

**NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL
SCIENCES OF UKRAINE**

General Ecology, Radiobiology and Life Safety Department



PROGRAM OF THE COURSE

“VETERINARY RADIOBIOLOGY”

Specialty: 211 - Veterinary Medicine
Educational program: «Veterinary Medicine»
Faculty: Veterinary Medicine
Volodymyr Illienko , PhD in Biology, senior lecturer of
General Ecology, Radiobiology and Life Safety
Developers: Department
Alla Klepko , PhD in Biology, docent of General
Ecology, Radiobiology and Life Safety Department

Kyiv – 2023

1. Description of academic discipline

Veterinary Radiobiology

(name)

Direction, speciality, educational program and qualification level		
Educational and qualification level	<i>Master</i>	
Speciality	<i>211 - Veterinary Medicine</i>	
Educational program	<i>"Veterinary Medicine"</i>	
Characteristics of academic discipline		
Mode	Obligatory	
Total number of hours	90	
Number of credits ECTS	4	
Number of meaningful modules	3	
Form of control	<i>exam</i>	
Indicators of academic discipline for full-time and part-time forms of education		
	full-time education	part-time education
Year of study (course)	4	-
Semester	7	-
Lectures	<i>15 hours</i>	<i>- hours</i>
Practical and seminar lessons	<i>-hours</i>	<i>- hours</i>
Laboratory practical	<i>30 hours</i>	<i>- hours</i>
Self-dependent work	<i>75 hours</i>	<i>- hours</i>
Self-dependent work	<i>- hours</i>	<i>hours</i>
Week hours for full-time education	<i>3 hours</i>	

2. PURPOSE AND OBJECTIVE OF THE DISCIPLINE

The purpose of studying the discipline "Veterinary Radiobiology" is to train a specialist who will be able to highly assess the radiation situation and develop measures to ensure the safety of animal husbandry in contaminated areas and obtaining "clean" from radionuclides livestock products.

The objectives of the discipline "Veterinary Radiobiology" are to form specialists capable of:

- independently assess the existing radiation situation and in cases of incidents related to the contamination of the environment with radioactive substances, the emergency radiation situation;

- conduct radiometric examination of objects of the environment of agricultural products, food products;
- predict the levels of possible entry of certain radionuclides into livestock and food products;
- develop measures to minimize the entry of radionuclides into livestock products.

AFTER FINISHING OF COURSE STUDENTS HAVE TO know:

- sources of ionizing radiation in the environment;
- ways of entry of radioactive elements into feed and organism of farm animals;
- principles of protection of animals from radiation damage;
- means of preventing the entry and accumulation of radioactive substances in crop and livestock products;
- methodology and technology of agricultural production in areas contaminated with radionuclides.

Students must be able to:

- evaluate radiation conditions using dosimetric devices of different systems;
- conduct radiometric examination of the surrounding objects environment and agricultural production;
- develop countermeasures to minimize the influx of radionuclides in livestock products.

Acquisition of competencies as a result of studying the discipline:

general competencies (GC):

3. Knowledge and understanding of the subject field and profession.
9. Ability to make informed decisions.

professional (special) competencies (PC):

16. The ability to protect the environment from contamination by livestock waste, as well as materials and means of veterinary use.

21. The ability to develop and implement measures for the management and prevention of radiation damage and contamination of domestic animals and coenoses in general, with radionuclides.

Program learning outcomes:

10. Propose and use expedient innovative methods and approaches to solving problematic situations of professional origin.

21. Develop measures to prevent radiation damage and contamination of domestic animals and coenoses with radionuclides.

3. CURRICULUM AND STRUCTURE OF THE COURSE

№	Topic	The topic content, recommended literature	Types of educational activity, hours.		
			lect ures	labo rato ry wor k	inde pen dent wor k

