NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL SCIENCES OF UKRAINE

AGROBIOLOGICAL FACULTY
DEPARTMENT OF ANALYTICAL AND BIOINORGANIC CHEMISTRY & WATER QUALITY

"CONFIRMED"
Dean of the Faculty of Plant Protection,
the Biotechnologies, and Ecology
Dr. Agr. Sci, Prof. _____ Yu. V. Kolomiets
"____" _____, 2023

"APPROVED"
at the meeting of the department of
Analytical and Bioinorganic Chemistry & Water Quality
Protocol № 8 dated "31" 04 2023.
Head of Department
_____ (Prof. Volodymyr Kopilevich)

"REVIEWED"
Program Coordinator of Ecology Bachelor
Prof. _____ (Volodymyr Bogolyubov)

PROGRAM OF THE COURSE

CHEMISTRYWITH THE FOUNDATIONS OF BIOGEOCHEMISTRY

Specialization 101 – Ecology
Educational program – Ecology
Faculty of of Plant Protection, the Biotechnologies, and Ecology
Developer: Associate Professor, Cand Chem Sci Larysa Voitenko
(position, academic degree, academic title)

Kyiv – 2023

1. Description of the course

Chemistry with the foundations of biogeochemistry

(назва)

Field of knowledge, specialization, educational program, educational degree		
Educational degree	*(Bachelor's, Master's)*	
Specialization	*Code and Name of specialization*	
Educational program	*Name of program*	
Characteristics of the course		
Type	Elective	
Total number of hours	120	
Number of ECTS credits	4	
Number of content modules	2	
Course project (work) (if applicable)	-	
Form of assessment	*Exam*	
Indicators of the course for full-time and part-time forms of study		
	Full-time form of study	Part-time form of study
Course (year of study)	The forth	The forth
Semester	7	7
Lecture classes	*30 hr.*	*8 hr.*
Practical, seminar classes	*hr.*	*6 hr.*
Laboratory classes	*30 hr.*	*hr.*
Self-study	*60 hr.*	*106 hr.*
Individual assignments	*hr.*	*hr.*
Number of weekly classroom hours for the full-time form of study	*4 hr.*	

2. Objectives, tasks, and competences of the academic discipline

Purpose, objectives, and competencies of the course

Purpose is to acquire basic concepts, principles, and techniques of modern biogeochemistry as a top level of chemistry understanding and special application for the specialists in the field of ecology, environmental protection, and sustainable development. The discipline that involves the study of the chemical, physical, and biological processes and reactions that govern the composition of the natural environment (including the biosphere, the cryosphere, the pedosphere, the atmosphere, and the lithosphere): chemical aspects of life origen. In particular, it is to study of cycles of chemical elements, such as carbon and nitrogen, and their interaction with and incorporation into living things transported through earth scale biological systems in space through time.

Tasks:

1. To develop the conceptual apparatus, general principles and fundamental provisions of biogeochemistry;
2. To study of the general geochemical organization of the biosphere;
3. To study of global biogeochemical cycles of elements;

4. To study of the geochemical evolution of the outer shells of the earth under the influence of the activity of living matter;

5. To study of the patterns of migration and concentration of various chemical elements depending on the internal and external factors, including those occurring in the biosphere as a result of anthropogenic impact;

6. To study of biogeochemical features of various endemic zones and endemic diseases;

7. To acquaintance with the techniques and methods of biogeochemical research used to study the processes of mass transfer and migration of chemical elements between living organisms and the environment, as well as for ecological and geochemical assessment of the state of the environment.

Competence acquisition:

integral competence (IC): The ability to solve complex specialized problems and solve practical problems in the field of ecology, environmental protection, and sustainable environmental management, which involves the application of basic theories and methods of science about environments that are characterized by complexity and uncertainty of conditions.

General competences (GC):

GC1. Knowledge and understanding of the subject area and professional area activity

GC8.The ability to conduct research at the appropriate level.

GC9. Skills of interpersonal interaction and teamwork.

GC10. The ability to evaluate and ensure the quality of performed works.

Professional (special) competences (PC):

PC2. Ability to critically understand basic theories, methods and principles of natural sciences.

