study the pass ways and species of biogenic and anthropogenic migrations of the chemical elements;

– To study the nature and mechanisms of the isotope fraction by living matter;

– To establish the role of living matter in geochemical processes of hypergenesis and weathering crust;

– To study the biogeochemical regularities based on the bio-indication methods of environmental monitoring;

– To develop the recommendations for preventing of environmental anthropogenic pollution.

The main **competencies** that the applicant must master as a result of studying the discipline are:

- Ability to abstract thinking, analysis and synthesis;

- Ability to retrospectively analyse scientific work in the direction of biogeochemistry of metals and trace elements;

- The ability to generate new scientific-theoretical and practically oriented ideas regarding the management of migration processes of metals and microelements, the action of biogeochemical barriers;

- Complexity in the possession of information regarding the current state and trends in the development of world and domestic science in the field of chemistry of metals and microelements;

- Complexity in the development and implementation of scientific projects and programs for the prevention of environmental pollution by metals and their compounds;

- Complexity in making informed decisions

As a result of studying the discipline, the applicant should **know**:

- Basic concepts and laws of biogeochemical cycles;

- Biogeochemical transmission chains and zones of anomalous distribution of metals and trace elements;

- Physiological aspects of lack, normal amount and excess of metals of trace elements; endemic diseases associated with anomalous distribution of metals and trace elements;

- Chemical methods of regulating migration flows through the hydrosphere, lithosphere and atmosphere of the migration of these elements;

- Methods of chemical and physicochemical analysis of the content of the specified elements in environmental components and living organisms.

Be able to:

- To determine the qualitative and quantitative composition of the main bioelements and toxicants in the objects of the geochemical environment;
- Typical equipment and devices for chemical analysis of environmental objects;
- To execute statistical treatment of the quantitative analytical results.
- To create new knowledge through original research, the quality of which can be recognized at the national and international levels;
- To participate in scientific discussions at the international level, defend one's own position at conferences, seminars and forums;
- Critically perceive and analyse other people's thoughts and ideas, look for one's own ways of solving the problem, carry out a critical analysis of one's own materials.

Student must to have practical skills:

– To use standard chemical and physical-chemical analyses for the determination of qualitative and quantitative composition of different objects of geochemical environment (soils, water, air, foods etc.);
– To know the probe sampling procedures and the ordinary operations of chemical analysis;
– To use modern analytical equipment, including express analysers for field experiment;
– To prepare equipment, glassware, reagents for analysis;
– To know safe rules in chemical lab.

Requirements to the knowledge and skills

General competences:

GC3. The ability to form a systematic scientific outlook, to generate new ideas (creativity), produce and make informed decisions.

GC5. Ability to use a foreign language for presentation scientific results in oral and written forms, for understanding foreign-language scientific and professional texts for communication in foreign-language scientific and professional environments.

Professional (Special) competences:

PC1. The ability to formulate a scientific problem, working hypotheses of the investigated problem in the field of chemistry

PC2. The ability to carry out a critical analysis of scientific sources, author's methods, specific educational, scientific and professional texts in the field of chemistry.

PC4. Possession of the general methodology of carrying out scientific research, the ability to organize, plan and implement a chemical experiment, calculate and process the obtained data.

Program learning outcomes:

PO1. Understand the scientific concepts and modern theories of chemistry and the fundamental foundations of related sciences. Be able to critically evaluate hypotheses in the field of chemical sciences. Formulate the conceptual foundations of the modern understanding of the chemical level of the organization of matter, the philosophy of scientific knowledge.

PO9. To have the basics of statistical processing of arrays of numerical data and to be able to interpret the results of experimental studies.

PO10. Plan, organize and implement experimental research in chemistry and related scientific areas using modern methods, technologies and equipment.

PO11. Know the relationships between the chemical composition of living organisms and the role of chemical elements in their development; methods of researching ways and mechanisms of biogenic and technogenic migration of chemical elements in the environment.

PO12. To be able to evaluate the nature of chemical processes that determine the state and properties of the environment - atmosphere, hydrosphere and soils, ecological phenomena and problems related to chemical pollution of the environment.

PO13. Understand the principles of building quantitative models of geochemical cycles of “Big Six”, macro- and micronutrients, toxicants; the chemical mechanism of action of geochemical barriers on the migration of chemical elements in the environment.