Module 1. Introduction. Physical basics of radiobiology and radioecology					
1.1.	Introduction to radiobiology. history	Definition of radiobiology (radiation biology) and radioecology (radiation ecology). Radioecology as a component of radiobiology. Radiobiology objects of studying. Organizational structure of radiobiology. A place of radiobiology among the allied science. Directions of radiobiology development. Tasks of radiobiology and radioecology. History of radiobiology and radioecology development. A role of achievements of nuclear physics is at the end of a 19 th century in an origin and development of radiobiology. Stages of radiobiology and radioecology development. Development of radiobiology and radioecology in Ukraine. Modern problems of radiobiology and radioecology: specific of influence on the living organisms of small doses of ionizing radiations, features of influence on the living organisms of chronic irradiation, prophylaxis and therapy of sharp and chronic radiation defeats, radiation dysimmunity, remote consequences of irradiation, general influence on the organism of ionizing radiations and other factors, migration of natural and artificial radionuclides in the objects of environment, features of influence on the organism of the incorporated radionuclides, in plants, organisms of animals and man, blocking of receipt of radionuclides, in plants, organism of animals and man, leading out of radionuclide from an organism. Theoretical and practical value of radiobiology. Necessity of wide propaganda of radiobiological knowledge.	2	4	10

		<i>Literature: 1, 8-12</i>			
1.2	Physical basics of radiobiology	Phenomenon of radioactivity. Law of radioactive decay. Nature atoms and molecules of matter ionization. Definition of concept of ionizing radiations. Types of ionizing radiations: electromagnetic and corpuscular radiation. Types of electromagnetic ionizing radiations: x-ray photography, gamma- and slowing-down radiation. Physical descriptions of basic types of radiations: alpha -, beta-, proton and neutron radiations. Exposure, absorbed and equivalent doses of ionizing radiations. Power of dose. Types of irradiation depending on power of dose, factor of time and multiplicity of irradiation: sharp and prolonged (chronic), non-permanent and frequent (fractionating). Units of radioactivity and doses of ionizing radiations. Connection between radioactivity of matter and dose ionizing a radiation.	2	2	10
		<i>Literature: 1, 2, 4, 8-11, 23</i>			
Module 2. Biological effects of ionizing radiation					
2.1	Sources of radioactive substances and ionizing radiation	Natural and artificial sources of ionizing radiations. Natural ionizing radiation. Space radiation and radiation of natural radioactive elements. Sun and galactic radiation. Radiation of radioactive elements from families of uranium, actinouranium and to thorium. Payment of radiation of radon. Radiation of non-family natural radionuclides. Payment of radiation radioactive calcium. Radiation of cosmogenic radioactive elements. Radioactive hydrogen and carbon. Natural radiation background. Estimations of doses of irradiation of living organisms, predefined a natural ionizing radiation. The possible value of natural radiation in the processes of vital functions of organisms. Ionizing a radiation from artificial radionuclides. Sources of artificial radionuclides in environment. Radiation from radionuclides which appear as a result of tests of nuclear-powered weapon. «Global» nuclear fall-outs. Radiation of radionuclides which enter environment from the enterprises of nuclear energy. Radiation	1	4	10

		from sources which are used in medicine and everyday life.			
		<i>Literature: 1, 3, 4, 7, 8, 10-13</i>			
2.2	Biological effects of ionizing radiation	<p>Concept of radiobiology effect. Classification of radiobiology effects. Somatic and genetic radiobiology effects. Essence of radiation stimulation. Radiation stimulation of plants and animals. Basic types of morphological changes of organs of plants under ionizing radiations influence. Animal morphological changes. Essence of teratogenic influence of ionizing radiations. Concept of radiation chimera. Carcinogenic influence of radiations. Mechanisms of morphological origin changes at the influence of ionizing radiations. Radiation illness of plants. Kinds and degrees of mammal's radiation illness. Influence of ionizing radiations is on the acceleration of senescence and life-span. Death of organisms is at the high doses of irradiation. «Death under a ray». Specific of plants radiation death. «Gamma-germs». Features of ionizing radiation influence on the forest planting. Reactions of trees on an irradiation. Unspecificity of types of mutations which arise up at the influence of ionizing radiations. Thresholdless and threshold conceptions of ionizing radiation influence. Thresholdless character of carcinogenic and genetic influence of ionizing radiations. Close and remote effects of ionizing radiations . Stochastic character of remote consequences of radiation defeat. Features of influence of small doses of ionizing radiations on living organisms: stimulative, antiimmune, carcinogenic, genetic effects. Biological effects of radiotelemetrings.</p>	2	2	10
		<i>Literature: 1, 3, 9-12, 24</i>			
2.3	Modification of radiation damage to the organism	<p>Classification of radiation lesions: radiation sickness during external and internal irradiation, radiation beta-burns of the skin. Radiation sickness during external irradiation. Classification of severity of radiation sickness in animals and periods of its course. Clinical signs of radiation syndromes (bone marrow, intestinal, nervous) in different species of animals. Diagnosis and prognosis of radiation sickness during external irradiation. Features</p>	2	4	10