PC7. Ability to monitor and assess the current state of the environment.

PC10. Ability to use modern information resources for ecological research**.**

Programmatic learning outcomes (PLO):

PLO3. To understand the main concepts, theoretical and practical problems in the field of natural sciences, which are necessary for analysis and decision-making in the field of ecology, environmental protection and balanced nature management.

PLO8. Be able to search for information using relevant sources to make informed decisions.

PLO11. Be able to predict the impact of technological processes and production on the environment.

PLO14. Be able to create texts, make presentations and messages for a professional audience and the general public, observing professional integrity and preventing plagiarism.

3. **Program and structure of the subject**

- for full-time (part-time) English-speaking students

Names of content modules and topics	Number of hours												
	Full-time form							Part-time form					
	weeks	total	including					total	including				
			l	p	lab	ind	self		l	p	lab	ind	self
Content Module 1. Biogeochemical characteristics of the ecosphere composition													
Topic 1. Introduction. The object of research and the goal of the discipline. Life origin on the Earth: hypotheses and experimental.	1-3	22	4		6		12	26	2		2		22
Topic 2. The ecosphere, the chemical elements and biogeochemical laws.	3-5	20	4		6		10	20	2				18
Topic 3. Biogeochemical zoning	6	8	4				4	7					7
Topic 4. Endemic diseases as result of abnormal distribution of chemical elements in biosphere	7-8	12	4		4		4	9			2		7
Total for content module 1	**8**	**62**	**16**		**16**		**30**	**62**	**4**		**4**		**54**
Content Module 2. Biogeochemical cycles of the main bioactive chemical elements													
Topic 1. The general notions of biogeochemical cycles. Biogeochemical cycles of gaseous (Nitrogen, Oxygen, Hydrogen) and Sedimentation types (Phosphorus, Sulfur). Biogeochemical barriers.	9-12	34	8		12		14	28	2		2		24
Topic 2. Biogeochemical cycles of micronutrients and toxic elements. Chemistry of preservatives and psychoactive compounds	13-15	24	6		2		16	30	2				28
Total for content module 2	**7**	**58**	**14**		**14**		**30**	**58**	**4**		**2**		**52**
Total, hours		**120**	**30**		**30**		**60**	**120**	**8**		**6**		**106**

4. Seminar topics - not provided by the curriculum

5. Practical class topics - not provided by the curriculum

6. Laboratory class topics

#	Title	Hours
1	Introduction. Safe rules in chemical laboratory. Qualitative methods of environmental chemical analysis. Probe sampling, conservation and storage of samples for analysis. Principles of statistic treatment of qualitative analytical results of environmental objects.	4
2	Express measuring of active residue chlorine (free, total) in chlorinated drinking water by photometric method using C-401 colorimeter.	4
3	Determination of nitrate content in natural fresh waters and drinking water by photometrical method according to DSTU 4078-2001 Water quality; determination of nitrate; part 3: spectrometric method using sulfosalicylic acid (ISO 7890 3:1998, MOD). Statistical treatment of analysis data.	4
4	Determination of ammonia content in natural fresh waters and drinking water by photometrical method according to DSTU ISO 7150-1-2003 Water quality - Determination of ammonium - Part 1: Manual spectrometric method. Statistical treatment of analysis data.	4
5	Determination of total iron content in tap water, buvette water and surface waters according to GOST 4011-72 Drinking water. Methods for determination of total iron. Statistical treatment of analysis data.	4
6	Determination of fluoride content in drinking water and a few sorts of leaf and packed according to GOST 4386-89 Drinking water. Methods for determination of fluorides mass. Statistical treatment of analysis data.	2
7	General chemical properties of alkaloids. Загальна характеристика алкалоїдів. Sublimation method for the caffeine dry extraction from tea leaves. Qualitative test of caffeine.	2
8	Determination of active oxygen content in detergents and oxygen-contained bleaches according to DSTU 2207.2-93 (GOST 22567.10-93) Synthetic detergents. Methods to determine total mass fraction of available oxygen.	6
	Total	**30**

