Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное
образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

Инженерная школа ядерных технологий
Направление подготовки 14.04.02 Ядерные физика и технологии
Отделение ядерно-топливного цикла

БАКАЛАВРСКАЯ РАБОТА

Тема работы
Влияние высоты слоя инверсии на вертикальный профиль природных радионуклидов в атмосфере

УДК 539.163:551.510.4

Студент

Группа	ФИО	Подпись	Дата
0А7А	Урманов Аслан Русланович		

Руководитель ВКР

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОЯТЦ ИЯТШ	Яковлева Валентина Станиславовна	д.т.н		

Консультант

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Старший преподаватель ОЯТЦ ИЯТШ	Побережников Андрей Дмитриевич	-		

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОСГН ШИП	Гасанов Магеррам Али оглы	д.э.н.		

По разделу «Социальная ответственность»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОЯТЦ ИЯТШ	Передерин Юрий Владимирович	к.т.н.		

ДОПУСТИТЬ К ЗАЩИТЕ:

Руководитель ООП	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОЯТЦ ИЯТШ	Бычков Петр Николаевич	к.т.н.		

Томск – 2021 г.

TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное
образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

School of Nuclear Science & Engineering
Field of training (specialty): 14.04.02 Nuclear Science and Technology
Nuclear Fuel Cycle Division

BACHELOR WORK

Topic of research work
The influence of the inversion layer height on the vertical profile of natural radionuclides in the atmosphere

UDC 539.163:551.510.4

Student

Group	Full name	Signature	Date
0A7A	Aslan R. Urmanov		

Scientific supervisor

Position	Full name	Academic degree, academic rank	Signature	Date
Professor NFCD	Valentina S. Yakovleva	DSc Docent		

Adviser

Position	Full name	Academic degree, academic rank	Signature	Date
Senior Lecturer NFCD	Andrey D. Poberezhnikov	-		

ADVISERS:

Section “Financial Management, Resource Efficiency and Resource Saving”

Position	Full name	Academic degree, academic rank	Signature	Date
Professor DSSH	Maharram A. Hasanov	DSc		

Section “Social Responsibility”

Position	Full name	Academic degree, academic rank	Signature	Date
Docent NFCD	Yuri V. Perederin	PhD		

ADMITTED TO DEFENSE:

Position	Full name	Academic degree, academic rank	Signature	Date
Docent NFCD	Petr N. Bychkov	PhD		

Tomsk – 2021

ПЛАНИРУЕМЫЕ РЕЗУЛЬТАТЫ ОБУЧЕНИЯ ООП

Код результата	**Результат обучения (выпускник должен быть готов)**
	Общекультурные компетенции
P1	Демонстрировать культуру мышления, способность к обобщению, анализу, восприятию информации, постановке цели и выбору путей ее достижения; стремления к саморазвитию, повышению своей квалификации и мастерства; владение основными методами, способами и средствами получения, хранения, переработки информации, навыки работы с компьютером как средством управления информацией; способность работы с информацией в глобальных компьютерных сетях.
P2	Способность логически, верно, аргументировано и ясно строить устную и письменную речь; критически оценивать свои достоинства и недостатки, намечать пути и выбирать средства развития достоинств и устранения недостатков.
P3	Готовностью к кооперации с коллегами, работе в коллективе; к организации работы малых коллективов исполнителей, планированию работы персонала и фондов оплаты труда; генерировать организационно-управленческих решения в нестандартных ситуациях и нести за них ответственность; к разработке оперативных планов работы первичных производственных подразделений; осуществлению и анализу исследовательской и технологической деятельности как объекта управления.
P4	Умение использовать нормативные правовые документы в своей деятельности; использовать основные положения и методы социальных, гуманитарных и экономических наук при решении социальных и профессиональных задач, анализировать социально-значимые проблемы и процессы; осознавать социальную значимость своей будущей профессии, обладать высокой мотивацией к выполнению профессиональной деятельности.
P5	Владеть одним из иностранных языков на уровне не ниже разговорного.
P6	Владеть средствами самостоятельного, методически правильного использования методов физического воспитания и укрепления здоровья, готов к достижению должного уровня физической подготовленности для обеспечения полноценной социальной и профессиональной деятельности.

Код результата	Результат обучения (выпускник должен быть готов)
Профессиональные компетенции	
Р7	Использовать основные законы естественнонаучных дисциплин в профессиональной деятельности, применять методы математического анализа и моделирования, теоретического и экспериментального исследования.
Р8	Владеть основными методами защиты производственного персонала и населения от возможных последствий аварий, катастроф, стихийных бедствий; И быть готовым к оценке ядерной и радиационной безопасности, к оценке воздействия на окружающую среду, к контролю за соблюдением экологической безопасности, техники безопасности, норм и правил производственной санитарии, пожарной, радиационной и ядерной безопасности, норм охраны труда; к контролю соответствия разрабатываемых проектов и технической документации стандартам, техническим условиям, требованиям безопасности и другим нормативным документам; за соблюдением технологической дисциплины и обслуживанию технологического оборудования; и к организации защиты объектов интеллектуальной собственности и результатов исследований и разработок как коммерческой тайны предприятия; и понимать сущность и значение информации в развитии современного информационного общества, сознавать опасности и угрозы, возникающие в этом процессе, соблюдать основные требования информационной безопасности, в том числе защиты государственной тайны).
Р9	Уметь производить расчет и проектирование деталей и узлов приборов и установок в соответствии с техническим заданием с использованием стандартных средств автоматизации проектирования; разрабатывать проектную и рабочую техническую документацию, оформление законченных проектно-конструкторских работ; проводить предварительного технико-экономического обоснования проектных расчетов установок и приборов.
Р10	Готовность к эксплуатации современного физического оборудования и приборов, к освоению технологических процессов в ходе подготовки производства новых материалов, приборов, установок и систем; к наладке, настройке, регулировке и опытной проверке оборудования и программных средств; к монтажу, наладке, испытанию и сдаче в эксплуатацию опытных образцов приборов, установок, узлов, систем и деталей.

Код результата	Результат обучения (выпускник должен быть готов)
Р11	Способность к организации метрологического обеспечения технологических процессов, к использованию типовых методов контроля качества выпускаемой продукции; и к оценке инновационного потенциала новой продукции.
Р12	Способность использовать информационные технологии при разработке новых установок, материалов и приборов, к сбору и анализу информационных исходных данных для проектирования приборов и установок; технические средства для измерения основных параметров объектов исследования, к подготовке данных для составления обзоров, отчетов и научных публикаций; к составлению отчета по выполненному заданию, к участию во внедрении результатов исследований и разработок; и проведения математического моделирования процессов и объектов на базе стандартных пакетов автоматизированного проектирования и исследований.
Р13	Уметь готовить исходные данные для выбора и обоснования научно-технических и организационных решений на основе экономического анализа; использовать научно-техническую информацию, отечественный и зарубежный опыт по тематике исследования, современные компьютерные технологии и базы данных в своей предметной области; и выполнять работы по стандартизации и подготовке к сертификации технических средств, систем, процессов, оборудования и материалов.
Р14	Готовность к проведению физических экспериментов по заданной методике, составлению описания проводимых исследований и анализу результатов; анализу затрат и результатов деятельности производственных подразделений; к разработки способов применения ядерно-энергетических, плазменных, лазерных, СВЧ и мощных импульсных установок, электронных, нейтронных и протонных пучков, методов экспериментальной физики в решении технических, технологических и медицинских проблем.
Р15	Способность к приемке и освоению вводимого оборудования, составлению инструкций по эксплуатации оборудования и программ испытаний; к составлению технической документации (графиков работ, инструкций, планов, смет, заявок на материалы, оборудование), а также установленной отчетности по утвержденным формам; и к организации рабочих мест, их техническому оснащению, размещению технологического оборудования.

PLANNED OOP LEARNING OUTCOMES

Result code	Learning Outcome (graduate have to be ready)
General cultural competences	
R1	Demonstrate a culture of thinking, the ability to generalize, analyze, perceive information, set a goal and choose ways to achieve it; striving for self-development, improving their qualifications and skills; possession of the basic methods, methods and means of obtaining, storing, processing information, skills of working with a computer as a means of information management; ability to work with information in global computer networks.
R2	Ability to logically, correctly, reasonably and clearly construct oral and written speech; critically assess their strengths and weaknesses, outline ways and choose means of developing strengths and eliminating weaknesses.
R3	Willingness to cooperate with colleagues, work in a team; to organizing the work of small teams of performers, planning the work of personnel and payroll funds; generate organizational and managerial solutions in non-standard situations and be responsible for them; to the development of operational plans for the work of primary production units; implementation and analysis of research and technological activities as an object of management.
R4	Ability to use regulatory legal documents in their activities; use the main provisions and methods of social, humanitarian and economic sciences in solving social and professional problems, analyze socially significant problems and processes; to be aware of the social significance of their future profession, to be highly motivated to carry out professional activities.
R5	Know one of the foreign languages at a level not lower than the spoken one.
R6	To own the means of independent, methodologically correct use of methods of physical education and health promotion, is ready to achieve the proper level of physical fitness to ensure full-fledged social and professional activity.

Result code	Learning Outcome (graduate have to be ready)
Professional competence	
R7	Use the basic laws of natural sciences in professional activities, apply the methods of mathematical analysis and modeling, theoretical and experimental research.
R8	Possess the basic methods of protecting production personnel and the population from the possible consequences of accidents, catastrophes, natural disasters; And be ready to assess nuclear and radiation safety, to assess the impact on the environment, to monitor compliance with environmental safety, safety, norms and rules of industrial sanitation, fire, radiation and nuclear safety, labor protection standards; to control the compliance of developed projects and technical documentation with standards, technical conditions, safety requirements and other regulatory documents; observance of technological discipline and maintenance of technological equipment; and to the organization of protection of intellectual property objects and the results of research and development as a commercial secret of the enterprise; and to understand the essence and significance of information in the development of a modern information society, to be aware of the dangers and threats arising in this process, to comply with the basic requirements of information security, including the protection of state secrets).
R9	To be able to calculate and design parts and assemblies of devices and installations in accordance with the terms of reference using standard design automation tools; to develop design and working technical documentation, registration of completed design and engineering works; to carry out a preliminary feasibility study of design calculations for installations and devices.
R10	Readiness for the operation of modern physical equipment and devices, for the development of technological processes in the course of preparing the production of new materials, devices, installations and systems; to commissioning, tuning, adjustment and experimental testing of equipment and software; for installation, commissioning, testing and commissioning of prototypes of devices, installations, assemblies, systems and parts.

Result code	Learning Outcome (graduate have to be ready)
R11	Ability to organize metrological support of technological processes, to use standard methods of quality control of manufactured products; and to assess the innovative potential of new products.
R12	The ability to use information technology in the development of new installations, materials and devices, to collect and analyze information source data for the design of devices and installations; technical means for measuring the main parameters of research objects, for preparing data for compiling reviews, reports and scientific publications; to prepare a report on the completed assignment, to participate in the implementation of research and development results; and carrying out mathematical modeling of processes and objects on the basis of standard computer-aided design and research packages.
R13	To be able to prepare initial data for the selection and justification of scientific, technical and organizational decisions based on economic analysis; to use scientific and technical information, domestic and foreign experience on the research topic, modern computer technologies and databases in their subject area; and carry out work on standardization and preparation for certification of technical means, systems, processes, equipment and materials.
R14	Willingness to conduct physical experiments according to a given methodology, compilation of a description of the research being carried out and analysis of the results; analysis of costs and results of activities of production units; to the development of methods for using nuclear energy, plasma, laser, microwave and powerful pulsed installations, electronic, neutron and proton beams, methods of experimental physics in solving technical, technological and medical problems.
R15	Ability to accept and master the equipment to be introduced, to draw up instructions for the operation of equipment and test programs; to the preparation of technical documentation (work schedules, instructions, plans, estimates, applications for materials, equipment), as well as established reporting on approved forms; and to the organization of workplaces, their technical equipment, the placement of technological equipment.

TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
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образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

Школа _________________________инженерная школа ядерных технологий____________
Направление подготовки ________14.03.02 Ядерные физика и технологии_____________
Отделение школы _____________отделение ядерно-топливного цикла________________

УТВЕРЖДАЮ:
Руководитель ООП
_____ _______ Бычков П.Н.
(Подпись) (Дата) (Ф.И.О.)

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

В форме:

бакалаврской работы

Студенту:

Группа	ФИО
0А7А	Урманов Аслан Русланович

Тема работы:

Влияние высоты слоя инверсии на вертикальный профиль природных радионуклидов в атмосфере	
Утверждена приказом директора (дата, номер)	28.04.2021 г. , №118-33/с

Срок сдачи студентом выполненной работы:	09.06.2021

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе	Экспериментальные данные по атмосферной альфа-радиоактивности, экспериментальные данные по метеорологическим величинам.

Перечень подлежащих исследованию, проектированию и разработке вопросов	- обзор литературных источников - Приборы и методы измерения объемной активности ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn - Моделирование вертикального переноса радионуклидов ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn в атмосфере при различных метеорологических условиях - Исследование влияния высоты слоя инверсии на вертикальный профиль природных радионуклидов в атмосфере - анализ полученных результатов; - финансовый менеджмент, ресурсоэффективность и ресурсосбережение; - социальная ответственность; - заключение по работе.
Перечень графического материала	- сборочный чертеж радиометра «Альфарад»

Консультанты по разделам выпускной квалификационной работы	
Раздел	**Консультант**
Социальная ответственность	Передерин Юрий Владимирович
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	Гасанов Магеррам Али оглы

Дата выдачи задания на выполнение выпускной квалификационной работы по линейному графику	26.04.2021

Задание выдал руководитель / консультант (при наличии):

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОТЯЦ ИЯТШ	Яковлева Валентина Станиславовна	д.т.н.		
Старший преподаватель ОЯТЦ ИЯТШ	Побережников Андрей Дмитриевич	-		

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А7А	Урманов Аслан Русланович		

TOMSK POLYTECHNIC UNIVERSITY

ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное
образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

School of Nuclear Science & Engineering
Field of training (specialty): 14.04.02 Nuclear Science and Technology
Nuclear Fuel Cycle Division

APPROVED BY:
Program Director
___________ Bychkov P.N.
«____» ____________ 2021

ASSIGNMENT
for the Graduation Thesis completion

In the form:

Bachelor work

For a student:

Group	Full name
0A7A	Aslan R. Urmanov

Topic of research work:

The influence of the inversion layer height on the vertical profile of natural radionuclides in the atmosphere	
Approved by the order of the Director of School of Nuclear Science & Engineering (date, number):	28.04.2021 г., №118-33/с

Deadline for completion of bachelor work:	09.06.2021

TERMS OF REFERENCE:

Initial date for research work	Experimental data on atmospheric alpha radioactivity, experimental data on meteorological values.
List of the issues to be investigated, designed and developed	- review of literary sources - Instruments and methods for measuring the volumetric activity of ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn - Modeling of vertical transport of radionuclides ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn in the atmosphere under various meteorological conditions - Study of the influence of the height of the inversion layer on the vertical profile of natural radionuclides in the atmosphere - analysis of the results obtained; - financial management, resource efficiency and resource conservation; - social responsibility;

	- conclusion on the work.
List of graphic material	Presentation of research

Date of issuance of the assignment for bachelor work completion according to the schedule	26.04.2021

Assignment issued by a scientific supervisor / advisor (if any):

Position	Full name	Academic degree, academic status	Signature	Date
Professor NFCD	Valentina S. Yakovleva	DSc Associate professor		
Senior Lecturer NFCD	Andrey D. Poberezhnikov	-		

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0A7A	Aslan R. Urmanov		

Министерство науки и высшего образования Российской Федерации
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образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

Школа инженерная школа ядерных технологий
Направление подготовки 14.03.02 Ядерные физика и технологии
Уровень образования бакалавриат
Отделение школы отделение ядерно-топливного цикла
Период выполнения весенний семестр 2020 /2021 учебного года

Форма представления работы:

бакалаврская работа

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Срок сдачи студентом выполненной работы:	09.06.2021

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
10.05.2021	Обзор литературных источников	10
24.05.2021	Приборы и методы измерения объемной активности ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn	10
25.05.2021	Моделирование вертикального переноса радионуклидов ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn в атмосфере при различных метеорологических условиях	10
25.05.2021	Исследование влияния турбулентности на вертикальный профиль радионуклидов в атмосфере	15
26.05.2021	Исследование влияния высоты слоя инверсии на вертикальный профиль природных радионуклидов в атмосфере	15
27.05.2021	Анализ полученных результатов	10
04.06.2021	Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	10
04.06.2021	Социальная ответственность	10
08.06.2021	Заключение по работе	10

СОСТАВИЛ:
Руководитель ВКР

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОТЯЦ ИЯТШ	Яковлева Валентина Станиславовна	д.т.н.		

Консультант

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Старший преподаватель	Побережников Андрей Дмитриевич	-		

СОГЛАСОВАНО:

Руководитель ООП

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОЯТЦ	Бычков П.Н.	к.т.н.		

TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное
образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

School of Nuclear Science & Engineering
Field of training (specialty): 14.04.02 Nuclear Science and Technology
Level of education: Bachelor degree program
Nuclear Fuel Cycle Division
Period of completion: spring semester 2020/2021 academic year

Form of presenting the work:

Bachelor work

SCHEDULED ASSESSMENT CALENDAR
for the bachelor work completion

Deadline for completion of bachelor work:	09.06.2021

Assessment date	Title of section (module) / type of work (research)	Maximum score for the section (module)
10.05.2021	Review of literary sources	10
24.05.2021	Instruments and methods for measuring the volumetric activity of ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn	10
25.05.2021	Study of the effect of turbulence on the vertical profile of radionuclides in the atmosphere	10
25.05.2021	Modeling the vertical transport of radionuclides ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{220}Tn in the atmosphere under various meteorological conditions	15
26.05.2021	Study of the influence of the inversion layer height on the vertical profile of natural radionuclides in the atmosphere	15
27.05.2021	Analysis of the obtained results	10
04.06.2021	Financial management, resource efficiency and resource saving	10
04.06.2021	Social responsibility	10
08.06.2021	Conclusion	10

COMPILED BY:
Scientific supervisor:

Position	Full name	Academic degree, academic status	Signature	Date
Professor NFCD	Valentina S. Yakovleva	DSc Associate professor		

Adviser

Position	Full name	Academic degree, academic rank	Signature	Date
Senior Lecturer NFCD	Andrey D. Poberezhnikov	-		

APPROVED BY:

Position	Full name	Academic degree, academic rank	Signature	Date
Associate professor NFCD	Petr N. Bychkov	PhD		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

Группа	ФИО
0А7А	Урманову Аслану Руслановичу

Школа	ИЯТШ	Отделение школы (НОЦ)	ЯТЦ
Уровень образования	бакалавр	Направление/специальность	14.03.02 Ядерные физика и технологии/ Радиационная безопасность окружающей среды

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. Стоимость ресурсов научного исследования (НИ): материально-технических, энергетических, финансовых, информационных и человеческих	Расчет стоимости материалов Накладные расходы
2. Нормы и нормативы расходования ресурсов	Нормы и нормативы расходования отсутствуют
3. Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования	Коэффициент отчислений во внебюджетные фонды –30% от ФОТ
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. Оценка коммерческого потенциала, перспективности и альтернатив проведения НИ с позиции ресурсоэффективности и ресурсосбережения	Определены потенциальные потребители результатов НТИ Проведен анализ конкурентных технических решений и SWOT-анализ
2. Планирование и формирование бюджета научных исследований	Разработан план проекта Определены бюджет и риски проекта
3. Определение ресурсной (ресурсосберегающей), финансовой, бюджетной, социальной и экономической эффективности исследования	Проведена оценка сравнительной эффективности исследования
Перечень графического материала (с точным указанием обязательных чертежей)**:**	
1. Оценка конкурентоспособности технических решений 2. Матрица SWOT 3. График проведения и бюджет НИ 4. Оценка ресурсной, финансовой и экономической эффективности НИ	

Дата выдачи задания для раздела по линейному графику	

Задание выдал консультант:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОСГН ШИП	Гасанов Магеррам Али оглы	д.э.н.		

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата

0A7A	Урманов Аслан Русланович		

TASK FOR SECTION
"FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING"

For a student:

Group	Full name
0A7A	Aslan R. Urmanov

School	ISNT	**School department (REC)**	NFC
The level of education	bachelor	**Direction / specialty**	14.03.02 Nuclear physics and technology/ Radiation safety of the environment

Initial data for the section "Financial Management, Resource Efficiency and Resource Saving":	
1. The cost of scientific research resources (SR): material and technical, energy, financial, informational and human	Calculation of the cost of materials Overheads
2. Norms and norms of resource consumption	There are no norms and standards for spending
3. The used system of taxation, rates of taxes, deductions, discounting and crediting	The rate of deductions to extra-budgetary funds is 30%.
List of questions to be researched, designed and developed:	
1. Assessment of the commercial potential, prospects and alternatives of conducting research from the standpoint of resource efficiency and resource conservation	Potential consumers of STI results identified Analysis of competitive technical solutions and SWOT analysis
2. Planning and budgeting of scientific research	Project plan developed The budget and risks of the project are determined
3. Determination of resource (resource-saving), financial, budgetary, social and economic efficiency of the research	The comparative effectiveness of the study was assessed
List of graphic material (with exact indication of the required drawings):	
1. Assessment of the competitiveness of technical solutions *2*. SWOT Matrix *3*. Schedule and budget of scientific research *4*. Assessment of the resource, financial and economic efficiency of scientific research	

Date of issuance of the task according to the schedule	

Assignment issued by an advisor:

Position	Full name	Academic degree, academic rank	Signature	Date
Professor DSSH	Maharram A. Hasanov	DSc		

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0A7A	Aslan R. Urmanov		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Студенту:

Группа	ФИО
0А7А	Урманову Аслану Руслановичу

Школа	ИЯТШ	Отделение школы (НОЦ)	ЯТЦ
Уровень образования	Бакалавриат	Направление/специальность	14.03.02 Ядерные физика и технологии/ Радиационная безопасность человека и окружающей среды

Исходные данные к разделу «Социальная ответственность»:	
1. *Описание рабочего места (рабочей зоны) на предмет возникновения:*	– вредных факторов производственной среды: повышенный уровень электромагнитных полей, отклонение показателей микроклимата от оптимальных, ионизирующее излучение, шум, вибрация. – опасных факторов производственной среды: вероятность возникновения пожара, вероятность поражения электрическим током.
2. *Знакомство и отбор законодательных и нормативных документов по теме*	– электробезопасность; – пожаровзрывобезопасность; – требования охраны труда при работе на ПЭВМ;
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. *Анализ выявленных вредных факторов проектируемой производственной среды в следующей последовательности:*	– действие фактора на организм человека; – приведение допустимых норм с необходимой размерностью (со ссылкой на соответствующий нормативно-технический документ); – предлагаемые средства защиты (коллективные и индивидуальные).
2. *Анализ выявленных опасных факторов проектируемой произведённой среды в следующей последовательности:*	– электробезопасность (в т.ч. статическое электричество, средства защиты); – пожаровзрывобезопасность (причины, профилактические мероприятия, первичные средства пожаротушения).

Дата выдачи задания для раздела по линейному графику	

Задание выдал консультант:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОЯТЦ ИЯТШ	Передерин Юрий Владимирович	к.т.н.		

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А7А	Урманов Аслан Русланович		

TASK FOR SECTION
"SOCIAL RESPONSIBILITY"

For a student:

Group	Full name
0A7A	Aslan R. Urmanov

School	ISNT	**School department (REC)**	NFC
The level of education	bachelor	**Direction / specialty**	14.03.02 Nuclear physics and technology/ Radiation safety of the environment

Initial data for the section "Social responsibility":	
3. Description of the workplace (working area) for the occurrence of:	– harmful factors of the working environment: increased level of electromagnetic fields, deviation of microclimate indicators from optimal ones, ionizing radiation, noise, vibration. – hazardous factors of the working environment: the likelihood of a fire, the likelihood of electric shock.
4. Acquaintance and selection of legislative and regulatory documents on the topic	– *electrical safety;* – *fire and explosion safety;* – *labor protection requirements when working on a PC;*
List of questions to be researched, designed and developed:	
3. Analysis of the identified harmful factors of the projected production environment in the following sequence:	– the effect of the factor on the human body; – bringing the permissible norms with the required dimension (with reference to the corresponding normative and technical document); – suggested remedies (collective and individual).
4. Analysis of the identified hazards of the designed manufactured environment in the following sequence:	– electrical safety (including static electricity, protective equipment); – fire and explosion safety (reasons, preventive measures, primary fire extinguishing means).

Date of issuance of the task according to the schedule	

Assignment issued by an advisor:

Position	Full name	Academic degree, academic rank	Signature	Date
Docent NFCD	Yuriy V. Perederin	PhD		

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0A7A	Aslan R. Urmanov		

Essay

The final qualifying work contains 111 pages, 47 figures, 17 tables, 26 sources of literature. Key words: radon, thoron, volumetric activity, atmosphere, turbulence. The object of research is the volumetric activity of radon in the surface atmosphere. The aim of this work is to investigate the influence of turbulence on the characteristics of the radon field. In the course of the study, the spatial (in the vertical direction) and temporal dynamics of the volumetric activity of radon formed in the surface atmosphere at different altitudes was simulated. The influence of the height of the inversion layer, the vertical component of the wind speed and turbulent processes on the vertical profile of natural radionuclides in the atmosphere in different seasons of the year, taking into account different meteorological conditions, has been numerically investigated. Turbulence is presented in the form of a constant coefficient, a linear function of altitude, a power function and a periodic function with a frequency of changing extremes of 12 hours. Comparison of the simulation results and experimental data on the dynamics of the volumetric activity of radon in the atmosphere showed good agreement.

Symbols and abbreviations

DPR - Daughter products of the decay of OA - Volumetric activity

EEVA - Equivalent equilibrium volumetric activity

AI - Ionizing radiation

PP - flux density

IMCES - Institute for Monitoring Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences

Table of contents

Introduction

Historically, atmospheric stability has usually been assessed using conventional or specialized near-surface meteorological observations. Such methods include: the Pasquill-Gifford model, the Monin-Obukhov theory, etc. Such methods differ in terms of their complexity, the required maintenance of instruments, accuracy and cost. A less traditional but relatively economical method for classifying the stability of the atmosphere, which has recently become popular, is based on surface measurements of the concentration of radon in the atmosphere.

Radon (Rn^{222}) is a radioactive gas that is a member of the decay chain of uranium (U^{238}). It is formed from the decay of radium (Ra^{226}), which is ubiquitous throughout the earth's crust. Being an inert gas, radon does not enter into a chemical reaction with other components of the atmosphere, and its low solubility makes it unlikely to be washed out by rainfall, so its main atmospheric runoff is radioactive decay. After being released into the atmosphere, radon is directly influenced by meteorological processes that regulate turbulent mixing, namely, the vertical and horizontal scattering components. Its half-life, conveniently located between the time frames of diurnal and synoptic events, is ideal for characterizing a wide range of meteorological phenomena. Together, these characteristics make radon a unique and powerful indicator of atmospheric stability [1].

Radon monitoring is important for solving applied problems in various fields of radioecology, geodynamics, and other sciences. Based on the foregoing, we can conclude that it is necessary to develop transport models in various environments and systems. Hence the relevance of this work follows.

In connection with the relevance of the work, goals and objectives were identified.

Purpose of the work: To study the effect of the inversion layer height on the characteristics of the radon field.

Tasks:

1. Analysis of the literature on the research topic.

2. Modeling of vertical transport of radionuclides ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, 220Tn in the atmosphere under various meteorological conditions.

3. Study of the influence of the inversion layer height on the vertical profile of natural radionuclides in the atmosphere.

4. Analysis of the results and conclusions.

Chapter 1. Literature review

1.1 Radon transport in "soil - atmosphere" system

According to the classical concept in the theory of the emanation method, four stages of the transfer of Rn in the "soil - atmosphere" system can be distinguished [2]:

– first stage: Rn is released (emanated) from the crystal lattice of minerals into small pores of the soil (the fraction of released Rn is characterized by the emanation coefficient;

– second stage: molecular diffusion propagation of Rn in small soil pores, the process continues until the radionuclide enters larger soil pores;

– third stage: diffusion-convective transfer of Rn occurs along large pores and cracks in the soil, then it is drained into the atmosphere;

– fourth stage: in the surface layer of the atmosphere, the role of molecular diffusion decreases, but the role of turbulent diffusion increases, which is caused by the temperature gradient of the surface atmosphere, as well as the speed and direction of the wind.

Figure 1 schematically shows the stages of the migration process in the soil-atmosphere system in the aeration zone (the upper part of the earth's crust, located above the groundwater level [3]), where it is also reflected that the transfer of Rn in the soil-atmosphere system in the zone aeration is carried out using two main processes - molecular diffusion and advection.

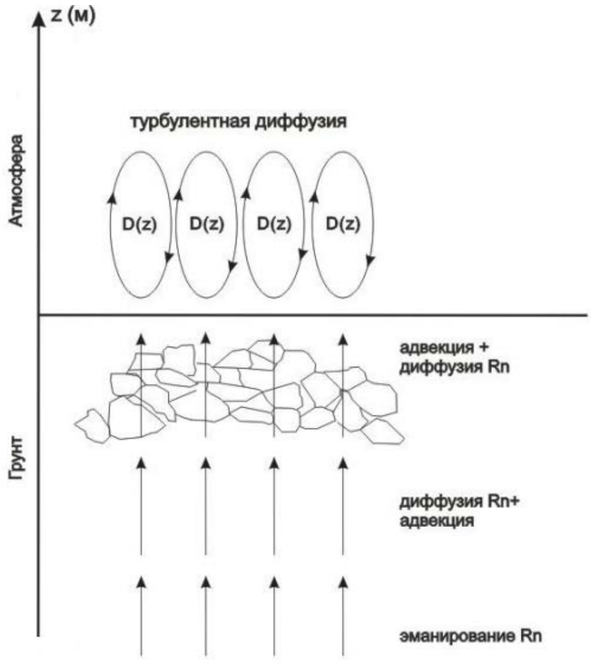


Figure 1 - Generalized scheme of radon transport in the "soil-atmosphere" system using the mechanisms of diffusion, advection and turbulent diffusion

The first process is the spread of gas molecules in the pore space of the soil, equalizes the concentration of Rn in all parts of the rock volume. The second process is characterized by the vertical movement of gas molecules through the pores as a result of heat exchange (convection), pressure variations (filtration), as well as the emergence of microbubbles in the zone of complete moisture saturation. Hence, it can be seen that the process of migration of Rn in loose sediments is strongly influenced by the permeability of the soil, which depends on its properties and structure, the presence of aquifers and changes in the stress-strain state of the geomedium. [4].

The atmosphere is almost always in a turbulent state, which is associated with the emerging contrasts in the wind field and in the temperature field. In the general case, turbulence of the atmosphere is called random vortex movements of small air masses (clusters of molecules), continuously changing in composition, which cause the mixing of horizontal air layers and contributes to an increase in the homogeneity of the atmosphere.

When classifying turbulence, they usually take into account not the causes of its occurrence, but the features of development, and distinguish mechanical (orographic), thermal (convective) and dynamic turbulence. Mechanical turbulence is a function of the wind speed at the Earth's surface and the roughness of the Earth's surface. Thermal turbulence is formed due to uneven heating of the earth's surface or when cold air advects onto a warm underlying surface. Dynamic turbulence occurs in the atmosphere in layers where large vertical and horizontal wind and temperature gradients are observed, as a result of which gravitational and gravity-shear waves are formed, which, under certain conditions, can collapse and turn into turbulent eddies of a smaller scale. In the surface layer, atmospheric turbulence decreases sharply as it approaches the earth's surface, the size of the vortices and the air masses carried by them decrease [5].

1.2 Daily variations of radon

In work [6], the National Laboratory for Atmospheric Research, located in rural areas in Gadanki, southern India, analyzed for the first time one-year measurements of radon (^{222}Rn) in situ and its DDP, as well as surface air temperature, relative humidity and pressure near the earth's surface. It was noticed that within 24 hours the activity of radon and its descendants reaches a peak in the morning hours, after which there is a significant decrease in the daytime. Diurnal variations in the activity of radon and its DDP, along with the temperature on February 23, 2012, are shown in Figures 2 and 3, respectively.

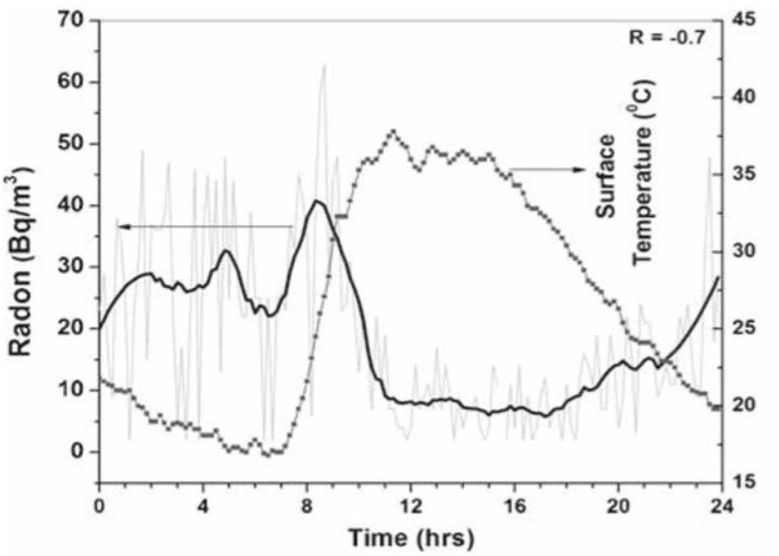


Figure 2 - Daily variations in hourly mean radon concentrations

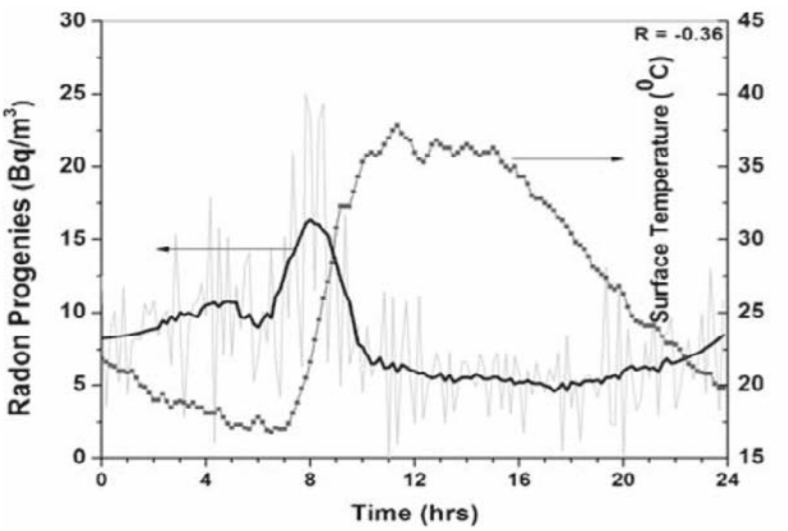


Figure 3 - Daily variations in the activity of radon DDP

From the figures presented, it can be concluded that concentrations show highs in the early morning hours, usually between 06:00 and 08:30 hours, and decrease after sunrise, reaching lows in the afternoon, around 14: 00-16: 00 hours. The radon concentration varied from 2 to 65 Bq/m^{-3}, which indicates a significant daily change by almost 33 times, while the values of DDP of radon ranged from 2 to 25 Bq/m^{-3}. The in situ daily radon cycle is caused by soil radiation and atmospheric dynamics (primarily small-scale vertical mixing), so when the atmosphere is stable (mostly at night), radon accumulates on the surface [7].

At SMEAR II station (Finland) [8], clear daily cycles in the median radon concentration based on 10-minute data were identified in all seasons, except for winter, the results are shown in Figure 4.