		<p>of radiation sickness during internal irradiation of animals. Classification of degrees of severity of radiation sickness at internal irradiation of animals and periods of its course. Features of influence of products of nuclear fission on an organism of animals. Defeat of animals by long-lived radionuclides. Diagnosis and prognosis of radiation sickness during the entry of radionuclides into the body of productive animals. The course of infectious diseases against the background of radiation pathology. Prevention of radiation sickness and basic principles of varnishing animals. Physical, chemical and biological means of animal protection. Theories and mechanisms of radioprotective action of chemical compounds - radioprotectors: attenuation of oxygen effect, interception and inactivation of free radicals, change of redox potential, increase of level of sulfhydryl groups, increase of biological background radioresistance. The main principles of treatment of radiation sickness: the use of pathogenetic therapy, detoxification drugs, the fight against opportunistic macroflora, the use of drugs that stimulate hematopoiesis. Radiation skin burns. Etiology, pathogenesis, clinical signs, course and consequences. Features of radiation burns and their difference from thermal and chemical skin burns. Prevention and treatment of radiation skin burns.</p>			
		<i>Literature: 1, 7-12, 19</i>			
2.4	Toxicology of radionuclides and radiation damage to animals by radioactive iodine	<p>Toxicology of radioactive substances. Factors that determine the degree of radiotoxic action: type and energy, ways of entry and excretion from the body, half-life, type of distribution in the body, solubility and other physicochemical properties of radionuclides. Classification of radionuclides by their toxicity to humans and animals. Ways of radionuclide entry into animals: inhalation, alimentary, percutaneous. Basic regularities of radionuclide metabolism in animals. Types of distribution of radionuclides in animals. Peculiarities of behavior and deposition of radionuclides of iodine, cesium, strontium, ruthenium, cerium, and plutonium in animals. Their transition to livestock</p>	2	2	10

		<p>products. The concept of the biological half-life and the effective half-life of radionuclides from the body and the factors that affect them. The influence of the composition of the diet on the transition of radionuclides from feed to milk and meat. Forecasting of radionuclide contamination of livestock products. Radiation hazard uranium period after radiation accidents. Classification of lesions of farm animals by isotopes of radioactive iodine: routes of entry and metabolism of radioactive iodine in the body of farm animals, acute and chronic forms of lesions of farm animals with radioactive iodine. Clinical signs of radiation damage to farm animals by radioactive iodine. Diagnosis and prognosis of radiation injuries of animals with radioactive iodine. Calculation of absorbed doses to the thyroid gland due to radioactive isotopes of iodine. Protection of farm animals from radioactive iodine. Use of farm animals affected by radioactive iodine. Features of the course of radiation exposure of farm animals with radioactive iodine in regions endemic for stable iodine.</p>			
		<i>Literature: 1-3, 7, 10, 13, 17</i>			
2.5	Fundamentals of agricultural radioecology	<p>Natural radiation background and sources of radioactive contamination of the environment with radionuclides. Characteristics of the main components of the natural background and cosmic radiation, radioactive elements of the Earth, natural radioactivity of the atmosphere, water, soil, plant and animal organisms. Doses of external and internal irradiation due to natural radiation background. Characteristics of the main dose-generating radionuclides. Ways of receipt of radionuclides on the earth's surface. Forms of radionuclides in the environment. General scheme of migration of radionuclides in the environment and objects of agricultural production. Factors influencing horizontal and vertical migration of radionuclides. Influence of soil properties on the behavior of radionuclides in the soil-plant system. Biological features of plants in the accumulation of radionuclides in them. The concept of accumulation coefficients (MP) and radionuclide transition (CP). The specifics of the transition of radionuclides</p>	1	4	5