7. Independent work topics

#	Chapter	Hours
1	2	3
1	Anthropogenic stage of biosphere development. The concept of the noosphere. The noosphere as a natural step in the development of the Earth. Characteristic features of the noosphere: a) emergence of new landscapes (cultural, man-made, agricultural landscapes); b) man as the main active force of the noosphere, man-made migration of chemical substances; c) significant increase in volumes of information, new types of information; d) use of biosphere energy. Conditions (according to V.I. Vernadskyi) for the complete transformation of the biosphere into the noosphere.	12
2	Landscape-geochemical zoning of Ukraine. Zonal and intrazonal provinces in Ukraine, endemic diseases in Ukraine. 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.	10

1	2	3
3	Biogeochemistry of the Earth's gas mantle. Value of atmospheric mass transfer of water-soluble forms of chemical elements. Vegetation as an absorber of gaseous pollutants.	4
4	Biogeochemistry of the lithosphere and pedosphere. Chemical composition of soils and bottom sediments. Types of migration of chemical elements in the pedosphere and lithosphere (hypogenic, supergenic and anthropogenic migration). Organic matter of the pedosphere.	4
5	Biogeochemistry of the hydrosphere. Classification of natural waters according to the level of mineralization, type of mineral matrix. Water requirements for different types of water use (drinking, irrigation, watering animals and poultry, fish farming, recreational purposes, etc.).	8
6	Biochemical cycles of substances and energy in the biosphere. Cycle of elements that entered the biosphere as a result of mantle degassing (hydrogen, carbon, oxygen, nitrogen). Cycles of elements that entered the biosphere as a result of mobilization from the earth's crust (calcium, potassium, silicon, phosphorus).	8
7	Interaction between living and non-living nature is the basis of biogenic migration of substances. The concept of a small biological cycle of chemical elements. The energy of living matter is the driving force of the geochemical and biogeochemical circulation of substances.	6
8	Hydrogen (water) cycle. Chemical characteristics of hydrogen, its content in the lithosphere, atmosphere, living organisms, humus, plants. Water as a source of Hydrogen for the formation of organic substances. Water as a living environment. Total water content in the biosphere. Biogeochemical cycle of water, its duration. Provision of drinking water and the degree of its use in different countries. Water pollutants, their classification.	8
	Total	60

8. Samples of control questions, tests for assessing the level of knowledge acquisition by students.

1. The object of research and tasks of the discipline. V.I. Vernadsky – the founder of biogeochemistry.
2. Genesis of Biogeochemistry. The relationships of biogeochemistry with other natural sciences.
3. Applied aspects of biogeochemistry. Modern directions of biogeochemistry. The environmental protection as a social factor.
4. The theories of life origin on the Earth. The Oparin-Haldane protein-coacervate Hypothesis; panspermia; DNA world.
5. Muller-Urey experiment. Experiments of “artificial life”. Alternative ecospheres. Gaia hypothesis of J. Lovelock.
6. Vernadsky’ Biosphere study. Notion of life matter, its composition.
7. Types of bio-spherical matter of the earth. The mail biochemical components of biosphere.
8. Conditions of the biosphere existing. Energy and matter fluxes in biosphere. Vernadsky biogeochemical principles (laws).
9. Different types of bioelements classification – based on biological functions, physiological functions etc.
10. Factors influences on the dynamics of bioactive elements. The consumption ratio of micronutrients. Notion of ionic potential.
11. Bioactive elements distribution in biosphere. Examples of geochemical role of life matter (calcium, iodine functions, atmospheric oxygen, formation of manganese-nickel concretions etc.).