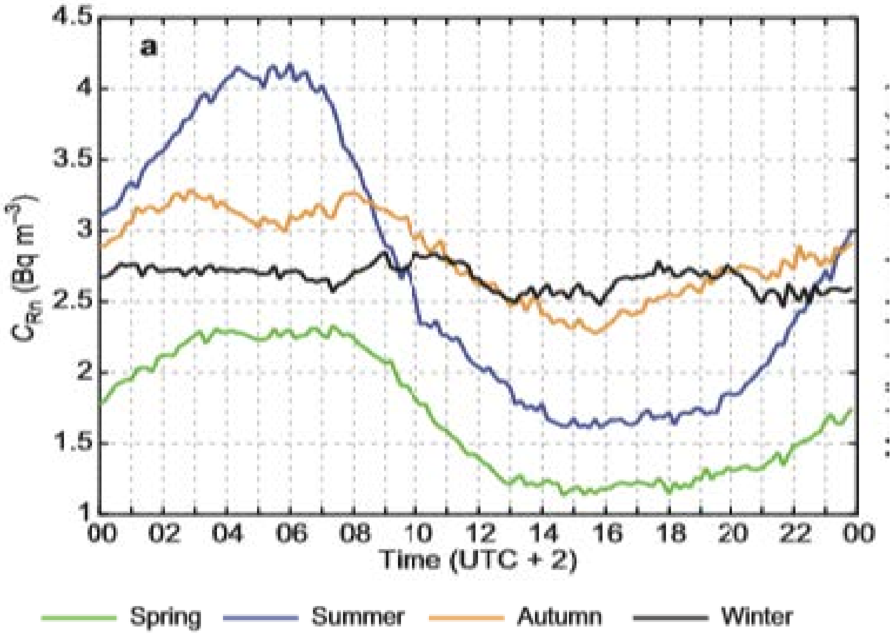


Figure 4 - Diurnal variations in different seasons in median radon concentrations (C_{Rn}) at a resolution of 10 minutes in 2000-2006

The largest amplitude of the diurnal variation was observed in summer (June-August) with the maximum median radon concentration at about 06:00 and a minimum at about 16:00. Comparable daily mean atmospheric concentrations of ^{222}Rn were observed in other seasonal.

1.3 Seasonal features of radon

The daily changes in the ^{222}Rn concentration in the surface atmosphere over Krakow and Heidelberg, averaged separately for each hour of the day during the entire observation period (January 2005 - December 2009) and for each season (spring, summer, autumn, winter), are summarized by Figures 5 and 6, respectively [9].

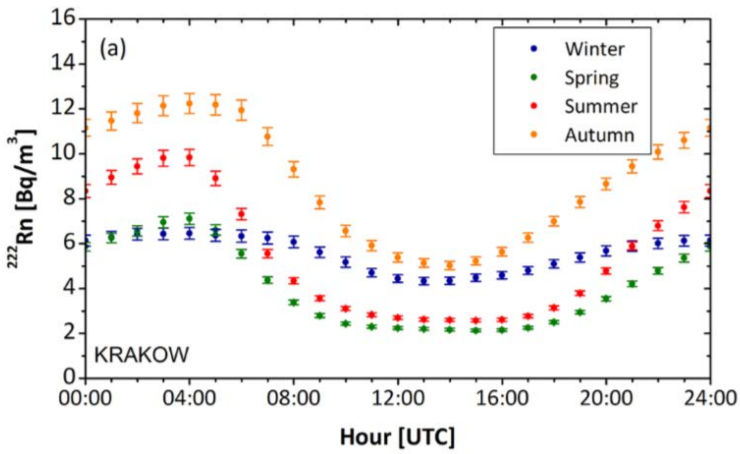


Figure 5 - Daily variations in the concentration of ^{222}Rn in the surface atmosphere over Krakow from January 2005 to December 2009 averaged over each hour and four seasons: winter (DJF), spring (MAM), summer (JJA) and autumn (SON)

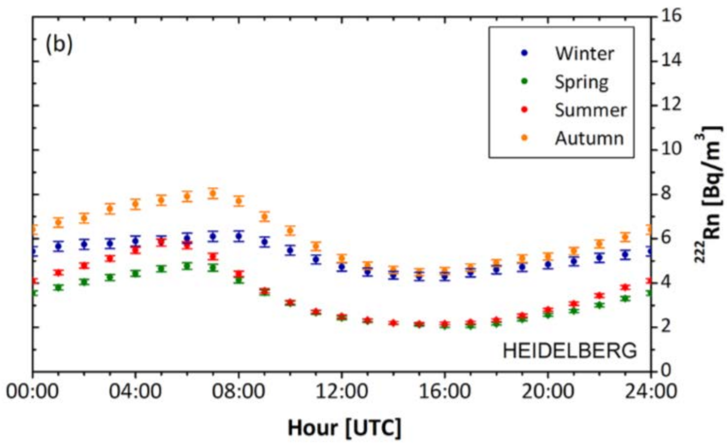


Figure 6 - Daily variations in the concentration of ^{222}Rn in the surface atmosphere over Heidelberg in the period from January 2005 to December 2009

averaged over each hour and four seasons: winter (DJF), spring (MAM), summer (JJA) and autumn (SON)

The shape and amplitude of the daily change in ^{222}Rn content differ significantly by season and place of observation. During the winter months (December-February), the diurnal variations of ^{222}Rn are remarkably similar in both locations. In the spring and summer months (March-May and June-August, respectively), the amplitude of daily changes in the ^{222}Rn concentration increases to a maximum. This increase is especially pronounced in Krakow (spring and summer amplitudes reach 4.7 and 7.0 Bq/m^{-3}, respectively) compared to Heidelberg (2.5 and 3.5 Bq/m^{-3}, respectively). At the same time, broader daily minima are observed in both areas, reflecting the increasing role of vertical mixing in PBL, due to the longer exposure of the surface to sunlight. The most pronounced differences between both sites are observed in the autumn months (September-November).

A strong seasonal cycle manifests itself in observed radon concentrations, with peaks in the winter months when wider atmospheric masses are observed reaching Cape Point from the African continental surface, and lows during the summer months when the ocean sample is dominant.

From seasonal comparison, the radon concentration over time in Gosan shows repeated seasonal variability. The results are shown in Figure 7. [10].

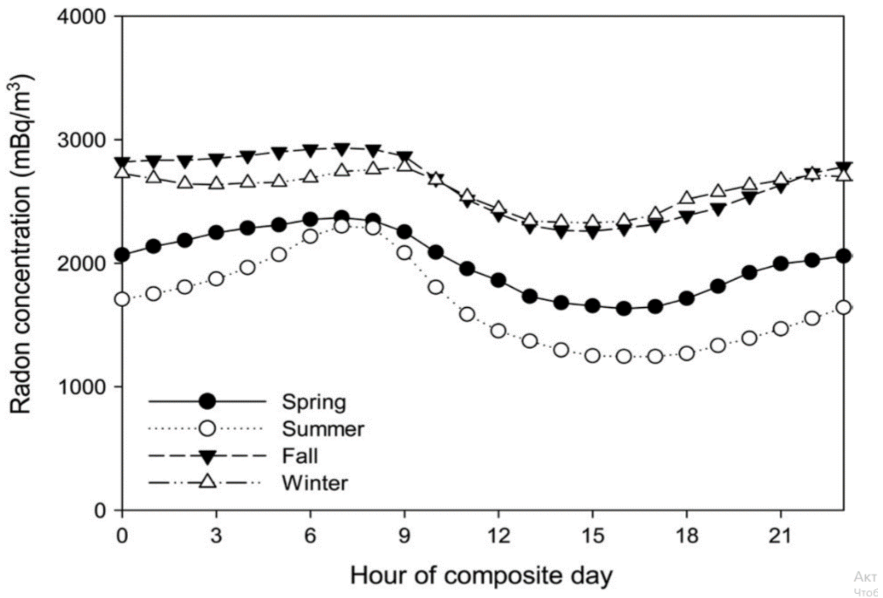


Figure 7 - Daily graph of hourly radon concentrations by season at Gosan station

Seasonal average radon concentrations were in the order of falling (2644 mBq/m^{-3}) ≈ winter (2612 mBq/m^{-3})> spring (2022 mBq/m^{-3})> summer (1666 mBk/m^{-3}). The seasonal cycle of radon was characterized by a winter maximum and a summer minimum, consistent with a reduction in the earth's intake from winter to summer. Seasonal changes in the concentration of radon in Gosan, as a rule, are caused by the variability of the monsoons in the direction of the wind. During the winter monsoon, the air flow in the lower atmosphere is directed from the north and west; the opposite happens in summer. In Gosan, the seasonal value of radon concentration indicates the potential for impact on large-scale terrestrial sources, while during the daytime radon concentrations respond to varying local mixing depth. During winter monsoons, regional air mass flow is usually northwestward to the north on Jeju Island. Although it is monsoon throughout the summer, regional flow is often in the southeast and wind speeds are about half of their winter values. In summer, the amplitude of the daily radon cycle is usually much higher than the daily average, which indicates that, on average, significant sea influence was observed at mixing depths in Gosan. However, the amplitude of the daily radon cycle and the mixing depth in Gosan in spring and autumn lies between the winter and summer extremes.

1.4 Annual changes

Hourly atmospheric radon concentrations were measured at Gosan station using a real-time radon detector system for two years during 2013-2014. Hourly radial time series for this study period are presented in Figure 8 [10].

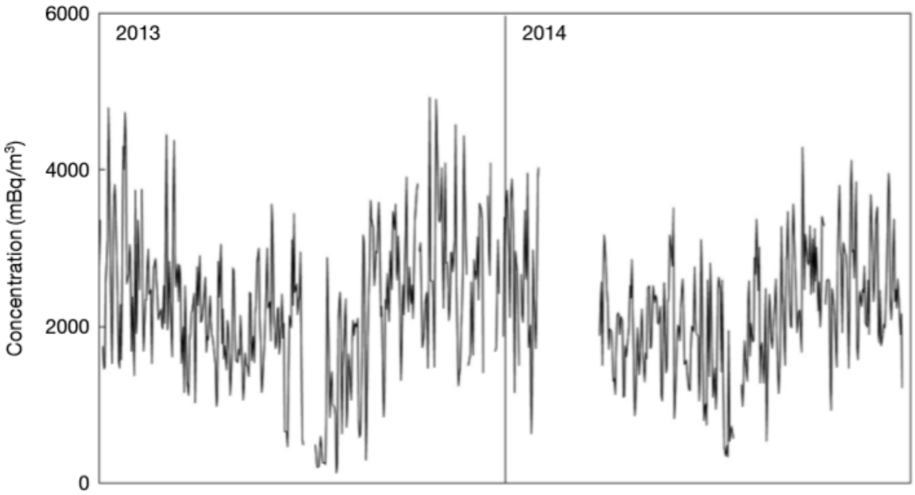


Figure 7 - Annual variation of atmospheric radon concentrations over time series measured at Gosan station in 2013-2014.

In this study, the hourly and daily mean radon concentrations were 2216 ± 1100 mBq/m^{-3} and 2226 ± 859 mBq/m^{-3}, respectively.

As shown in the case of annual changes, Toaca station (Romania), located in higher mountainous concentrations corresponding to the A2 and A3 aspirations, can be explained by the transfer of air mass by thermal convection from low-lying areas, characterized by higher concentrations of DDP of radon. The results are shown in Figure 8.

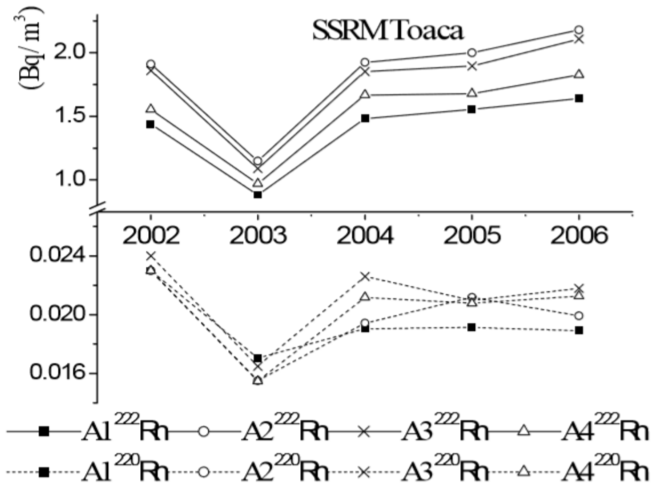


Figure 8 - Annual dynamics of the concentration of ^{222}Rn and ^{220}Rn DDP for aspirations

From the analysis of the average annual concentration of ^{222}Rn and ^{220}Rn DDP obtained at the station in 2002-2006, it can be seen that the average annual DDP of radon and thoron in the daytime (aspirations A2 and A3) are lower than the results obtained in aspirations of the night (aspirations A1 and A4). The physical explanation for these changes is that during the daytime, turbulent diffusion is enhanced by an increased temperature specific planetary boundary layer, and atmospheric stability at night is more pronounced due to thermal inversions and a calm atmosphere.

1.5. Influencing factors

Atmospheric concentrations of radon gas (^{222}Rn) were continuously monitored every four hours at ground level in the city of Jeddah, Kingdom of Saudi Arabia [11] and the results are presented in Figures 9 and 10, respectively.

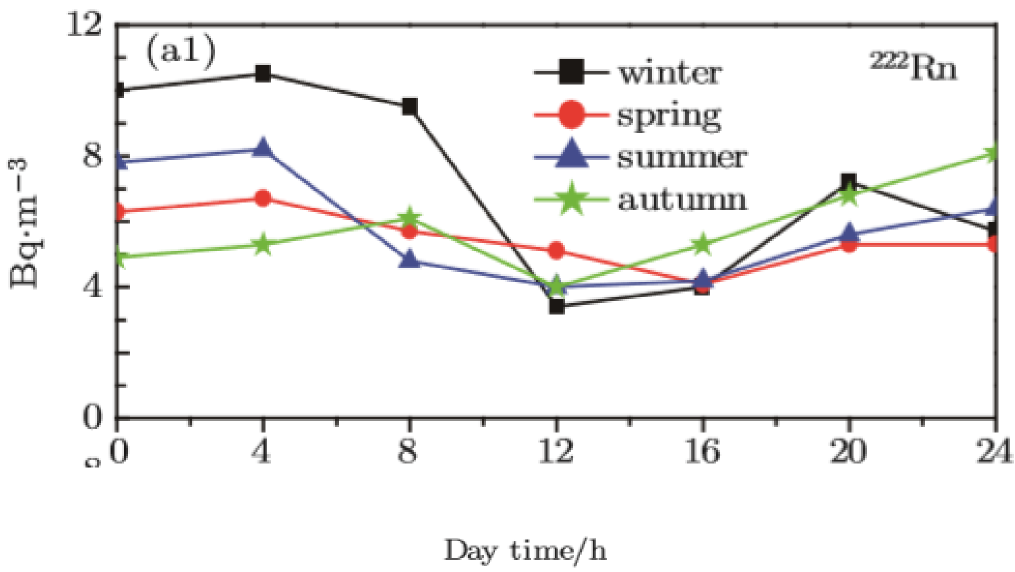


Figure 9 - Average daily variation of ^{222}Rn for each season over one year (November 2014 - October 2015) for surface air measurements in Jeddah, KSA.

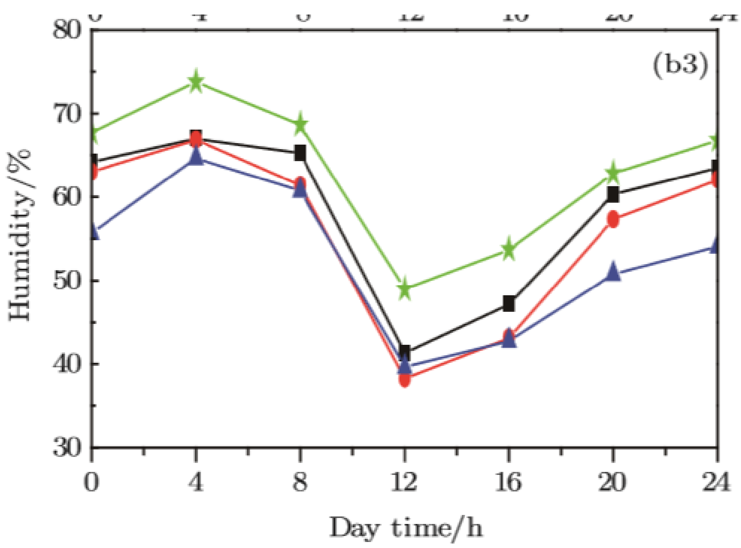


Figure 10 - Average daily change in relative humidity over one year (November 2014 - October 2015) for surface air measurements in Jeddah, KSA

In the autumn-winter season, a decrease in temperature and an increase in air humidity lead to an accumulation of activity concentration in the air. In the spring-summer season, convection currents are activated due to the higher temperature. Therefore, 222Rn and its DDP are transferred to the upper boundary layer of atmospheric air and there will be no enrichment of radioactivity in the lower layers. The winter average is higher than the summer average. This is due to the higher air humidity in the winter season (average value 58%), which increases the rate of adhesion of ^{222}Rn and its DDP to aerosol particles.

We can also consider the results obtained in Australia. [12]. Meteorological parameters and ^{222}Rn concentrations varied greatly during the 1-year study period (Fig. 10).