		into crop products, animal bodies and livestock products, feed. Forecasting of contamination of agricultural products with radionuclides.			
		<i>Literature: 1, 7, 9-12</i>			
	Module 3. Standardization of radiation exposure				
3.1	Standardization of radiation exposure, basics of radiation safety and agricultural production in areas contaminated with radionuclides	Comparative assessment of sources of external and internal exposure of the population. Radiation safety standards. Principles of radiation safety. The concept of categories of irradiated persons and permissible doses of their irradiation. Hygienic regulations and dose limits. Permissible content of the most important radionuclides in air and water. The limit of annual intake of radionuclides in the human body through the digestive system. Standardization of radionuclide intake in agricultural products. Permissible daily intake of radionuclides in the body of productive animals. Legislative documents that are the basis for the construction, equipment and organization of radiological laboratories. Basic sanitary rules of work with radioactive substances and other sources of ionizing radiation. Regulations on radiological departments of the laboratory of veterinary medicine. Sanitary passport of the radiological laboratory. Open and closed radioactive sources. Basic principles of protection against external and internal irradiation when working with radioactive substances: distance, time, quantity, shielding. Permissible norms of pollution of workplaces, overalls, hands, etc. Decontamination methods. Measures during emergencies. General principles of organization of agro-industrial production in the conditions of radioactive contamination of the territory. Measures to reduce the supply of radionuclides to agricultural plants: conventional and special, mechanical, agrotechnical, chemical, agrochemical and biological. Complex systems for reducing the inflow of radionuclides into plants: tillage, application of organic and mineral fertilizers, introduction of new crops into crop rotation, change of irrigation regime, introduction of special compounds into the soil. Methods of	1	4	5

		decontamination of crop products. Reduction of receipt and accumulation of radionuclides in the organism of farm animals. Basic rules of organization of fodder base. The use of chemicals to accelerate the excretion of radionuclides. Methods of decontamination of livestock products.			
		<i>Literature: 1-4, 8-12, 15, 17</i>			
3.2	Radiation and veterinary-sanitary examination of objects of veterinary control, use of ionizing radiation in animal husbandry and veterinary medicine	Regulations on radiological departments of state laboratories of veterinary medicine, laboratories of veterinary examination in the markets, laboratories of enterprises of meat and dairy industries. Tasks of radiometric control, sequence of stages of its performance. Objects of study, sampling and transmission rules. Radiometry of animal bodies. Express methods for determining the total beta activity. Gamma spectrometry. Evaluation of radiometric survey data. Dosimetric control and features of its carrying out. Radiochemical analysis, its purpose and tasks. Features of radiochemical analysis in determining the radioactivity of objects of veterinary control over the content of ⁹⁰ Sr, ¹³¹ I, ¹³⁷ Cs, ^{238,239,240} Pu. Radiation examination of veterinary control objects. Medical examination of animals after radiation injury. Veterinary-sanitary and radiometric examination of livestock products during external irradiation of animals and their destruction by incorporated radionuclides. The procedure for removal, disposal or utilization of products contaminated with radionuclides above the levels established by the National Commission for Radiation Protection of the Population of Ukraine. Execution and issuance of certificates based on the results of radiometric examination. Application of the method of labeled atoms during the study of the functional status of organs and systems of the organism. Radioimmunological method of analysis and its use in biochemistry, toxicology, microbiology, epizootology, virology, etc. Method of autoradiography. The use of biological action of ionizing radiation on plant and animal organisms in order to stimulate growth, development, productivity, change the hereditary properties of the organism. Possibilities of	2	4	5

		using ionizing radiation for canning of forages, products of animal origin, for sterilization of tools, dressings, leather raw materials, wool, containers, and also for destruction of harmful insects. The use of ionizing radiation in the diagnosis of diseases and treatment of animals, food, pharmacological industry and other sectors of the economy.			
		<i>Literature: 1, 5, 8, 10-12, 18</i>			
		Total:	15	30	75

4. Topics of seminars

№ s/n	Topic name	Number of hours
	not provided	

5. Topics of practical classes

№ s/n	Topic name	Number of hours
1	not provided	-

6. Topics of laboratory classes

№ s/n	Topic name	Number of hours
1	Hygienic regulations and basic rules of radiation safety (OSPU-2006; NRBU - 97)	4
2	Characteristics of ionizing radiation and their interaction with matter	2
3	Units of radioactivity and doses of ionizing radiation. Solve problems in the transition from non-system units to SI units	4
4	Methods for detecting ionizing radiation. Types of detectors	2
5	Methods and devices of radiometric and dosimetric control. Purpose, classification and structure of dosimetric devices	4
6	Practical dosimetry to determine the content of ^{137}Cs in the human body. Calculations of external and internal radiation doses.	2
7	Practical radiometry. Estimation of the degree of radioactive damage to the thyroid gland by radioactive iodine	4
8	Measurement of specific and bulk activity of β -emitting radionuclides on a Beta radiometer	4
9	Lifetime determination of ^{137}Cs content in animals and humans	4
	Total	30