12. Biogeochemical functions of life matter.
13. Biogeochemical zoning as an unity of geochemical environment and functioning of life matter (according to V.V. Kowalsky). Biogeochemical chains.
14. Biogeochemical provinces and zones (taiga-forest non-chornozemic; forest-steppe and steppe chornozemic; dry-steppe; semiarid and desert; mountain).
15. Endemic diseases as a consequence of abnormal distribution of chemical elements in biogeochemical environment.
16. History of endemic diseases studying. Endemic goiter, correlation of human iodine status and IQ level. Methods of iodine deficit prevention – pro and contra.
17. Fluorosis as a consequence of increaser content of fluorine in drinking water. Adding of fluoride compounds in toothpastes and fluoridation of drinking water.
18. Endemic podagra, Kashin-Bek disease (Urov), Keshan disease. Endemic diseases of farm animals.
19. The basic notions of biogeochemical cycles. Processes of cycling migration of chemical elements in environment. Fluxes and reservoirs of biogeochemical cycles.
20. Thermodynamics laws and biogeochemical cycles. Experimental evidences of cycling (Witherspoon radioisotope experiment; Habbard-Brook experimental forest study). Exogenic and endogenic cycles.
21. Types of ogranogenic elements cycles. Hydrological cycle. Hydrogen degasation. V. Larin theory. Global model of carbon cycle according to V. Kovda.
22. Global carbon cycle according to R. Radkliffs as the ratio of chemical state of carbon compounds (oxiding-reducting). Detrite as biogeochemical reservoir of carbon. Fossilises. Isotope distribution of carbon. Radiocarbon analysis.
23. Nitrogen biogeochemical cycle. Biogenic and abiogenic nitrogen fixation. Hypotetic structure of nitrogenaze-nitrogen metal-ferment complex. “Nitrogen barrier” in biosphere production.
24. Phosphorus biogeochemical cycle. Reservoir and exchange founds of phosphorus cycle. Ephtrofication: mechanism and prevention. Artificial ephtrofication experiments. “Phosphorus falling” in fertilizer resources and limitation of crop production.
25. Classification of biogeochemical barriers: physical, mechanical, biogenical, techogenical. Practical using of biogeochemical barrier study for the analysis and prognosis of chemical substance transformation in polluted soils. Rationale of methods for pollution localization. Biological barriers – result of biological concentration of chemical elements. Notion of biological remediation of soils.. Physical-chemical barriers – acidic-basic, sulphide, carbonate, sulfates, Red-Ox. Example of complex geochemical barrier – oxygen-absorption – Fe(III), Mn(IV) A/G.
26. General classification of psychoactive substances and food additives. Chemical structure, properties, health risks. Chemophobia.

Example of the module test 1

Module quiz 1 (20 points) (Module 1 – the main concepts of biogeochemistry)

Question 1. Presence in the atmosphere of the any planet in the Universe of gaseous _____ means the life like in the Earth (according to J. Lovelock) *(1 point):*

A	N_2	C	CO	E	O_2
B	H_2S	D	CO_2	F	CH_4

Answer: _____

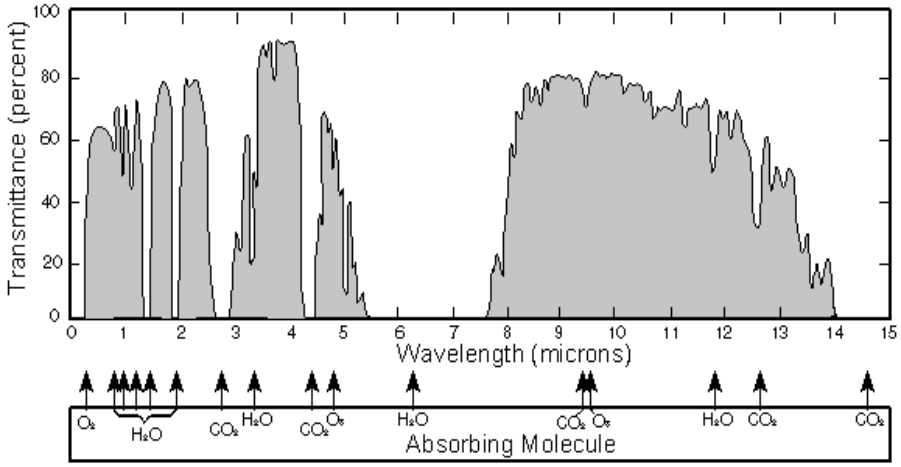
Question 2. Describe the examples of extremely ecosystems illustrated the Vernadsky’s term «all over» propagation of life on the surface of the Earth *(at least two examples) (2 points)*