PO14. Know the procedures for registration of intellectual property rights and registration of security documents. Be able to conduct a patent search in the field of chemical inventions, technologies and objects.

PO15. Communicate freely in English and (if possible) another foreign language on professional matters, orally and in writing present the results of research in chemistry in a foreign language, participate in the discussion of chemistry problems.

PO17. To have the basics of public speaking, oral and written professional communication.

PO20. Possess communication skills and know the principles of organization, forms of implementation of the educational process in modern conditions, its scientific, educational-methodical and normative support, processing of scientific and informational sources when preparing classes, application of innovative teaching methods.

3. SYLLABUS AND STRUCTURE OF COURSE

- total of full-time and part time form of education

Names of content modules and chapters	Hours											
	Full-time						Part time					
	total	included					total	included				
		L	Pr	Lab	Ind	Self		L	Pr	Lab	Ind	Self
Module the 1st. Biogeochemical characteristics of the ecosphere composition												
Chapter the 1st. Introduction. Ecosphere as the highest level of alive matter chemical organization.	10	2		2		6	10	2		2		6
Chapter the 2d. Chemical elements as a matter foundation of inorganic and organic nature. Biochemical migration of chemical elements	16	2		2		12	16	2		2		12
Chapter the 3d. Features of trace elements migration. Primary, secondary and tertiary dispersions of trace elements in the environment.	28	4		4		20	28	4		4		20
Totally the 1st Module	**54**	**8**		**8**		**38**	**54**	**8**		**8**		**38**
Module the 2d. The biogeochemical laws and chemical functions metal-micronutrients												
Chapter the 4th. Bioinorganic compounds and physiological role of trace elements. Kowalsky's concept of biogeochemical provinces. The role of trace elements in the endemic diseases occurrence.	18	4		2		12	18	4		2		12
Chapter the 5th. Biogeochemical zoning, landscape-geochemical zoning of Ukraine. Zonal and diffuse provinces in Ukraine, human and animal endemic diseases in Ukraine as a result of abnormal distribution of metal-micronutrients.	18	2		2		14	18	2		2		14
Totally the 2d Module	**36**	**6**		**4**		**28**	**38**	**6**		**4**		**28**
Module the 3d. Technogenic emission and redistribution of trace metals												
Chapter the 6th. echnophilicity of chemical elements including typical potentially toxic elements and amount of waste. Technogenesis and	20	2		2		16	20	2		2		16

technogenic geochemical anomalies.												
Chapter the 7th. Anthropogenic stage of biosphere development. The concept of biogeochemical functions and biogeochemical principles of living matter. Organisms - concentrators of trace metals.	24	2		4		18	24	2		4		18
Chapter the 8th. Mathematical modeling of metal microelements chemical transformation processes in the environment	16	2		2		12	16	2		2		12
Totally the 3d Module	**60**	**6**		**8**		**46**	**60**	**6**		**8**		**46**
Total hours	**150**	**20**		**20**		**110**	**150**	**20**		**20**		**110**

4. LAB TRAINING CHAPTERS

#	Title	Hours
1.	**Lab 1.** Qualitative analysis of the model solution containing cations of metal mirconutrients and toxic metal and metalloids	2
2.	**Lab 2**. Quantitative spectrophotometric determination of metal micronutrients in natural waters (On the example of Iron, Manganese)	2
3.	**Lab 3.** Quantitative electrochemical (method of inversion chrono potentiometry) determinations of metal micronutrients in soil soils (on the example of Copper, Zinc, Cobalt, Nickel).	6
4.	**Lab 4.** Quantitative determination of metal microelements in organic matter via extraction by water and organic solvents (on the example of Copper and Selenium)	4
5.	**Lab 5.** Phytotoxic assessment of natural waters by biotesting methods using hydrobionts of different systematic groups.	6
Total		**20**

5. EVALUATION CRITERIA

Content of modules and chapters	Hours (lectures/labs)	**Content of the activities evaluated**	**Scores**
Module the 1st. Biogeochemical characteristics of the ecosphere composition			
Chapter the 1st. Introduction. Ecosphere as the highest level of alive matter chemical organization.	2/2	**Lab 1.** Qualitative analysis of the model solution containing cations of metal mirconutrients and toxic metal and	**10**