7. Test questions, sets of tests to determine the level of knowledge acquisition by students.

National University of Life and Environmental Sciences of Ukraine				
Bachelor 3rd year study Specialty 211 « Veterinary Medicine »	Veterinary Medicine Department	Test № 1 from the course Veterinary Radiobiology	Approved Head of department <hr/>	
Questions				
1. Factors affecting the migration of radionuclides in the atmosphere.				
2. Definition of oxygen effect concept.				
Tests				
1.	Water has _____ action a) Radiosensitizing; b) Radioprotective; c) Both; d) There is no correct answer			
2.	What element has an antagonist with Cs? a) Sr; b) Ca; c) K; d) Pb			
3.	What phase of cell cycle is the most radiosensitive? a) S; b) G ₁ ; c) M; d) G ₂			
4.	Arrange the correct links on types of radionuclides distribution in animals (few radionuclide can respond to one type)			
	1	bone	a	Transuranic elements
	2	diffuse	b	Cs
	3	reticuloendothelium	c	Sr
			d	Rb
			e	Pu
5.	Critical tissue in plants are: a) phloem; b) xylem; c) meristem; d) parenchyma			
6.	Which of the natural potassium isotopes is radioactive? a) ³⁹ K; b) ⁴⁰ K; c) ⁴¹ K; d) ⁴² K			
7.	Among vertebrate animals, the highest radioresistance have: a) fishes; b) birds; c) mammals; d) reptile			
8.	A critical organ to ¹⁴ C is: a) eye lens; b) bone tissue; c) spleen; d) fatty tissue			
9.	To construct the survival curve is carried out: a) experiments in vacuum conditions; b) experiments on the neutralization of ionizing radiation; c) experiments with irradiation in different doses; d) experiments on irradiation in stimulating doses			
10.	What statements are correct for α-particles: a) Have '2-' charge; b) Consists of 2 protons and 2 neutrons; c) Is a nuclei of helium d) Is the most harmful for organism			

8. Teaching methods

The main form of knowledge control is to conduct modular tests and tests. Based on the results of modular tests, the main score is derived, which is translated into rating points. To them are added points for oral knowledge in each content module.

9. Forms of control

According to the "Regulations on examinations and assessments at the National University of Bioresources and Nature Management of Ukraine", approved by the academic council of the National University of Bioresources and Nature Management of Ukraine on April 26, 2023, protocol No. 10, the types of knowledge control of higher education students are current control, intermediate and final attestation.

Current control of the discipline is carried out during practicals, and aims to check the level of preparedness of higher education applicants to perform a specific job.

Intermediate attestation is conducted after studying the program material and should determine the level of knowledge of higher education students in the program material obtained during all types of classes and independent work.

Form of intermediate certification - testing,

The assimilation of the program material by the student of higher education is considered successful, if its rating is at least 60 points on a 100-point scale.

Semester certification is conducted in the form of a semester exam.

Applicants of higher education are required to take exams and tests in accordance with the requirements of the working curriculum within the time limits provided by the schedule of the educational process. The content of the exam is determined by the working curriculum of the discipline.

10. Distribution of points received by students

Assessment of student knowledge is on a 100-point scale and is translated into national assessments according to table. 1 "Regulations on examinations and tests in NULES of Ukraine" (order of entry into force from 26.04.2023)

Student rating, points	National assessment based on the results of the compilation of	
	exams	credits
90-100	Excellent	Passed
74-89	Good	
60-73	Satisfactory	
0-59	Unsatisfactory	Failed

To determine the rating of the student (listener) for mastering the discipline **Rdis** (up to 100 points) the obtained rating for attestation (up to 30 points) is added to the rating of the student (listener) for academic work **R aw** (up to 70 points): **Rdis = R aw + R a t.**