Question 3. Note the main dangerous result of drinking water chlorination *(1 point)*

A	Bad water odor and taste	C	Corrosion of water pipes
B	Formation of by-products – Trihalomethanes and other chloroderivates of cancer activity	D	The risk of any leakage of gaseous chlorine for water treatment plants

Question 4. Insert the missing word: First biogeochemical law - biogenic _____ of chemical elements in the biosphere tends to its maximum development *(1 point).*

Question 5. Using data about the atmospheric transparency in Infra red spectra (see picture), note the substances (excepting carbon dioxide) which are the absorbers of IR radiation (Answer – as the chemical formulas) *(2 points)*



Question 6. Note the maximum permitted limit of total and free residual chlorine content of drinking water according to the requirements of DSanPiN 2.2.4-171-10 *(two figures and unit of concentration) (2 points).*

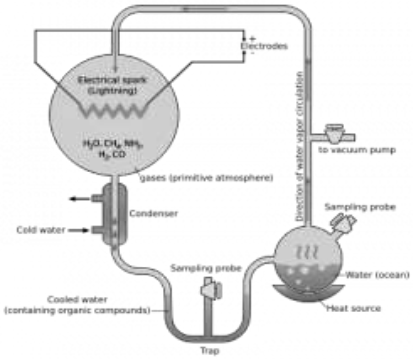
Question 7. Why is no reason to include the dissolved oxygen content as the parameter of the drinking water quality for human consumption? *(Answer – as a sentence) (1 point)*

Question 8. What is the name of American social activist and former US Vice President, who received in 2007 the Nobel Peace Prize for a campaign against the "greenhouse effect" *(1 point)*

Question 9. What type of drinking water pollution and its duration is a cause of "blue baby" syndrome? *(1 point)*

A	Chronic toxicity of nitrates
B	Acute poisoning of nitrates
C	Chronic toxicity of ammonia
D	Acute poisoning of nitrites
E	Acute poisoning of ammonia

Question 10. The Muller-Urey experiment was a reason of the life origin theory: *(1 point)*



A	Panspermia
B	Creationism
C	Spontaneous generation
D	Biochemical evolution (Oparin-Haldane's)
E	The RNA world

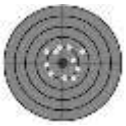
Answer: _____

Question 11. Insert the missing word: Second Biochemical law - the evolution of species, leading to the creation of life forms that are stable in the biosphere should be in the direction, _____ expression of the biogenic migration of atoms in the biosphere. *(1 point)*

Question 12. Describe the risks to human health associated with chlorination of drinking water for its disinfection *(answer as the sentences) (2 points)*

Question 13. Note the main sources of underground water pollution of nitrates in Ukraine *(2 points)*

Question 14. Note relationship of accuracy versus precision for the next situation (*high, low) (1 point):*



Answer: _____ accuracy, _____ precision

Question 15. Note analytical method used for the residual chlorine content in drinking water of express-method (Colorimeter C 401, for example) *(1 point)*

A	Neutralization	C	Permanganatometry
B	Atomic absorption	D	Photometry

9. Teaching methods

Before teaching a course, the instructor must identify what she or he intends for the students to learn. For most chemistry instructors, this usually involves an assessment of what methods and techniques to include and at what depth to cover them. There are many other skills, though, that will be important to students for their future success. Most university classes in chemistry are taught in a lecture format. An alternative to lecturing is the use of cooperative learning. Cooperative learning offers the potential to develop skills such as teamwork, communication, and problem-solving that is more difficult to impart in a lecture format. The laboratory component of chemistry courses is often an underutilized learning resource. More often than not, the lab is used to demonstrate fundamental wet and instrumental analysis techniques and develop rudimentary laboratory skills. The analytical lab should also be used to develop meaningful problem-solving skills and to demonstrate and have students participate in the entire analytical process.

A teaching method comprises the principles and methods used for students teaching. Commonly used teaching methods for studding subject “Chemistry with the foundations of biogeochemistry” 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 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 students visualize an object or problem.

Demonstrating is the process of teaching through examples or experiments. A demonstration may be used to prove a fact through a combination of visual evidence and associated reasoning.