Chapter the 2d. Chemical elements as a matter foundation of inorganic and organic nature. Biochemical migration of chemical elements	2/2	metalloids **Lab 2.** Quantitative spectrophotometric determination of metal micronutrients in natural waters (On the example of Iron, Manganese)	**20**
Chapter the 3d. Features of trace elements migration. Primary, secondary and tertiary dispersions of trace elements in the environment.	4/4	**Lab 3.** Quantitative electrochemical (method of inversion chronopotentiometry) determinations of metal micronutrients in soil soils (on the example of Copper, Zinc, Cobalt, Nickel). **Module control test** (via Elern)	**20** **50**
Total the 1st module	8/8		**100**
Module the 2d. The biogeochemical laws and chemical functions metal-micronutrients			
Chapter the 4th. Bioinorganic compounds and physiological role of trace elements. Kowalsky's concept of biogeochemical provinces. The role of trace elements in the endemic diseases occurrence.	4/2	**Lab 4.** Quantitative determination of metal microelements in organic matter via extraction by water and organic solvents (on the example of Copper and Selenium) **Module written report and oral presentation**	**30** **50**
Chapter the 5th. Biogeochemical zoning, landscape-geochemical zoning of Ukraine. Zonal and diffuse provinces in Ukraine, human and animal endemic diseases in Ukraine as a result of abnormal distribution of metal-micronutrients.	2/2	**Discussion**	**20**
Total the 2d module	6/4		**100**
Module the 3d. Technogenic emission and redistribution of trace metals			
Chapter the 6th. Technophilicity of chemical elements including typical potentially toxic elements and amount of waste. Technogenesis and technogenic geochemical anomalies.	2/2	**Lab 5.** Phytotoxic assessment of natural waters by biotesting methods using hydrobionts of different systematic groups. **Module control work**	**40** **60**
Chapter the 7th. Anthropogenic stage of biosphere development. The concept of biogeochemical functions and biogeochemical principles of living matter. Organisms - concentrators of trace metals.	2/4		
Chapter the 8th. Mathematical modeling of metal microelements chemical transformation processes in the environment	2/2		
Total the 3d module	6/6		**100**
Education activity	20/20		**300/70**
Exam			**30**
Finally			**100**

6. CONTROL QUESTIONS

1. Describe the task and subject of metal microelements biogeochemistry research.
2. General description of V.I. Vernadskyi's teaching about "living matter" and "biosphere".
3. Define biogeochemistry of bioactive micronutrients as a science of interaction between living and non-living nature.
4. Two biogeochemical laws of V.I. Vernadskyi.
5. How are micronutrient elements classified - by biogenic functions, physiological role, etc.?
6. To characterize the factors affecting the dynamics of metal micronutrients.
7. How is the rate of consumption of trace elements established?
8. How are the biological role of chemical elements and their ionic potential related?
9. According to what laws is the distribution of biogenic elements in the components of the biosphere?
10. Define biogeochemical zoning as the unity of the geochemical environment and the functioning of living matter according to V.V. Kowalsky.
11. What are biogeochemical chains of micronutrients?
12. What are the characteristics of biogeochemical provinces and zones (taiga-forest non-black earth; forest-steppe and steppe black earth; dry steppe, semi-desert and desert; mountain)?
13. To characterize endemic diseases as a consequence of abnormal distribution of chemical elements in the biogeochemical environment.
14. What is the history of the concept of endemic diseases?
15. What are the causes and consequences of the most pronounced endemic diseases - endemic goiter, fluorosis, endemic gout, Kashin-Beck (Urov) disease, Keshan disease.
16. Give a general description of endemic diseases of farm animals.
17. Define the concept of metal-microelements BGC cycles.
18. How are the processes of realizing the cyclical migration of trace elements in the environment?
19. Describe the flows and reserve funds of metal-microelements BGC cycles.
20. Give the characteristics of man-made complex geochemical barrier using the example of oxygen-sorption – Fe(III), Mn(IV) A/G.
21. Landscape-geochemical zoning of Ukraine. Zonal and diffuse provinces in Ukraine, endemic diseases in Ukraine.
22. The influence of the geochemical environment on the evolution of plants. Adaptogenic plants: indifferent to changes in the concentration of chemical elements, common and unusual concentrators, endemic plants.
23. Quantitative methods of environmental analytical chemistry of metal micronutrients.