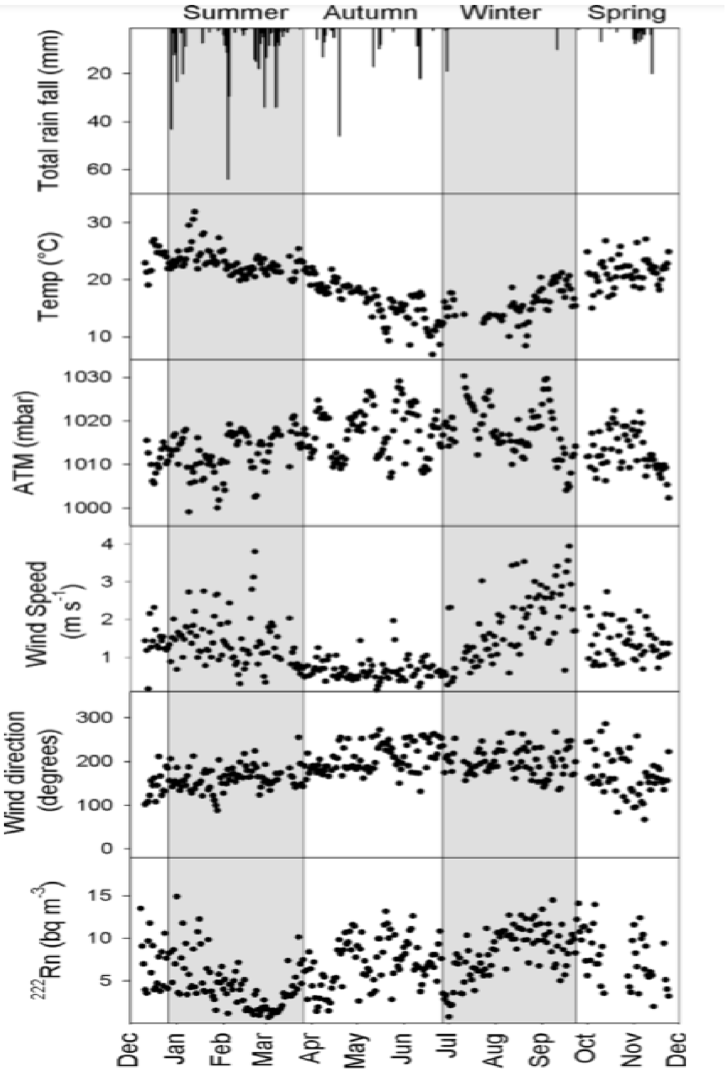


Figure 11 - Average daily precipitation (n = 353), temperature (n = 311), ATM (n = 327), wind speed / direction (n = 328) and ^{222}Rn concentration (n = 353) throughout the study

Meteorological data reflected a seasonal pattern for a region with warmer summers with stronger storm activity and predominantly winds and cold and wind waves. Compared to a 1-year time series (750.4 mm), it was 30% lower than the average annual rainfall. The lowest 222Rn concentrations over a long period were observed towards the end of summer (1.4 ± 0.5 Bq/m^{-3} for 13 days). This corresponded to daily rainfall between 0.3 and 34.0 mm with rain on 26 of 27 days from 13 February to 11 March 2014. Overall, the average daily rainfall in summer (4.2 ± 9.3 mm per day) was more than ten times higher than the average daily rain in winter (0.4 ± 2.2 mm per day). In this study, the average daily concentration of ^{222}Rn was highest in winter (8.3 ± 3.0 Bq/m^{-3}) and lowest in summer (4.5 ± 3.1

Bq/m^{-3}). This corresponded to the average summer temperature (23,1 ± 2,3 °C), which was higher than the spring (21,8 ± 2,7 °C), autumn (16,6 ± 3,5 °C) and winter (15,6 ± 3,0 °C) temperature. In general, there was a significant negative linear relationship between the ^{222}Rn concentration and temperature. This response of ^{222}Rn activity to temperature is most likely due to the higher emissivity of ^{222}Rn from soils. Radon emanation is the fraction of radon generated from ^{226}Ra that can penetrate into the pore space of sediments, and at higher temperatures, emanation can increase, so lower ^{222}Rn concentrations in summer during this study probably indicate a greater effect of soil moisture on ^{222}Rn emissions from soil.

1.6 Study of the influence of atmospheric inversions and turbulence on the volumetric activity of radionuclides

Hourly concentrations of radon in the atmosphere and meteorological parameters were monitored in the subalpine basin (South Africa, Ljubljana Bezigrad) and the sub-Mediterranean valley (Dolenie pri Aydovschina) in the summer period (June-August) 2018 [13].

The results of this study are presented in Figures 12 and 13.

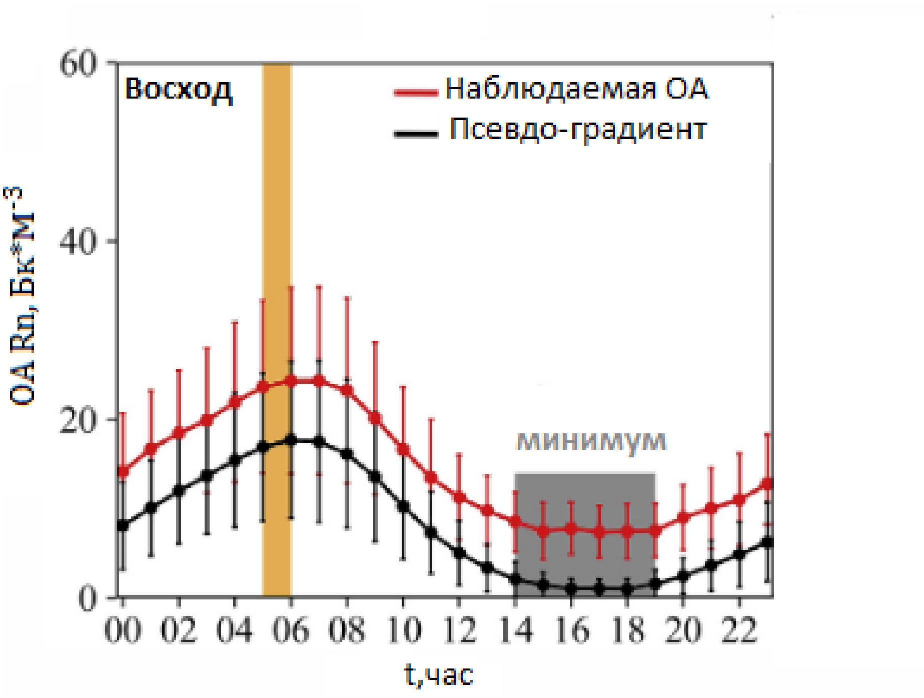


Figure 12 – Summer average value of hourly average daily composites of observed radon and local contribution to radon (pseudo-gradient) in the subalpine basin

Figure 13 – Summer average value of hourly average daily composites of observed radon and local contribution to radon (pseudo-gradient) in the sub-Mediterranean valley

Daytime cycles have a minimum in the middle of the day, when the lower atmosphere is most deeply mixed, and a nighttime maximum at dawn, when the lower atmosphere is at its lowest. The amplitude of these diurnal cycles is primarily related to the average daytime and nighttime change in the mixing depth in the summertime in the atmosphere (or "stability") due to factors such as local impact, surface characteristics (roughness, albedo, etc.) and topography. Shades of gray in Figures 2 and 3 represent the period of the daily cycle in which the minimum concentration of radon was usually found every day. At this time, the lower atmosphere is most deeply mixed, the ratio of the influence of a remote source on the measured radon concentrations is maximum.

Also, studies were carried out in the Department of Physics of the University of Milan (Italy), where the short-lived decay products of radon were regularly monitored. Milan is located in the Po valley, a famous European polluted area. The Alps and Apennines very often impede the exchange of air masses in Povalla [14].

The research results are presented in Figure 4.

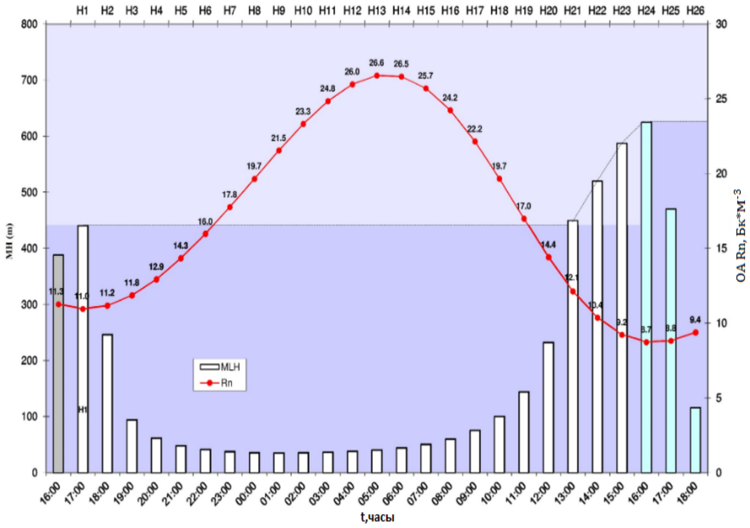


Figure 14 – An example of the equivalent time evolution of the mixing height. Red line and dots represent radon concentration.

Based on the figure, we can conclude that at the minimum value of the height of the mixing layer VA of Rn reaches the maximum values.

Atmospheric inversion - an increase in air temperature with height in a certain layer of the atmosphere, instead of its usual decrease. It occurs in the surface air layer and in these cases is called the surface air, as well as in the free atmosphere and is most often formed on calm nights (sometimes in winter and during the day) as a result of intense heat radiation from the earth's surface, which leads to cooling of both itself and the adjacent layer air. In addition, surface inversion occurs during night cooling of the layer above the soil, snow and ice cover, and accumulation of cold air. The thickness of surface inversions is tens - hundreds of meters. The increase in temperature in the inversion layer ranges from tenths of degrees to 15 - 20 °C and more.

1.7 Conclusion on chapter 1

Soil is the main source of radon in the surface atmosphere.

In the near-ground atmosphere, radon VA can vary greatly (by a factor of 2 or more) during the day, which is caused by daily changes in vertical turbulent mixing in the atmosphere, advection, and the magnitude of the radon flux from the soil. As a result of the analysis of the literature, it was revealed that there is a daily maximum concentration, which is observed when the atmosphere is the least mobile, and a minimum that is observed during the day, when vertical mixing of air due to turbulent diffusion have maximum levels.

The power and intensity of the inversion are characterized by significant seasonal variability. The climate characteristics of each different region directly affect the seasonal variations in radon. In a continental climate and in some coastal regions of the world, the maximum power and intensity of the inversion are observed in winter and minima in summer. Ground reversals of low power are more often observed in the warm season, and more powerful ones - in the cold season.

Wind strongly changes the vertical profile of the volumetric activity of radon isotopes and decay products. The wind directed towards the earth's surface reduces the activity of radon isotopes and daughter decay products at high altitudes and, conversely, greatly increases and compares their activities at the earth's surface.

Chapter 2 Methods for measuring the characteristics of the radon field

The second chapter describes the instruments used to measure the characteristics of the radon field. Also, their main technical characteristics and scope of devices are given.

2.1 Alpharad PLUS - Radon radiometer

This modification includes a complete set of measuring units and sampling devices.

The modification includes two measuring units (EEVA measurement unit, VA measurement unit), which are combined in a single housing.

This modification also includes an autonomous blower with sampling devices for sampling when measuring the radon content in water and soil air samples and measuring the radon flux density (RFD) from the soil surface.

The modification is intended for the following operating modes:

– using the EEVA measurement unit to monitor the content of daughter decay products (DDP) of radon and thoron in the air by the aspiration method, when aerosols, by pumping, are deposited on the filter, and then their content is measured by alpha spectrometry;

– using the VA measurement unit to monitor the volumetric activity of radon and thoron in the air;

– using an autonomous blower and sampling devices to take samples and measure the radon content in water samples, the radon content in soil air samples, measure the RFD from the soil surface.

A single-board PC-computer as part of the radiometer allows:

– set different measurement modes;

– process the results;

– test the operating modes of the radiometer units;

– present measurement results;

– store them in a convenient form;

– copy information to flash memory, over a network or to a personal computer via a USB port.

Figure 15 - Radiometer Alpharad PLUS

The radiometer has a high-resolution touchscreen display, which allows data to be displayed on the screen in the form of graphs; it can be used in the field, since the radiometer is powered from an autonomous power supply of increased capacity.

2.2 Radiometer RTM 2200

RTM-2200 is a radon / thoron monitor that is used for all types of radon measurements. The functions of the RTM-2200 radiometer are not limited to receiving and storing data, it can also control sampling equipment (pumps, valves, positioning, etc.).

Figure 16 - Radiometer RTM 2200

The measurement chamber is based on the principle of electrostatic deposition in a high voltage field and, despite its small volume, the chamber has incredible sensitivity. This is of decisive importance when analyzing thoron samples as well as when analyzing small volumes of pumped gas, in particular soil gases. Long-term contamination caused by ^{210}Po build-up in the chamber, to which other measuring systems are exposed, is completely eliminated. There is also no cross-sensitivity associated with external gamma radiation. Changes in ambient humidity do not affect the performance of the RTM-2200 measuring chamber, so there is no need for dryers required in other ESD devices.

2.3 Radon radiometer RRA-01M-03

Radon radiometer RRA-01M-03 is designed as a portable device with autonomous and mains power supply.

Figure 17 - Radiometer RRA-01M-03

Its main parts are:

- microblower;
- measuring chamber with aerosol filter and semiconductor detector;
- charge sensitive preamplifier;
- climatic chamber with temperature, humidity and pressure sensors;
- high voltage power supply;

– autonomous power supply;
– control unit with microprocessor-based control and display elements located in it;
– AC adapter (supplied separately).

2.2 Experimental conditions

Continuous monitoring of the characteristics of radon fields has been carried out from the end of 2016 to the present at the experimental site of TPU-IMCES using devices of the German company SARAD, based on semiconductor α-spectrometry. To determine the VA of radon decay daughter products, the method of pumping air through a membrane filter with parallel α-spectrometry with a semiconductor detector is used.

The monitoring process is fully automated, air is pumped continuously. One measurement time is 30 min. Installation height of devices 1 m above the ground. The following characteristics of the radon field are measured continuously: volumetric activity of radon and thoron; equivalent equilibrium volumetric activity of radon; latent energy of the DDP of radon and thoron in the air; number of pulses from isotopes of polonium.

Also, in parallel, monitoring was carried out using the American RAD 7 device at a height of 1 and 25 m. The principle of operation is based on spectrometric analysis of alpha decays of radon and thoron.

2.3 Experiment Results

The volumetric activities of radon and thoron strongly depend on different seasons of the year. In Tomsk, a higher average radon VA in winter can be traced, and thoron VA is maximum in summer.

As previously revealed, radon VA in the near-surface atmosphere depends on the sampling site, time, altitude, and meteorological conditions. The spread of radon in the atmosphere after they are exhaled from the soil is mainly due to turbulent diffusion and is limited only by radioactive decay.

As a result of the analysis of experimental data, the dynamics of the values of the monthly average volumetric activity of radon in the surface atmosphere at a height of 1m and 25m was obtained. For the analysis, two months were taken: summer (August) 2018 and autumn (October) 2017. The analysis results are presented in Figures 10 and 11, respectively.

Figure 18 – Dynamics of radon and thoron VA in August at a height of 1 m (green line) and 25 m (purple line)

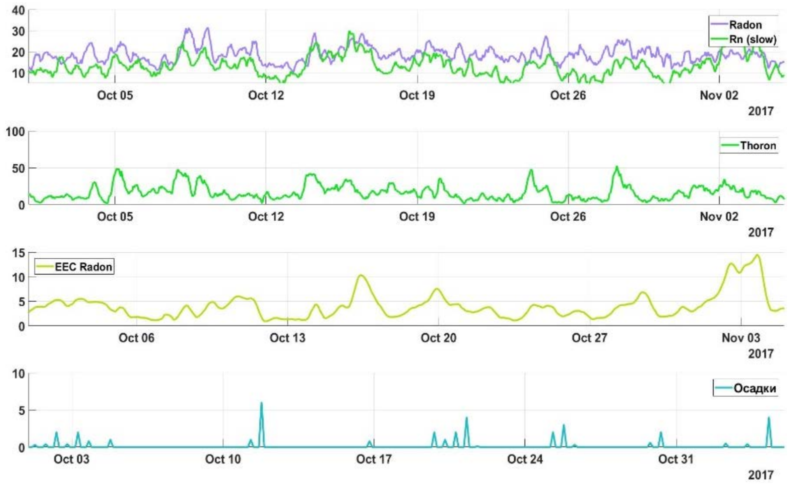


Figure 19 – Dynamics of radon and thoron VA in October at a height of 1 m (green line) and 25 m (purple line)

The figures show the values of the amount of precipitation in mm, which fell during the observation period. After analyzing the figures, it can be concluded that during the period of precipitation, the VA of radon and thoron decreases.

There are diurnal variations with a minimum at lunchtime and highs at night. Chapter 1 details the reasons for this behavior.

It is also seen from the figures that at heights of 1 and 25 m in August, OA differ during the period of increasing wind speed (data on meteorological parameters are taken from [18]). At the same time, radon VA at a height of 1 and 25 meters differs in this observation period by no more than 15 Bq/m^3.

In October, OA of radon retains its values regardless of altitude. The fall of OA on some days can be justified by negative temperatures and also by an increase in wind speed.

2.4 Conclusion on chapter 2

It was found that during the entire observation period, diurnal variations were observed for both radon and thoron.

When comparing the VA values of radon with meteorological parameters, it was concluded that the greatest scatter of values at different heights is observed with an increase in wind speed.

From the results obtained experimentally, it can be concluded that in August, at a height of 1 m, radon VA is higher than at a height of 25 m. In October, the differences in the values of VA at different heights are not so noticeable, however, at an altitude of 25 m, the value of VA is higher than at a height of 1 m.

Chapter 3. Modeling of vertical distributions of radon volumetric activity in the surface atmosphere

The transport of radon in the soil-atmosphere system is mainly carried out using the main processes of diffusion and advection. The advection process is characterized by the vertical movement of radon in the soil as a result of heat exchange (convection), pressure variations (filtration), moisture circulation, and other processes. In this work, the soil is considered as a porous medium with open and interconnected pores, which provides diffusion, and the atmosphere is limited by the surface layer. In the mathematical modeling of the radon transfer process in the "soil-atmosphere" system, we will consider the transfer characteristics to be constant and known values. Of practical interest, in most cases, is the consideration of only the vertical transfer of radon from the soil to the earth's surface.

3.1 Описание традиционной модели

The following model is traditionally used in such studies

$$\frac{\delta A}{\delta t} = \nabla((D_M + D_t)\nabla A) - \lambda A, \qquad (3.1)$$

where is $A(z,t)$ the function of volumetric activity Rn, Bq/m^3;

D_m — molecular diffusion coefficient, m^2/s;

$D_T(\mathrm{z},\mathrm{t})$ - function of the atmospheric turbulence coefficient, m^2/s;

Is the decay constant of the i-th radionuclide, s^{-1}.

As mentioned earlier, we consider a one-dimensional case when the transfer of radionuclides is carried out along the z-axis directed upward from the earth's surface. Then the equation will be rewritten as

$$\frac{\delta A(z,t)}{\delta t} = \frac{\partial}{\partial z}(D_M + D_t(z,t)\frac{\partial A(z,t)}{\partial z}) - \lambda A(z,t) \qquad (3.2)$$

The equations must be solved with the initial condition $A\ (z, 0)\ =\ 5$, and the boundary conditions

$$(D_M + D_t(z,t)\frac{\partial A_i(z,t)}{\partial z})\bigg|_{z=0} = q(t), \quad (3.3)$$

$$A(z,t) \to 0, z \to 10^6, \quad (3.4)$$

q (t) is a function of the radon flux density.