Demonstrations in chemistry 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 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. Teachers may employ collaboration to assess students’ abilities to work as a team, leadership skills, or presentation abilities.

Learning by teaching in the method, when students assume the Lecturer’r role 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 students participate in the teaching process, they gain self-confidence and strengthen their speaking and communication skills.

10. Forms of assessment

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 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 form of writing control module work.

III. Credits. Some subjects (theoretical courses, practical training) is applied differential test of performance appraisal on a 100-score scale.

IV. Examinations. Exam is a final step in the study of the whole or part of the discipline and are designed to test 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.

Distribution of grades received by students. Evaluation of student knowledge is carried out on a 100-point scale and is converted to national grades according to Table 1 "Regulations and Examinations and Credits at NULES of Ukraine" (order of implementation dated 26.03.2023, protocol №10)

Student rating, points	**National grade based on exam results**	
	Exams	**Credits**
90-100	Excellent	Passed
74-89	Good	
60-73	Satisfactory	
0-59	Unsatisfactory	Not passed

In order to determine the rating of a student (listener) in the discipline $\mathbf{R_{dis}}$ (up to 100 points), the rating from the exam $\mathbf{R_{ex}}$(up to 30 points) is added to the rating of a student's academic work $\mathbf{R_{aw}}$ (up to 70 points): $\mathbf{R_{dis} = R_{aw} + R_{ex}}$ **.**

11. Educational and methodological support.

A complete set of educational and methodological support for the study of the discipline "Chemistry with the foundations of biogeochemistry" is available on the educational and informational portal of NUBIP of Ukraine (https://elearn.nubip.edu.ua/course/view.php?id=2314).

1. Voitenko L. Chemistry with the foundations of biogeochemistry (2019). Kyiv: Naukova stolytsa, 2019. (400 p.) (In Ukrainian).
2. Schlesinger, William & Bernhardt, Emily. (2013). Biogeochemistry: An Analysis of Global Change, Third Edition. Biogeochemistry: An Analysis of Global Change, Third Edition. 672 pp. Academic Press, San Diego,
3. Lab Manual / Voitenko, L.V. (2020). Lab workbook of Biogeochemistry for Bachelor students of Ecology, NUBIP Publ., Kyiv. (98 pp.)

12. Recommended sources of information

1. Аналітична хімія природного середовища:Підручник/Б.Й. Набиванець, В.В. Сухан, Л.В. Калабіна. – К,: Либідь, 1996. – 304 с.
2. Аналітична хімія поверхневих вод //Б.Й.Набиванець, В.І.Осадчий, Н.М.Осадча та ін. – Київ: Наук. Думка, 2007. – 457 с.
3. Мікроелементози сільськогосподарських тварин. – К.: Урожай, 1974. – 151 с.
4. World Water Day: A Billion People Worldwide Lack Safe Drinking Water - [Електронний ресурс]. – Режим доступу: http://environment.about.com/od/environmentalevents/a/waterdayqa.htm
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. Ware supply for rural areas and small communities/E.G.Wagner, J.N.Lanoix. – World Health Organization, Palais des Nations, Geneva. – 1959. – 337 pp. – [Електронний ресурс] /Режим доступу: whqlibdoc.who.int/publications/1948-60/9241400420.pdf.
7. Abraham, Ralph. (2009). A Review of "Geochemistry and the Biosphere: Essays by Vladimir I. Vernadsky". World Futures. 65. 436-441. 10.1080/02604020802631709. https://www.researchgate.net/publication/249036756_A_Review_of_Geochemistry_and_the_Biosphere_Essays_by_Vladimir_I_Vernadsky
8. Samuel S. Butcher et al. (Eds.), 1992, Global Biogeochemical Cycles. Academic, ISBN-
8. Global Biogeochemical Cycleshttp://www.agu.org/journals/gb/Biogeochemistry http://www.springer.com/west/home/geosciences?SGWID=4-10006-70-35757517-0. A journal published by Springer.
10. Biogeochemistry articles from across Nature Portfolio. - https://www.nature.com/subjects/biogeochemistry