24. Principles of determining the content of total iron in tap water, tap water and surface water.
25. Technophilicity of chemical elements including typical potentially toxic elements and amount of waste. Technogenesis and technogenic geochemical anomalies of trace elements.
26. Methods of water and soil bioteching for the intergal assessment of phytotoxity of metal microelements.

7. TEACHING METHODS

A teaching method comprises the principles and methods used for students teaching. Commonly used teaching methods for styding of course "Biogeochemical cycles of metals-micronutrients" include on-time participation, demonstration, recitation, memorization, or combination of these. The choice of teaching method or methods to be used depends largely on the information or skill that is being taught, and it may also be influenced by the aptitude and enthusiasm of the PhD students.

Explaining, or lecturing, is the process of teaching by giving spoken explanations of the subject that is to be learned. Lecturing is often accompanied by visual aids to help PhD students visualize an object or problem.

Demonstrating is the process of teaching through examples or experiments. For example, a chemistry teacher must teach an idea by performing an experiment for students. A demonstration may be used to prove a fact through a combination of visual evidence and associated reasoning.

Demonstrations and own experiment are permit to obtain experimental skills needed for environmental monitoring etc. Memorization of a list of facts is a detached and impersonal experience, whereas the same information, conveyed though demonstration, becomes personally relatable. Demonstrations help to raise student interest and reinforce memory retention because they provide connections between facts and real-world applications of those facts. Lectures, on the other hand, are often geared more towards factual presentation than connective leaning.

Collaboration allows PhD students to actively participate in the leaning process by talking with each other and listening to other points of view. Collaboration establishes a personal connection between students and the topic of study and it helps students think in a less personally biased way. Module written report, its oral presentation, and discussions are examples of this teaching method. Teachers may employ collaboration to assess students' abilities to work as a team, leadership skills, or presentation abilities.

Collaborative discussions can take a variety of forms, such as fishbowl discussions. After some preparation and with clearly defined roles, a discussion may constitute most a lesson, with the teacher only giving short feedback at the end or in the following lesson.

Learning by teahing in the method, when PhD students assume the role of teacher and teach their peers. Students who each other's as a group or as individuals must study and understand a topic well enough to teach it to their peers. By having PhD students participate in the teaching process, they gain self-confidence and strengthen their speaking and communication skills.

8. FORMS OF CONTROL

The main forms of knowledge control are control at the lectures at labs and workshops, outside the classrooms, and the consultations, tests and exams.

I. Control of the lectures can be conducted as a selective oral questioning of PhD students or tests using the previously laid material, particularly in sections of the course that are necessary for the understanding of the lecture topics, read, or to establish a degree of mastery of the material lectures (held by the manner of the late first or early second hour lectures). Testing during lectures designed to teach students to systematic elaboration covered material and prepare for the upcoming lectures, establish the degree of assimilation theory to identify the most difficult students to read chapters from the following explanation of them. Control of ther lectures has to subtract time. By spending time to conrol oral examination yields control, programmable for cards.

II. Current control on laboratory studies conducted to elucidate ready students for employment in the following forms:

1. Writing (30 min.) module control test.

2. Credits. Some subjects (theoretical courses, practical training) is applied differential test of performance appraisal on a 100-point scale. In a lecture course or its individual parts, which are not accompanied by laboratory or practical classes, the teacher may conduct interviews or colloquium, offer oral or written questions. Often, PhD students are subject to crediting as a minor, insignificant and do not give enough time to prepare for it.

3. Examinations. Exam is a final step in the study of the whole or part of the discipline and are designed to test PhD students' knowledge on the theory and identify the skills apply the acquired knowledge in solving practical problems, as well as independent work skills with educational and scientific literature.

PhD student's rating of knowledge of an academic discipline consists of training work rating – 70 scores, and exam – 30 scores. Thus, rating of content modules, that are constituents of an academic discipline, makes 70 scores. Rating of content modules as well as attestation rating are also measured by 100-point-scale.