For modeling, the following values of the parameters presented in Table 3.1 were taken

Table 3.1- Meaning of simulation parameters

	Radon
Dm, м²/с	$1.2 \cdot 10^{-5}$
	10-100
s	0,01-10 / K·φ, where φ- unknown function
	$2{,}1 \cdot 10^{-6}$

3.1.1 Simulation with constant turbulent diffusion coefficient

Consider the case when φ = 1, hence D_t = K. The time interval is 72 hours. In the experiment, the value of VA was considered at heights of 1 and 25 meters, therefore, an interval for heights from 0 to 30 meters was chosen. The SPR value was selected to be maximum and amounted to 100 mBq m^2s^{-1}. K takes the following values: 0.01; 0.5; 5; 10. The models obtained with the given values of the coefficient of turbulent diffusion are presented in Figures 12,13,14,15, respectively.

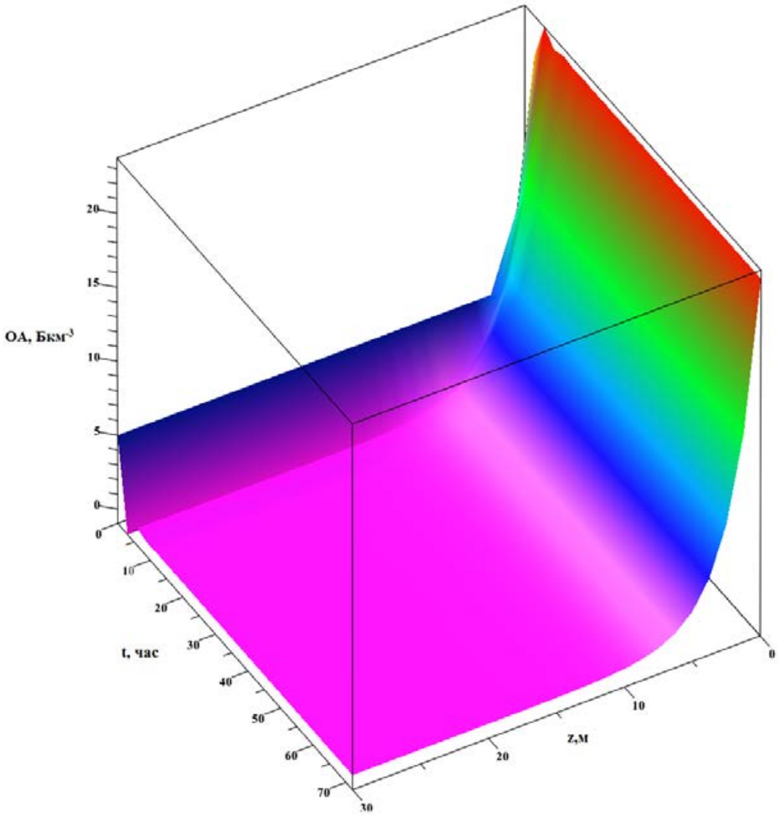


Figure 20 - Model of the vertical distribution of VA ^{222}Rn at D_t = 0.01, Bqm^{-3}

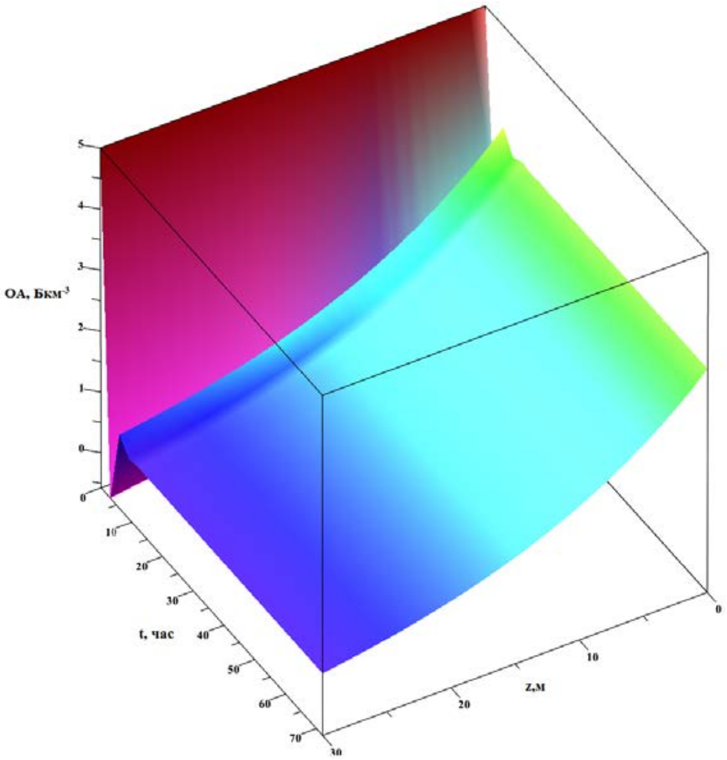


Figure 21 - Model of the vertical distribution of VA ^{222}Rn at D_t = 0.5, Bqm^{-3}

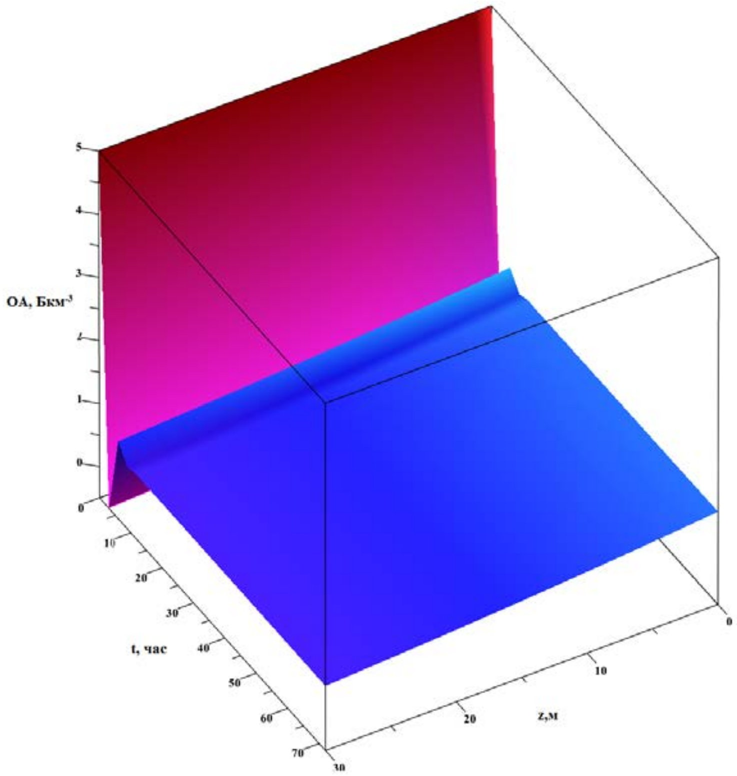


Figure 22 - Model of the vertical distribution of VA ^{222}Rn at D_t = 5, Bqm^{-3}

It is noticeable that for the given values of the turbulent diffusion function it is impossible to observe, the dependence of OA on time is similar to the dependence obtained in the course of the experiment.

It can be noted that with an increase in the height, the OA decreases, which contradicts the experimental data.

With an increase in the coefficient of turbulent diffusion, a transition from exponential to linear dependence is observed.

3.1.2 Simulation with linear turbulent diffusion coefficient

The case is considered when φ=exp(z). The time interval is 72 hours. The range for heights is from 0 to 30 meters. The PPR value was chosen to be minimal and amounted to 10 $mBqm^2s^{-1}$ (since even at the minimum PPR value, the VA takes large values). K takes the following values: 0.01; 0.5; 5; 10. The models obtained for the given values of the turbulent diffusion coefficient are shown in Figures 20, 21, 22, 23, respectively.

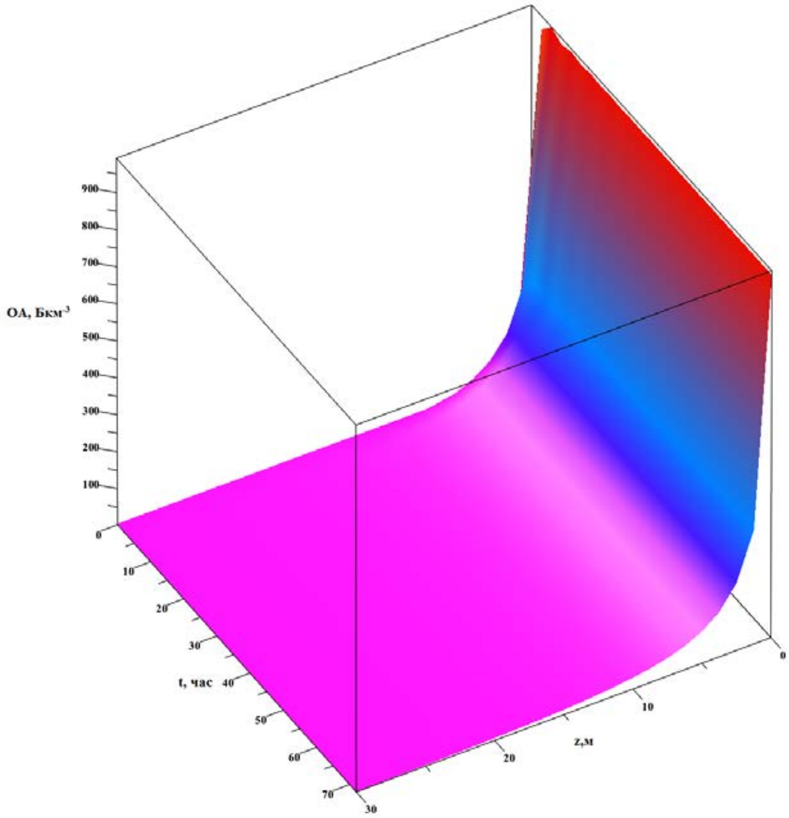


Figure 23 - Model of the vertical distribution of OA Rn222 at Dt = 0.01·z, Bq m^{-3}

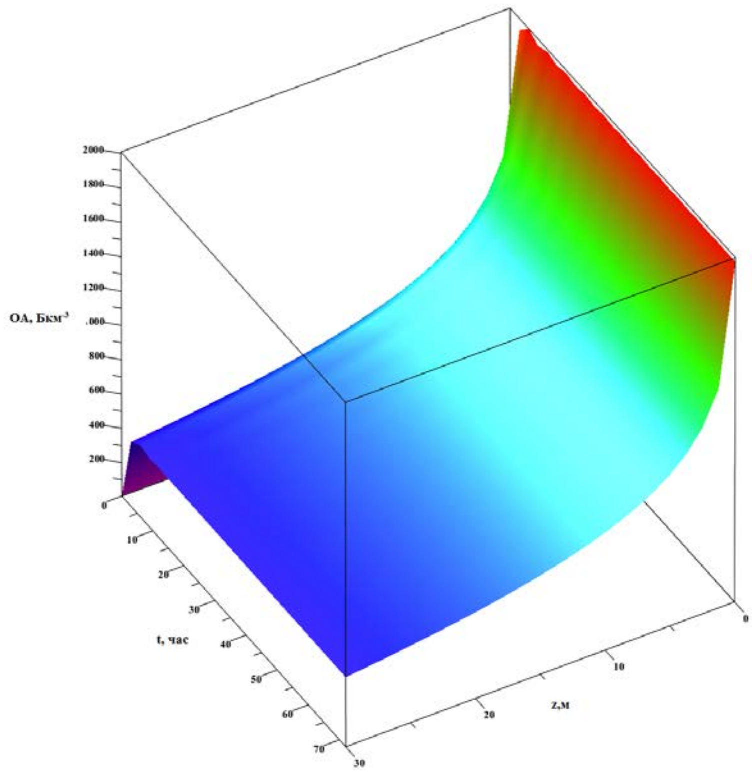


Figure 24 - Model of the vertical distribution of VA ^{222}Rn at Dt = 0.5·z, Bqm^{-3}

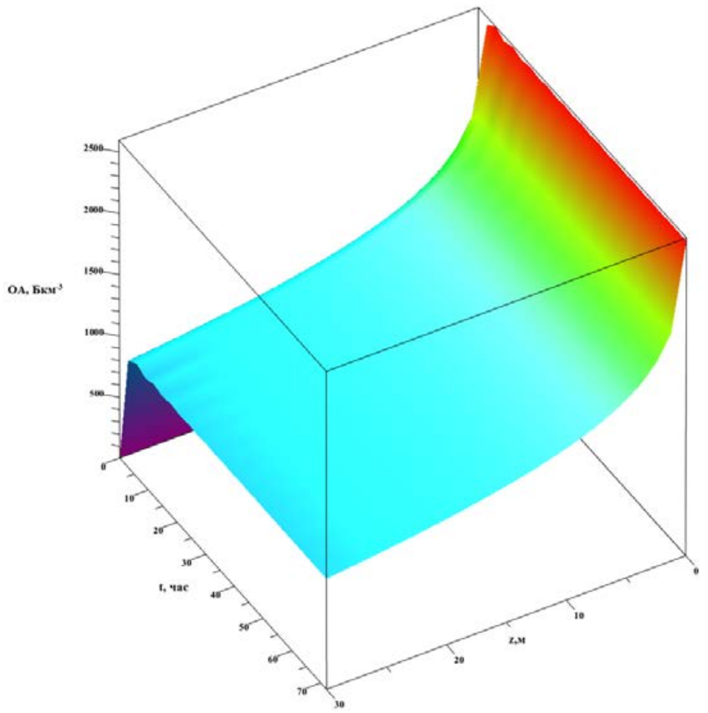


Figure 25 - Model of the vertical distribution of VA ^{222}Rn at Dt = 5·z, Bqm^{-3}

At the given values of the turbulent diffusion function, it is also impossible to observe in the previous case, the dependence of OA on time is similar to the dependence obtained in the course of the experiment.

With an increase in the height, the OA decreases, which contradicts the experimental data.

With an increase in the coefficient of turbulent diffusion, an exponential dependence of OA is observed. Also, with an increase in Dt, the value of OA increases.

3.1.3 Simulation with exponential turbulent diffusion coefficient

The case is considered when φ=exp(z·K) and Dt= exp(z·K). The time interval is 72 hours. The range for heights is from 0 to 30 meters. The PPR value was 10 $mBqm^2s^{-1}$. K takes the following values: 0.01. The model obtained for a given value of the turbulent diffusion coefficient is shown in Figure 20. Previously, 4 values for K were considered, however, with this model, with an increase in K, the equation has a unique solution.

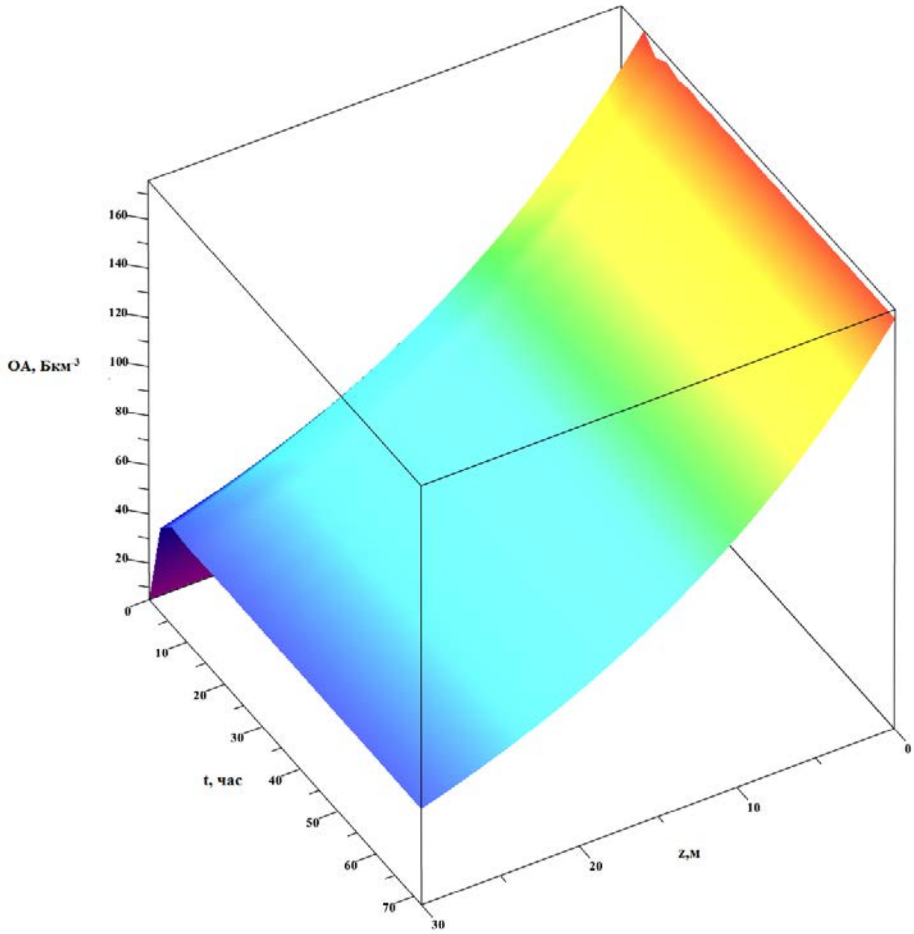


Figure 26 - Model of the vertical distribution of VA ^{222}Rn at Dt = exp (0.01 * z), Bqm^{-3}

Analyzing the figure, we can conclude that with an increase in the height, OA decreases exponentially. As in the previous models, there is no connection similar to experiment in the dependence of OA on time.

3.1.4 Simulation with a power-law turbulent diffusion coefficient

We can consider the case when Dt = z^K. The range for heights is from 0 to 30 meters. The PPR value was 10mBkm2s-1. K takes the following values: 0.01; 0.5; 5; 10. The time interval was 72 hours. The models obtained with the given values of the coefficient of turbulent diffusion are presented in Figures 16,17,18,19, respectively. The models obtained for the given values of the coefficient of turbulent diffusion are presented in Figures 24,25,26,27, respectively.