12. RECOMMENDED LITERATURE

1. Gudkov I. M. Radiobiology and Radioecology / I. M. Gudkov, M. M. Vinichuk. – K. : NAUU, 2006. – 295 p.
2. Choppin G. R., Liljenzin J.-O., Rydberg J. Radiochemistry and nuclear chemistry. 4th ed., Academic Press, 2013, 858 p.
3. Chernobyl: 30 Years of Radioactive Contamination Legacy. Report. Lead writer and coordination of report: Prof. Valerii Kashparov, Kyiv, 2016, 59 p.
4. Climate change and nuclear power. International Atomic Energy Agency, VIENNA, 2005, 112 p.
5. Natural and induced radioactivity in food. International Atomic Energy Agency, VIENNA, 2002, 136 p.
6. Gleyzes, C., Tellier, S. & Astruc, M. Fractionation studies of trace elements in contaminated soils and sediments: a review of sequential extraction procedures. Trac-Trends in Analytical Chemistry, 21 (6-7), 2002, p. 451-467.
7. International Atomic Energy Agency Safety Standards Series No. RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection for protecting people and the environment, Safety Guide, IAEA, VIENNA, 2005, p.119.
8. Radiation biology: a handbook for teachers and students. International Atomic Energy Agency, VIENNA, 2010, 150 p.
9. Гродзинський Д.М. Радіобіологія. – К.: Либідь, 2000. – 448 с.
10. Гудков І.М. Радіобіологія: підручник. – Херсон : Олді-Плюс, 2016. – 504 с.
11. Гудков І.М., Гайченко В.А., Кашпаров В.О. Сільськогосподарська радіоекологія: підручник. – К.: Ліра-К, 2017. – 268 с.
12. Кічно В.О., Поліщук С.В., Гудков І.М. Основи радіобіології та радіоекології. – К.: Хай-Тек Прес, 2008 (2009). – 316 с.
13. Моисеев А.А., Иванов В.И. Справочник по дозиметрии и радиационной гигиене. - М.: Энергоатомиздат, 1990. - 252с.
14. НРБУ-97/2000.
15. Пристер Б.С., Лоцилов Н.А., Немец О.Ф., В.А. Поярков. Основы сельскохозяйственной радиологии. - К.: -Урожай, 1991.- 472с.

Supporting literature

16. Хомутінін Ю.В., Кашпаров В.О., Жебровська К.І. Оптимізація відбору і вимірювань проб при радіоекологічному моніторингу, Монографія. – К.: Український науково–дослідний інститут сільськогосподарської радіології, 2002, 160 с.

17. Радиационный мониторинг облучения населения в отдаленный период после аварии на Чернобыльской АЭС, Рабочий Документ: ТС проект RER/9/074, Вена, Австрия, 2006, 81с.
18. Паренюк О.Ю., Ілленко В.В., Гудков І.М. Мікрофлора забруднених радіонуклідами ґрунтів. – К.: Вид-во НУБіП України, 2018. – 198 с.
19. Бондар О.І., Фещенко В.П., Гудков І.М., Гуреля В.В. Радіоекологічний термінологічний словник (україно-англійсько-російський). – Житомир: ПП Експертний центр Укрколбіокон, 2018. – 254 с.
20. Якість ґрунту. Методи відбору проб ґрунту для радіаційного контролю, СОУ 74.14-37-425:2006.
21. Якість ґрунту. Визначення щільності забруднення території сільськогосподарських угідь радіонуклідами техногенного походження, СОУ 74.14-37-424:2006
22. Якість продукції рослинництва. Методи відбору проб для радіаційного контролю, СОУ 01.1-37-426:2006.
23. Якість продукції тваринництва. методи відбору проб для радіаційного контролю, СОУ 01.2-37-427:2006.
24. Якість продукції тваринництва. Проведення прижиттєвого контролю тварин на територіях, забруднених радіонуклідами, СОУ 01.2-37-428:2006.

13. INFORMATION RESOURCES:

1. <https://www.iaea.org/publications>
2. https://web.archive.org/web/20110515164252/http://www-pub.iaea.org/MTCD/publications/PDF/INES-2009_web.pdf
3. <https://www.who.int/news/item/05-09-2005-chernobyl-the-true-scale-of-the-accident>
4. <https://www.iaea.org/newscenter/news/fukushima-nuclear-accident-update-log-15>
5. http://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_C.pdf
6. <https://www.wright.edu/sites/www.wright.edu/files/page/attachments/radiation-safety-biological-effects-of-ionizing-radiation.pdf>
7. <https://doi.org/10.1016/j.jenvrad.2008.12.013>
8. <https://doi.org/10.1007/978-3-319-22171-7>