9. METHODICAL SUPPORT

Scientific and methodical support of the educational process includes: educational plans, textbooks and study aids; instructional and methodical materials

for laboratory classes; state standards, individual educational and research tasks; control works; text and electronic versions of tests for current and final control, methodical materials for organizing independent work of applicants.

10. RECOMMENDED LITERATURE

Basic

1. Kopilevich, V.A. et al. (2004), Environmental chemistry, Fenix Publ., Kyiv (412 pp.) (In Ukrainian) (available in NUBiP Library).
2. Schlesinger, W. H. 1997. Biogeochemistry: An Analysis of Global Change, 2nd edition. Academic Press, San Diego, Calif. ISBN 012625155X.
3. Domy C. Adriano. Biogeochemistry of Trace Metals: Advances In Trace Substances Research 1st Edition, CRC Press Revivals Kindle Edition, 2019. – 526 p.
4. Voitenko, L.V. et al. (2015), Lab manual of Biogeochemistry for Bachelor students of Ecology, NUBIP Publ., Kyiv (120 pp.)
5. Войтенко Л.В. Хімія з основами біогеохімії. – К.: Наукова столиця, 2019. – 400 с.

Additive

6. Аналітична хімія природного середовища:Підручник/Б.Й. Набиванець, В.В. Сухан, Л.В. Калабіна. – К,: Либідь, 1996. – 304 с.
7. Аналітична хімія поверхневих вод //Б.Й. Набиванець, В.І. Осадчий, Н.М.Осадча та ін. – Київ: Наук. Думка, 2007. – 457 с.
8. Skalniy A., Microelementoses of man: hygienic diagnostics and correction, Microelem. in med. 1 (2000).

11. IT RESOURCES

1. Ayers R.S.Water quality for agriculture/ R.S. Ayers, D.W. Westcot // FAO Irrigation and Drainage paper. – Roma, 1994. – 147 pp. [Електронний ресурс] / Режим доступу: http://www.fao.org/DOCREP/003/T0234E/ T0234E00.HTM
2. Національна доповідь про якість питної води та стан питного водопостачання в Україні за 2020 рік – К.: Мінрегіонрозвитку України, 2021. [Електронний ресурс]/ - Режим доступу: https://www.minregion.gov.ua/napryamki-diyalnosti/zhkh/teplo-vodopostachannya-ta-vodovidvedennya/natsionalna-dopovid/naczionalna-dopovid-pro-yakist-pytnoyi-vody-ta-stan-pytnogo-vodopostachannya-v-ukrayini-za-2020-rik-2/
3. Екологічні карти України (25 карт) - [Електронний ресурс]. Режим доступу: http://road.elitno.net/?attachment_id=21

4. World Water Day: A Billion People Worldwide Lack Safe Drinking Water - [Електронний ресурс]. – Режим доступу: http://environment.about.com/od/environmentalevents/a/waterdayqa.ht
5. Ayers R.S.Water quality for agriculture/ R.S. Ayers, D.W. Westcot // FAO Irrigation and Drainage paper. – Roma, 1994. – 147 pp. [Електронний ресурс] / Режим доступу: http://www.fao.org/DOCREP/003/T0234E/ T0234E00.HTM
6. Dmitrii Malyuga, 1995, Biogeochemical Methods of Prospecting. Springer, ISBN 978- 0306106828. 8. Global Biogeochemical Cycles. – URL: http://www.agu.org/journals/gb/
7. Kakareka S, Kukharchyk T, Kurman P. Major and trace elements content in freshwater lakes of Vecherny Oasis, Enderby Land, East Antarctica. Environ Pollut. 2019 Dec;255(Pt 1):113126. doi: 10.1016/j.envpol.2019.113126. Epub 2019 Sep 11. PMID: 31542663. – URL: https://pubmed.ncbi.nlm.nih.gov/31542663/
8. Bargagli R. Trace metals in Antarctica related to climate change and increasing human impact. Rev Environ Contam Toxicol. 2000;166:129-73. PMID: 10868078. – URL: https://pubmed.ncbi.nlm.nih.gov/10868078/
9. Winkel Lenny H. E., Sunderland E. M. Introduction to the biogeochemistry of the trace elements : Environ. Sci.: Processes Impacts, 2022, 24, 1277 – URL: https://pubs.rsc.org/en/content/articlepdf/2022/em/d2em90031a