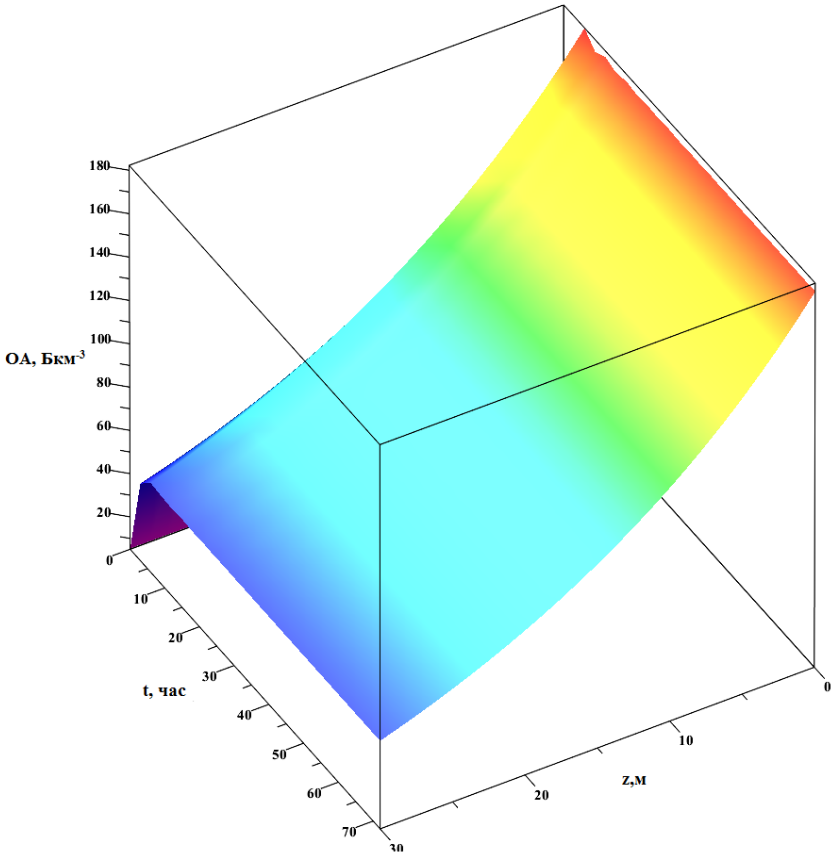


Figure 27 - Model of vertical distribution of VA ^{222}Rn at $Dt = z^{0.01}$, Bqm^{-3}

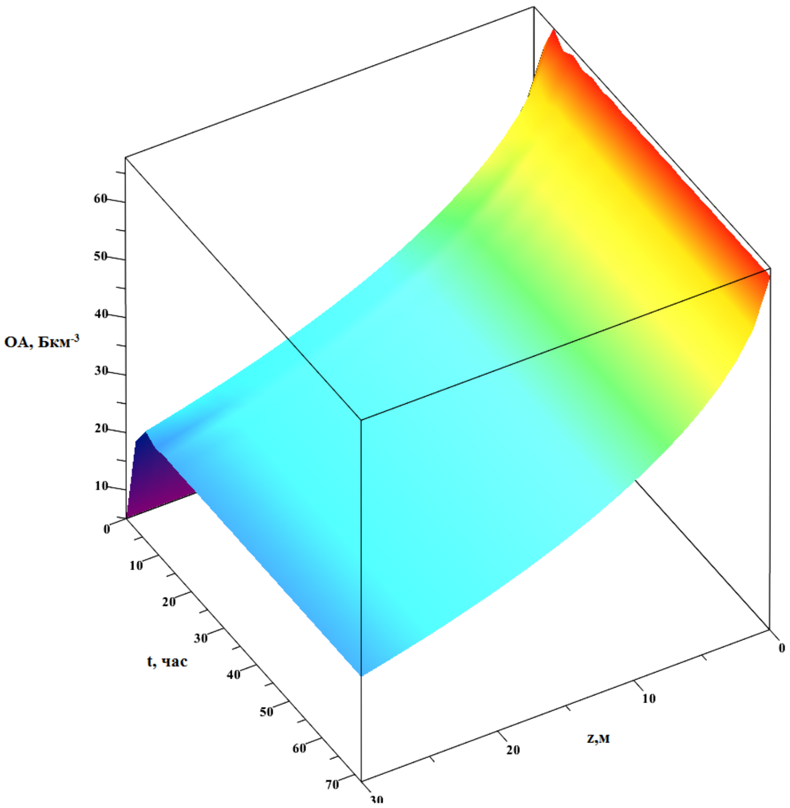


Figure 28 - Model of the vertical distribution of OA ^{222}Rn at $Dt = z^{0.5}$, Bqm^{-3}

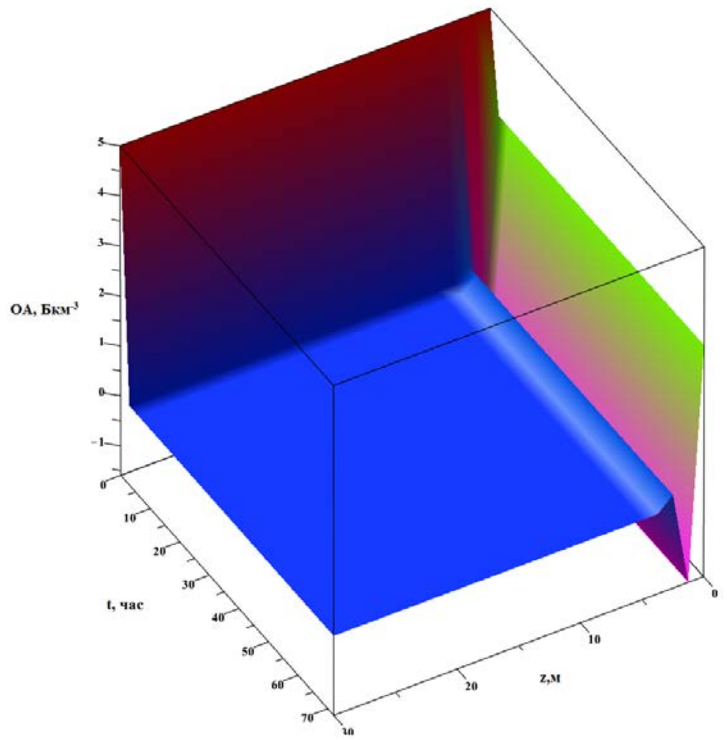


Figure 29 - Model of the vertical distribution of VA ^{222}Rn at Dt = z^5, Bqm^{-3}

At the given values of the turbulent diffusion function, it is also impossible to observe in the previous case, the dependence of OA on time is similar to the dependence obtained in the course of the experiment.

With an increase in the height, the OA decreases, which contradicts the experimental data.

With an increase in the coefficient of turbulent diffusion, an exponential dependence of OA is observed at K less than 1, at K more than 1, it can be observed that OA changes only at a height of less than five meters, while at some values of the OA height it acquires negative values, which contradicts the experiment. At an altitude of more than 5 m, OA at high turbulence is equal to zero.

3.1.5 Simulation with sinusoidal turbulent diffusion coefficient

The case should be considered when $\varphi=(1-\sin(\omega\cdot t))\cdot z$, where ω is the angular velocity of the Earth's rotation ($7{,}2921\cdot10^{-5}c^{-1}$). Therefore, $Dt=K\cdot\varphi=(1-\sin(\omega\cdot t))\cdot z\cdot K$. The time interval is 72 hours. The range for heights is from 0 to 30 meters. The PPR value was chosen to be minimal and amounted to 10 mBqm^2 s^{-1}. K takes the following values: 0.01; 0.5; 5; 10. The models obtained for the given values of the coefficient of turbulent diffusion are presented in Figures 25,26,27,28, respectively.

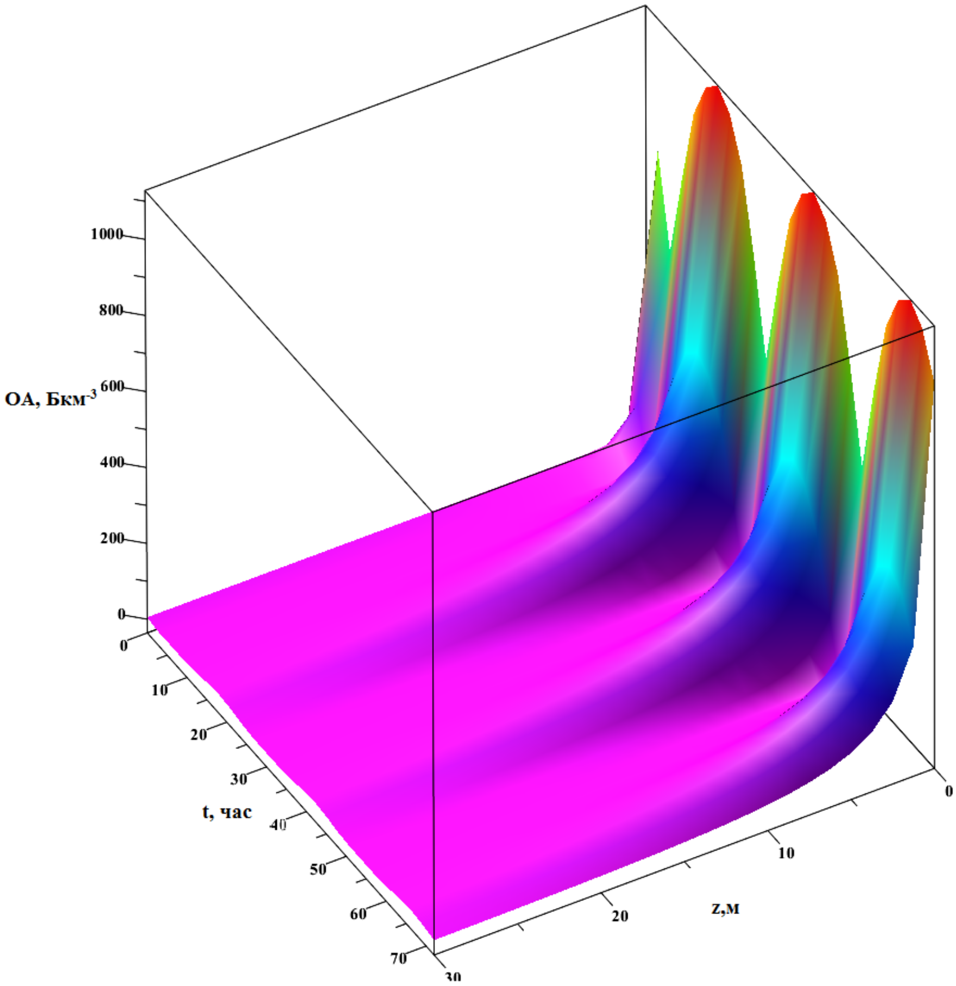


Figure 30 - Model of the vertical distribution of VA ^{222}Rn at $Dt=(1-\sin(\omega\cdot t))\cdot z\cdot 0.01$, Bqm^{-3}

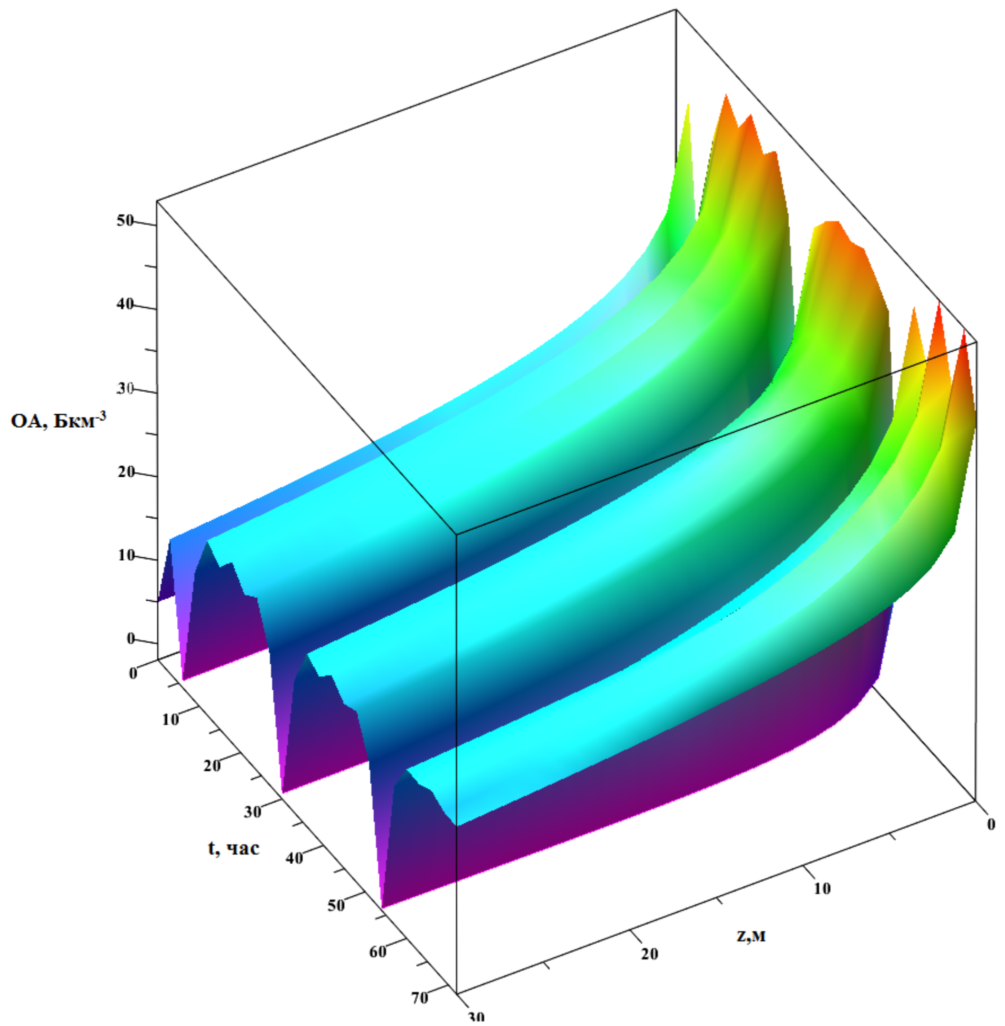


Figure 31 - Model of vertical distribution of VA ^{222}Rn at $Dt=(1-\sin(\omega\cdot t))\cdot z\cdot 10$, Bqm^{-3}

For these values of the turbulent diffusion function, a similar dependence of OA on time, obtained in the course of the experiment, is observed.

With an increase in the height, the OA decreases, which contradicts the experimental data.

With an increase in the turbulent diffusion coefficient, an exponential dependence of OA on altitude is observed.

None of the functions considered above allows one to describe the relationship between OA and the height obtained during the experiment. When analyzing the experimental data, it was noted that the discrepancy in the values occurred with an increase in wind speed. However, in the classical model, this meteorological parameter is not taken into account.

3.2 Description of the modified model

To modify the traditional model, it was decided to add another parameter, the wind speed. Then the resulting model will take the form

$$\frac{\delta A}{\delta t} = \nabla(D_M + D_t)\nabla A) - \nabla \vec{v}_w A - \lambda A, \qquad (3.5)$$

where $v_w(z,t)-$ functions of the vertical component of wind speed, m/s

For the one-dimensional case, the model will take the form

$$\frac{\delta A(z,t)}{\delta t} = \frac{\partial}{\partial z}(D_M + D_t(z,t)\frac{\partial A(z,t)}{\partial z}) - \frac{\partial}{\partial z}(\vec{v}_w(z,t)A(z,t)) - \lambda A(z,t), \qquad (3.6)$$

The system of equations must be solved with the initial condition A (z, 0) = 5, and the boundary conditions

$$(D_M + D_t(z,t)\frac{\partial A(z,t)}{\partial z})\bigg|_{z=0} - (\vec{v}_w(z,t)A(z,t))\big|_{z=0} = q(t), \qquad (3.7)$$

$$A(z,t) \to 0, z \to 10^6, \qquad (3.48)$$

For modeling, the following values of the parameters presented in Table 3.2 were taken

Table 3.2 - Meaning of simulation parameters

	Радон
Dm, м^2/с	1.2·10^{-5}
q, мБк м^2 с$^{-1}$	10-100
Dt, м^2/с	0,01-10 / K(1–sinωt)z, K=0,15-5
ω, с$^{-1}$	7,2921·10^{-5}
,с$^{-1}$	2,1*10^{-6}
ν_w, м/с	|0,001-0,01|

With negative values of ν_w, the wind speed is directed towards the earth's surface, with positive values upward from the surface.

3.2.1 Simulation with positive wind speeds

The function Dt=(1–sin(ω·t))·z·5 should be considered, since the values of VA at a height of one meter most of all coincided with the experimental data. The time interval is 72 hours. Height interval 30 meters. Let's take the PPR value equal to 10 mBqm^{2}s^{-1}. For speed, let's take values equal to: 0.001; 0.005; 0.01. The simulation results are shown in Figure 29, 30, 31, respectively.

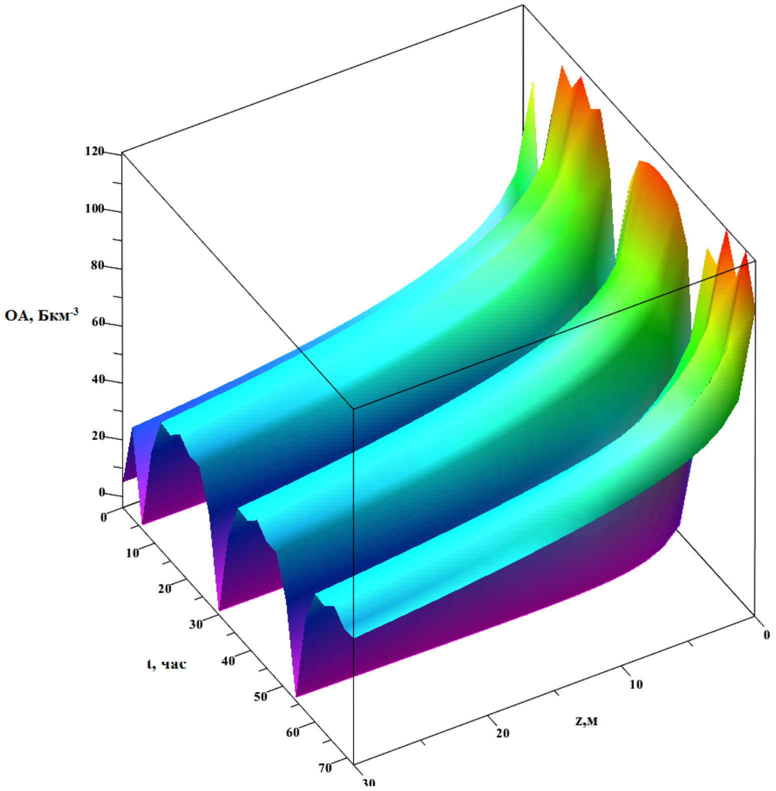


Figure 32 - Model of vertical distribution of OA ^{222}Rn at Dt=(1–sin(ω·t))·z·5 and speed v = 0.001, Bqm^{-3}

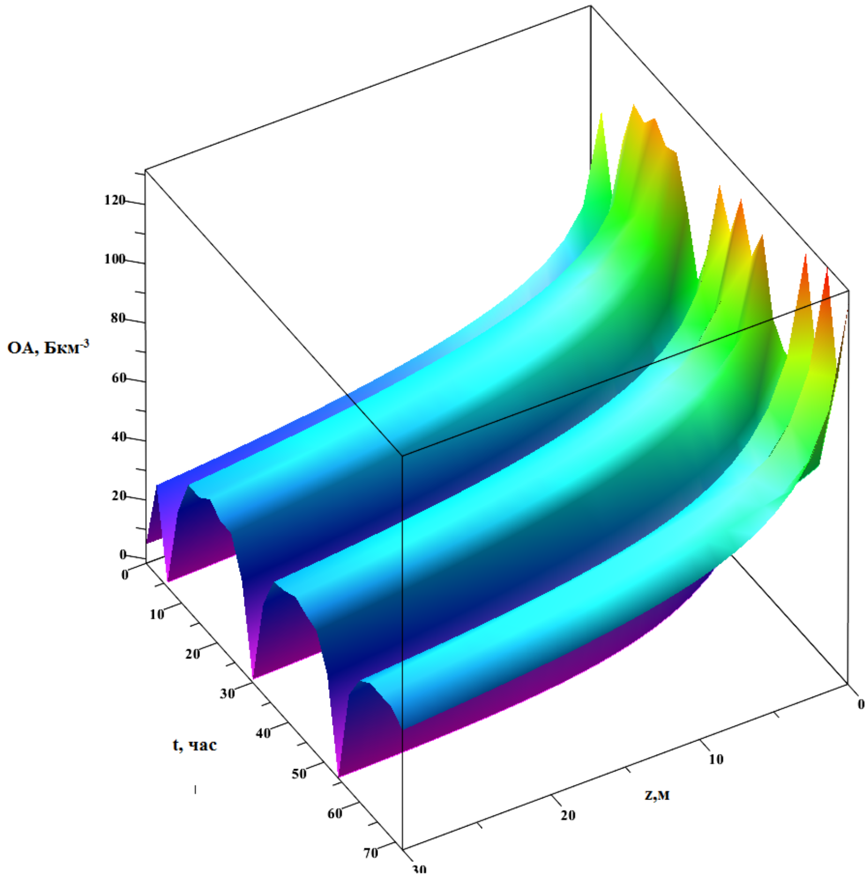


Figure 33 - Model of vertical distribution of OA ^{222}Rn at, Bkm-3Dt=(1–sin(ω·t))·z·5 и скорости v=0,005, Bqm^{-3}

At a given value of the turbulent diffusion function, a similar dependence of OA on time, obtained in the course of the experiment, is observed.

With an increase in the height, the OA decreases, which contradicts the experimental data. An exponential dependence of OA on altitude is also observed.

As the speed increases, VA increases. However, it can be seen that the spread between the VA values at an altitude of 1 and 25 meters does not exceed 15 Bqm^{-3}. Hence, we can conclude that this model can be used to describe the experimental dependence in the month of July.

3.2.2 Simulation at negative wind speeds

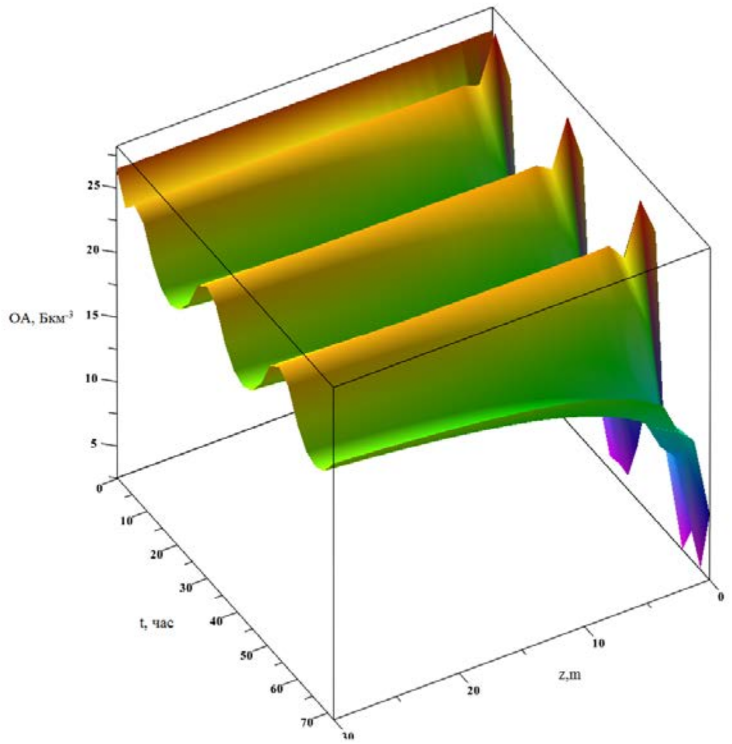
The function Dt=(1–sin(ω·t))·z·5 is preserved. The time interval is 72 hours. Height interval 30 meters. Let's take the PPR value equal to 10 mBqm2s^{-1}.

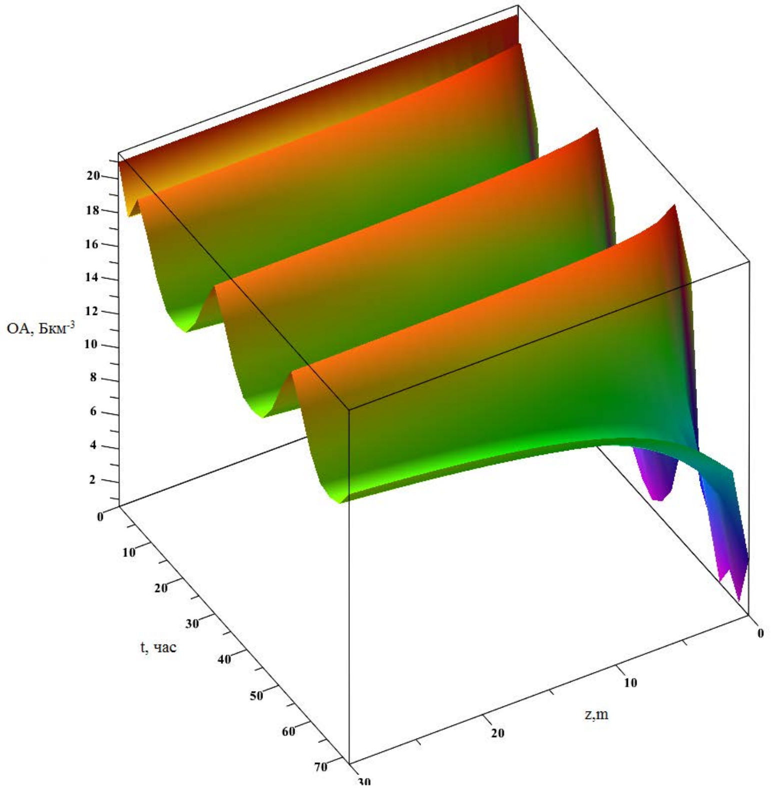
For speed, let's take values equal: -0.001; -0.005; -0.01. The simulation results are presented in Figure 34, 35, respectively.

Figure 34 - Model of vertical distribution of VA ^{222}Rn at Dt=(1−sin(ω·t))·z·5 and speed v = – 0,001, Bqm^{-3}

Figure 35 - Model of vertical distribution of VA ^{222}Rn at Dt=(1−sin(ω·t))·z·5

v = - 0.01, Bqm^{-3}





For a more detailed analysis, consider the projection of the model shown in Figure 34 in the OA and z axes. The projection is shown in Figure 35.

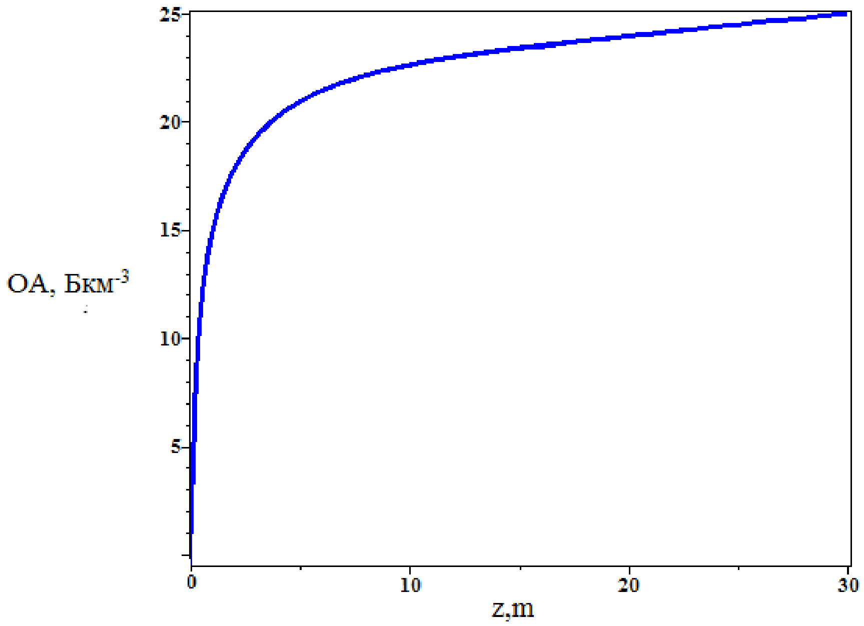


Figure 36 - Projection of the model of the vertical distribution of OA ^{222}Rn at at $Dt=(1-\sin(\omega\cdot t))\cdot z\cdot 5$ and speed v = – 0,001, Bqm^{-3}

At a given value of the turbulent diffusion function, a similar dependence of OA on time, obtained in the course of the experiment, is observed.

With an increase in the height, OA increases, which confirms the experimental data obtained in October.

As the speed increases, OA increases. However, it can be seen that the spread between the OA values at a height of 1 and 25 meters is no more than 10 mBkm-3. This confirms our experimental data.

3.3 Modeling the influence of inversion on the volumetric activity of radon

Coming out of the soil surface, the radon flux has a vertical profile. We have created a model in which the vertical profile of radon has risen in the air to the blocking layer of the temperature inversion. Faced with this layer, the vertical profile can turn into a horizontal one.

To construct the models, the mean values of the radon volumetric activity at different times of the year were taken. In our model, these are summer and winter.

3.3.1 Modeling the influence of inversion in summer

The volumetric activity of the radon flux decreases, reaching the blocking layer. Figure 37 shows the dependence of volumetric activity on temperature inversion. According to our measurements, the flux density is reduced by 30%.

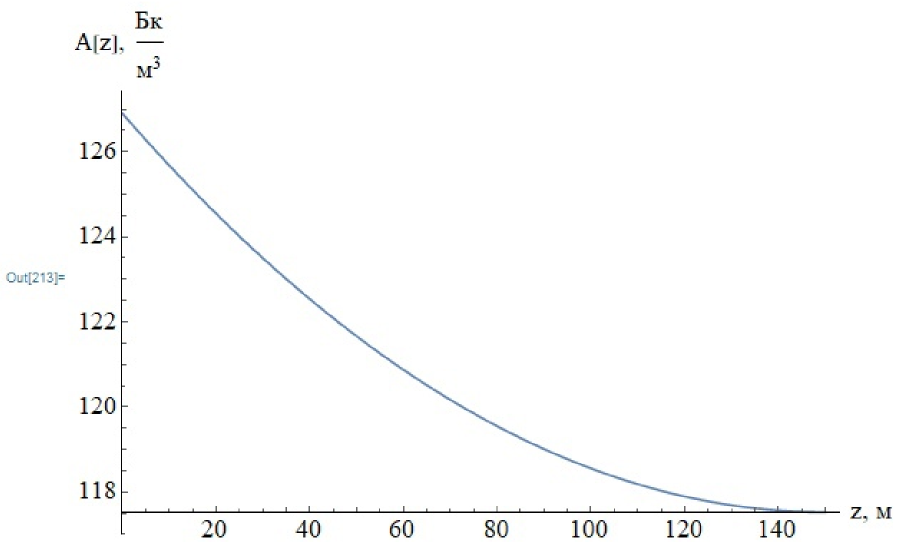


Figure 37 - Dependence of the volumetric activity of the radon flux taking into account the temperature inversion in summer.

3.3.2 Modeling the influence of inversion in winter

Temperature inversions are more common in winter. As the air is cooled by snow and ice cover. According to our measurements, the average value of the volumetric activity in winter is 120 Bq / kg. In winter, as in summer, we see in Fig. 38 an exponential dependence of the decrease in volumetric activity on altitude, taking into account temperature inversions.

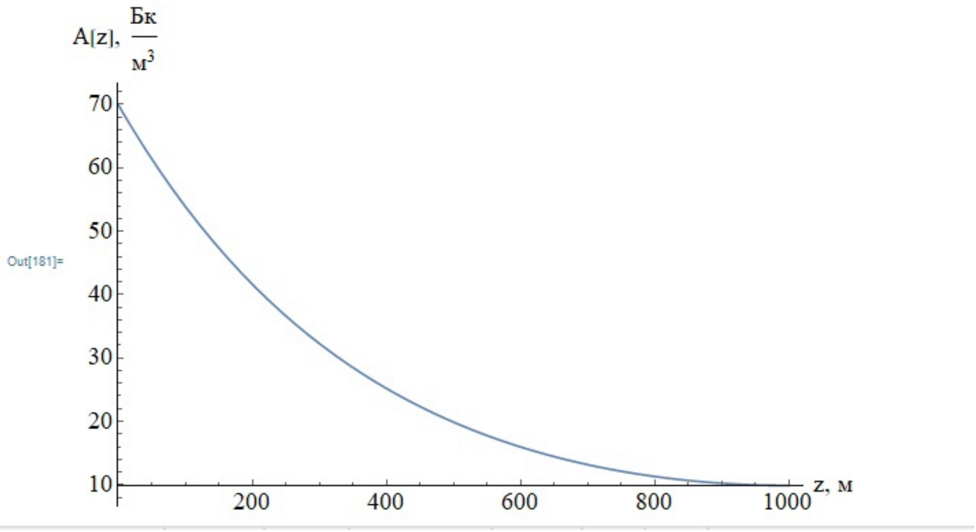


Figure 38 - Dependence of the volumetric activity of the radon flux, taking into account the temperature inversion.

3.4 Conclusion on chapter 3

A change in the coefficient of turbulence of the atmosphere strongly changes the profile of the volumetric activity of radon, especially at the earth's surface.

It was experimentally established that the best convergence with real measurements was obtained with the coefficient of turbulent diffusion as a function of height and time.

When simulating using the traditional model, no convergence with experimental data was found. It is concluded that the traditional model does not describe the real research results.

Modeling with the modified model showed a good relationship with experimental data. It is concluded that when modeling the vertical component of radon VA, it is necessary to take into account the wind speed.

Chapter 4 Financial Management, Resource Efficiency and Resource Conservation

4.1 Assessment of the commercial potential and the prospects for conducting scientific research from the standpoint of resource efficiency and resource conservation

4.1.1 Potential consumers of research results

In the past, the dependence of the influence of precipitation intensity on the radiation background in the surface atmosphere was found. In this work, the contribution of ^{214}Pb and ^{214}Bi to the γ-background during showers in the surface layer of the atmosphere was determined. Various meteorological and geological organizations as well as operational radiological services may show interest in the project. By researching the market of potential consumers, a number of enterprises can be identified that are potentially interested in the research results.

– Federal Service of Russia for Hydrometeorology and Environmental Monitoring, Moscow;

- Federal State Unitary Enterprise Emergency Technical Center of the Ministry of Atomic Energy of Russia;
- Siberian Geological Association, Novosibirsk;
- Tomsk Center for Hydrometeorology and Environmental Monitoring, Tomsk.

4.1.2 Analysis of competitive technical solutions

For the analysis of competitive technical solutions, an optical-acoustic-electronic device (K1) was taken, since it is the most accurate of the currently existing devices for measuring the intensity of precipitation. The scorecard shown in the table lists the strengths and weaknesses of the competitor.

The position of the development and competitors is assessed for each indicator by an expert way on a five-point scale, where 1 is the weakest position, and 5 is the strongest. The weights of the indicators, determined by expert judgment, should add up to one.

The analysis of competitive technical solutions is determined by the formula:

$$К = \sum B_i \cdot Б_i \tag{4.1}$$

where К – competitiveness of a scientific development or a competitor, where

$К_ф$ – competitiveness of scientific research,

$К_1$ – competitiveness of an optical - acoustic - electronic device;

Bi – indicator weight (in fractions of a unit), where $В_ф$ – scientific development indicator weight, $В_1$ – indicator weight of optical - acoustic - electronic device;

Бi – score of i index, where $Б_ф$ – scientific development indicator score, $Б_1$ – score of the indicator of the optical - acoustic - electronic device.

This analysis shows that the determination of the intensity of rainfall by the developed method has a number of advantages over the competitor.

Table 4.1 – Evaluation card for comparing competitive technical solutions (developments)

Evaluation criteria	Criterion weight	Points		Competitiveness	
		Бф	Бк1	Кф	Кк1
Technical criteria for assessing resource efficiency					
1. Reliability of the received data	0,35	5	3	1,75	1,05
2.Immunity of detecting devices	0,2	4	2	0,8	0,4
3. Reliability of the received data	0,12	4	3	0,48	0,36
4.Easy to operate	0,15	5	4	0,75	0,6
5. Convenience in operation	0,1	5	3	0,5	0,3
6. Energy efficiency	0,08	4	5	0,32	0,4
Total:	**1**	-	-	**4,6**	**3,11**

4.1.3 SWOT- analysis

SWOT- analysis – Strengths, Weaknesses, Opportunities and Threats – is a comprehensive analysis of a research project.

SWOT analysis consists in describing the strengths and weaknesses of the project, in identifying opportunities and threats for the implementation of the project, which have manifested or may appear in its external environment.

Strengths are factors that characterize the competitive side of a research project. Strengths indicate that a project has a distinctive advantage or special resources that are special in terms of competition. In other words, strengths are the resources or capabilities that project management has and that can be effectively used to achieve the goals.

Weaknesses are a flaw, omission or limitation of a research project that hinders the achievement of its objectives. This is something that does not work well within a project or where it lacks the capacity or resources compared to its competitors.

Opportunities include any preferable present or future situation that arises in the project's environment, such as a trend, change, or perceived need, that sustains demand for project outcomes and allows the project management to improve its competitive position.

A threat is any undesirable situation, trend or change in the environmental conditions of a project that is destructive or threatening to its competitiveness in the present or future. A threat can be a barrier, restriction, or anything else that can cause problems, destruction, harm or damage to the project.

The table presents the SWOT analysis in the form of a table, also shows the results of the intersections of sides, opportunities and threats.

Table 4.2 – SWOT analysis

	Strengths of the research project:	**Weaknesses of the research project:**
	−S1. The reliability of the data received; −S2. High noise immunity; −S3. Low cost of detectors; −S4. Expanding the boundaries of applicability.	– W1. Additional mathematical calculations; – W2. Measurement error of the dose rate of γ-radiation; − W3. Finding a γ-ray detector in the area of precipitation.
Capabilities: – C1. The development of seismology will expand the market, which will increase interest in this technique; – C2. Reducing the cost of γ-detectors; − C3. Improvement of γ-detectors to reduce the error.	1. Due to the reliability of the data and good noise immunity, the chance of the method entering the market increases. 2. Reducing the cost of γ-detectors and their improvement will expand the boundaries of applicability	1. The development of seismology and a decrease in the cost of γ-detectors will allow an increase in the number of detectors to expand the area of dose rate measurement; 2. Improvement of γ-detectors will lead to a decrease in the measurement error.
Threats: – T1. High competition due to the modernization of other devices; − T2. Lack of demand in the market due to the attachment of customers to the use of	1. Expanding the boundaries of applicability will allow you to go beyond the boundaries of meteorology and draw attention to new markets; 2. High reliability combined with low cost of data significantly increases	1. Development of software for mathematical calculations and error reduction will significantly increase the competitiveness of the product on the market; 2. Reducing the cost of γ-detectors will allow

old and proven ones; – T3. Improvement of precipitation and rain gauges, due to the development of meteorology.	competitiveness; 3. Increasing customer demand through high noise immunity.	purchasing an additional number of detectors to expand the area of dose rate measurement, which will lead to an increase in demand for this technique.

To identify the degree of need for strategic changes, an interactive matrix was built, presented in the table.

Table 4.3 – Interactive matrix

Strengths of the research project					
Capabilities		C1	C2	C3	C4
	B1	+	+	+	0
	B2	-	-	+	+
	B3	+	+	-	+

Based on the data of the interactive matrix, we can conclude that the strengths of the project are related to the capabilities of the external environment and thanks to them the project can be implemented and in demand on the market.

4.2.1 The structure of work in the framework of scientific research

To carry out scientific research, a working group is formed, which may include researchers and teachers, engineers, technicians and laboratory assistants, the number of groups may vary. For each type of planned work, the corresponding position of performers is established. As part of this work, a working group was formed, which included:

– leader;
– student.

In this section, a list of stages and works for the implementation of research work is compiled, the distribution of performers by type of work is carried out. The order of the stages and works during the performance of the FQP is given in Table 4.4.

Table 4.4 - List of stages, works and distribution of performers

Main steps	No. of Works	The content of the work	Executor
Development of technical specifications for research	1	Preparation and approval of technical specifications	Supervisor
Choosing a direction of research	2	Search for materials on the topic: "The effect of radon, thoron and their DPR on the radiation background in the surface atmosphere"	Student
	3	Development of a general research methodology	Supervisor
Theoretical research	4	Study of documentation, literature search	Student
	5	Search for articles in journals on the subject: "Influence of precipitation on the rad. Background in the near-ground atmosphere"	Student
Calculations	6	Obtaining data on the dose rate of γ-radiation in the	Supervisor Student

Main steps	No. of Works	The content of the work	Executor
		near-ground atmosphere from the IMCES data	
	7	Obtaining Precipitation Intensity Data from IMCES	Supervisor Student
	8	Obtaining cloud height data from Gesmeteo	Supervisor Student
	9	Creation of graphical dependencies of the intensity of precipitation and the dose rate of γ-radiation in the surface atmosphere	Student
	10	Analysis and description of results	Student
Preparation of the WRC report	11	Verification of the results obtained with data from IMCES	Supervisor
	12	Drawing up an explanatory note	Student

4.2.2 Determination of the complexity of work

Labor costs in most cases form the bulk of the development cost, therefore, an important point is to determine the labor intensity of the work of each of the research participants.

The complexity of performing a scientific research is estimated by an expert in man-days and is of a probabilistic nature, since depends on many factors that are difficult to take into account. To determine the expected (average) value of labor intensity, the following formula is used:

$$t_{\text{ожі}} = \frac{3t_{\min i} + 2t_{\max i}}{5}, \tag{4.1}$$

where $t_{ожi}$ – expected complexity of execution of *i-th* work person. -day.;

$t_{\min i}$ – the minimum possible labor intensity of performing the given i-th job (optimistic estimate: assuming the most favorable coincidence of circumstances), person-days.;

$t_{\max i}$ – the maximum possible laboriousness of performing a given i-th job (pessimistic assessment: assuming the most unfavorable combination of circumstances), man-days.

Based on the expected labor intensity of the work, the duration of each work in working days Tp is determined, taking into account the parallelism of the work performed by several performers. Such a calculation is necessary for a reasonable calculation of wages, since the share of wages in the total estimated cost of scientific research is about 65%.

$$T_{\text{р}_i} = \frac{t_{\text{ожі}}}{\text{Ч}_i} \tag{4.2}$$

where $T_{\text{р}i}$ – duration of one job, working days;

$t_{\text{ож}i}$ – expected labor intensity of one job, man-days.

$Ч_i$ – number of performers performing the same work at the same time at this stage, people

4.2.3 Development of a scientific research schedule

At the next stage, a calendar plan for the implementation of research works is developed. A strip chart of research work was built in the form of Ganges diagrams. Gantt chart is a horizontal strip chart, in which works on a topic are represented by lengthy time intervals, characterized by the dates of the beginning and end of the execution of these works.

For the convenience of building a calendar schedule, the duration of stages in working days is converted to calendar days and is calculated using the following formula:

$$T_{ki} = T_{pi} \cdot k \qquad (4.3)$$

where T_{ki} - duration of one job, (calendar days.);

T_{pi} - duration of one job, (working days);

k - calendar coefficient, designed to convert working hours into calendar.

The calculation of the calendar coefficient is made according to the following formula:

$$k = \frac{T_{кг}}{T_{кг} - T_{вд} - T_{пд}}, \qquad (4.4)$$

where $T_{кг}$ - number of calendar days in a year ($T_{кг} = 365\ days$.);

$T_{вд}$ - number of days off per year ($T_{вд} = 52$);

$T_{пд}$ – number of holidays per year, ($T_{пд} = 14$).

Estimated value of the duration of work T_{ki} бhas been rounded to whole numbers.

The value of the calculated calendar coefficient:

$$k = \frac{365}{365-52-14} = 1{,}22. \qquad (4.5)$$

The calculated data are summarized in the table, on the basis of which the calendar schedule was built.

Table 4.5 – Time indicators of scientific research

i	Executor	$t_{min\ i}$	$t_{max\ i}$	$t_{ож\ i}$	$Ч_i$	$T_{р\ i}$, working days	T_k, calendar days
1	Supervisor	1	2	2,2	1	2,2	2,7
2	Student	2	4	2,8	1	2,8	3,4
3	Supervisor	2	4	2,8	1	2,8	3,4
4	Student	3	6	4,2	1	4,2	5,1
5	Student	3	6	4,2	1	4,2	5,1
6	Supervisor Student	2	4	2,8	2	1,4	1,7
7	Supervisor Student	2	4	2,8	2	1,4	1,7
8	Supervisor Student	2	4	2,8	2	1,4	1,7
9	Student	14	31	20,8	1	20,8	25,4
10	Student	2	4	2,8	1	2,8	3,4
11	Supervisor	2	3	2,4	1	2,4	2,9
12	Student	2	4	2,8	1	2,8	3,4
Total		37	76	53,4	-	49,2	60

Based on the calculated data, a schedule was built in the form of a Gantt chart. The graph is built with a timeline, divided into months and decades, covering the entire period of research and writing of FQPs. Each artist is assigned their own hatch type. Schedule schedule for the implementation of this thesis is presented in the table.

Table 4.6 – Schedule of research work on the topic

№	Executor.	T_{ki}, calendar days.	Duration of work											
			March				April				May			
			1	2	3	4	1	2	3	4	1	2	3	4
1	P	2,7												
2	C	3,4												
3	P	3,4												
4	C	5,1												
5	C	5,1												
6	P C	1,7												
7	P C	1,7												
8	P C	1,7												
9	C	25,4												
10	C	3,4												
11	P	2,9												
12	C	3,4												

- student; - supervisor; - supervisor + student.

4.2.4 Scientific and technical research budget (STI)

When planning a scientific and technical research (STI) budget, a complete and reliable reflection of all types of costs associated with its implementation must be ensured. In the process of forming the NTI budget, the following grouping of costs by item is used:

1. The main salary of the performers of the topic.
2. Contributions to extrabudgetary funds.
3. Overhead costs.

4.2.4.1 Basic salary of theme performers

This section includes the basic wages of employees directly involved in the performance of work on this topic. The amount of wage costs is determined based on the labor intensity of the work performed and the current system of salaries and tariff rates. The basic salary includes a bonus paid monthly from the payroll in the amount of 20-30% of the tariff or salary.

The article includes the basic wages of workers directly involved in the implementation of STI, (including bonuses, additional payments) and additional wages:

$$З_{зп} = З_{осн} + З_{доп}, \tag{4.6}$$

where $З_{осн}$ – basic salary;

$З_{доп}$ – additional wages (12-20 % of $З_{осн}$).

The basic salary of a research supervisor is calculated based on the industry salary. The sectoral wage system at TPU assumes the following wages:

1) salary is determined by the enterprise. At TPU, salaries are distributed in accordance with the positions held, for example, assistant, art. lecturer, associate professor, professor;

2) incentive payments - set by the head of departments for effective work, performance of additional duties, etc.

The basic salary of a manager is calculated according to the formula:

$$З_{осн} = З_{дн} \cdot T_{раб}, \qquad (4.7)$$

where $З_{осн}$ – basic salary of one employee;

$T_{раб}$ – duration of work performed by a scientific and technical worker, working days.;

$З_{дн}$ – average daily wage of an employee, rub.

Average daily wages are calculated using the formula:

$$З_{дн} = (З_м \cdot M) / F_д, \qquad (4.8)$$

where $З_м$ – employee's monthly salary, rub.;

M – the number of months of work without vacation during the year, with a vacation of 48 working days M=10,4 months, 6 days week;

$F_д$ – actual annual fund of working time of scientific and technical personnel, working days.

Table 4.7– Balance of working hours

Working time indicators	**Supervisor**	**Student**
Calendar number of days	365	365
Number of non-working days - weekend - holidays	52 14	52 14
Lost working time - vacation - absenteeism due to illness	48	48
Valid annual working time fund	251	251

An employee's monthly salary, taking into account the regional coefficient for Tomsk $k_р$ = 1,3, calculated:

$$З_м = З_{тс} \cdot 1{,}3. \qquad (4.9)$$

The basic salary of the manager for the period of work is equal to:

$$З_м = З_{тс} \cdot 1{,}3 = 36800 \cdot 1{,}3 = 47840 \text{ rub./month};$$

$$З_{дн} = (З_м \cdot M) / F_д = (47840 \cdot 10{,}4) / 251 = 1982 \text{ rub./month};$$

$$З_{осн} = З_{дн} \cdot T_{раб} = 1982 \cdot 12 = 23784 \text{ rub.}$$

Table 4.8 – Calculation of basic wages

Executor	$З_{тс}$, rub.	$k_р$	$З_м$, rub./month	$З_{дн}$, rub./day	$T_р$, working. days.	$З_{осн}$, rub.
Supervisor	36800	1,3	47840	1982	12	23784
Student	9893	1,3	12861	533	42	22386
Total $З_{осн}$						**46170**

4.2.4.2 Contributions to extrabudgetary funds

This expense item reflects the mandatory deductions in accordance with the norms established by the legislation of the Russian Federation to the bodies of state social insurance (FSS), the pension fund (PF) and medical insurance (FFOMS) from the costs of wages of employees.

The amount of contributions to extrabudgetary funds is determined based on the following formula:

$$З_{внеб} = k_{внеб} \cdot (З_{осн} + З_{доп}) \qquad (4.10)$$

where $k_{внеб}$ – the ratio of contributions to payments to non-budgetary funds (pension fund, compulsory health insurance fund, etc.).

For 2015, in accordance with the Federal Law of July 24, 2009 No. 212-FZ, the amount of insurance premiums is set equal to 30%. On the basis of paragraph 1 of Article 58 of Law No. 212-FZ, for institutions carrying out educational and scientific activities in 2014, there is a reduced rate of 27.1%.

$$k_{внеб} = k_{пф} + k_{с} + k_{пн}, \qquad (4.11)$$

where $k_{пф}$ - coeff. contributions to the pension fund; $k_{с}$ - coeff. deductions of insurance premiums;

$k_{пн}$ - coeff. income tax deductions.

$$k_{внеб} = 0{,}271.$$

Thus, deductions to extra-budgetary funds from the cost of remuneration of the manager are calculated as follows:

$$З_{внеб} = 0,271 \cdot 46170 = 12512 \text{ rub.}$$

Table 4.9 – Contributions to off-budget funds

Executor	Supervisor
Basic salary, rubles	46170
Ratio of contributions to extrabudgetary funds	0,271
Amount of deductions	12512
Total	**12512**

4.2.4.3 Overheads

The electricity costs for running a computer are calculated using the formula:

$$C = Ц_{эл} \cdot Р \cdot F_{об} \qquad (4.12)$$

where $Ц_{эл}$= 5,8 – electricity tariff, rub / (kW · h);

$F_{об}$ = 49 · 6 = 294 – time of equipment use, (h).

When performing the work, a personal computer with an average power of 350 W (0.35 kW) was used. If we assume that all the work was done on it, then, according to the table, everything was spent (60 calendar days, six-hour working day):

$$E_{ПК} = P \cdot F_{об} = 0,35 \cdot 294 = 103 \text{ kW;}$$

then the cost of consumed electricity is:

$$C = Ц_{эл} \cdot E = 5,8 \cdot 103 = 597 \text{ rub.}$$

Overhead costs include other costs of the organization that were not included in the previous items of expenses: printing and photocopying of research materials, payment for communication services, electricity, postal and telegraph costs, reproduction of materials, etc. Their value is determined by the following formula:

$$C_{накл} = k_{накл} \cdot (З_{осн.} + З_{доп}) \qquad (4.13)$$

where $k_{нр}$ – coefficient that takes into account overhead costs. We take the value of the invoice coefficient in the amount of 16%, hence:

$$C_{накл} = 0{,}16 \cdot 46170 = 7387 \text{ rub.}$$

4.2.4.4 Formation of the budget for the costs of a research project

The calculated amount of research costs is the basis for the formation of the project cost budget. Determination of the budget for the costs of a research project for each execution option is given in the table

Table 4.10 – Research project budget

Article title	Amount, rub.
1. Costs for the basic salary of the performers of the topic	46170
2. Contributions to extrabudgetary funds	12512
3. Overhead costs	7387
4. Electricity costs	597
NTI cost budget	**67000**

4.3 Determination of resource (resource-saving), financial, budgetary, social and economic efficiency of research

Efficiency can be determined by calculating the integral indicator of the effectiveness of a scientific research. Its value is the sum of the coefficients of financial efficiency and resource efficiency.

An integral indicator of the financial efficiency of a scientific research is obtained in the course of assessing the budget of the costs of three (or more) variants of the implementation of a scientific research. For this, the largest integral indicator of the implementation of the technical problem is taken as the calculation base (as the denominator), with which the financial values are correlated for all execution options.

The integral financial development indicator is defined as:

$$\mathrm{I}_{\text{финр.}}^{\text{исп.i}} = \frac{\Phi_{\text{pi}}}{\Phi_{\max}}, \tag{4.14}$$

where $I_{\text{финр}}^{\text{исп.i}}$ – integral financial development indicator;

$\Phi_{\text{p}i}$ – cost of the i-th version;

$\Phi_{\max}$ – maximum cost of execution of a research project (including analogues).

The resulting value of the integral financial development indicator reflects the corresponding numerical increase in the development cost budget in times (the value is greater than one), or the corresponding numerical reduction in the development cost in times (the value is less than one, but greater than zero).

Since the development has one execution, then:

$$\mathrm{I}_{\text{финр.}}^{\text{исп.i}} = \frac{\Phi_{\text{pi}}}{\Phi_{\max}} = \frac{67000}{67000} = 1 \tag{4.15}$$

The integral indicator of resource efficiency of variants of the research object can be determined as follows:

$$\mathrm{I}_{\text{pi}} = \sum a_i \cdot b_i\,, \tag{4.16}$$

where I_{pi} – integral indicator of resource efficiency for the i-th development option;

a_i – weighting factor of the i-th design option;

b_i^a, b_i^p – the point score of the i-th version of the development, is established by an expert according to the selected rating scale;

n – number of comparison parameters.

The calculation of the integral indicator of resource efficiency is presented in the form of a table 4.11.

Table 4.11 – Assessment of the characteristics of project execution

Object of study / Criteria	Parameter weighting factor	Evaluation
1. Promotes the growth of user productivity	0,23	5
2. Convenience in operation	0,10	5
3. Immunity	0,20	4
4. Energy saving	0,20	3
5. Reliability	0,12	4
6. Material consumption	0,15	4
Total	1	

$$I_{pi} = 5 \cdot 0.23 + 5 \cdot 0.1 + 4 \cdot 0.2 + 3 \cdot 0.2 + 4 \cdot 0.12 + 4 \cdot 0.15 = 4.13$$

Integral indicator of the effectiveness of development options ($I_{исп i}$) is determined on the basis of the integral indicator of resource efficiency and the integral financial indicator according to the formula:

$$I_{исп.1} = \frac{I_{p-исп1}}{I_{финр}^{исп.1}}, \quad I_{исп.2} = \frac{I_{p-исп2}}{I_{финр}^{исп.2}} \text{ etc.} \qquad (4.17)$$

Comparison of the integral indicator of the efficiency of the development options will allow to determine the comparative efficiency of the project and choose the most appropriate option from the proposed ones. Comparative project effectiveness ($Э_{ср}$):

$$Э_{ср} = \frac{I_{исп1}}{I_{исп2}} \quad (4.18)$$

Table 4.12 – Development efficiency

No.	**Indicators**	**Evaluation**
1	Integral financial development indicator	1
2	Integral indicator of resource efficiency of development	4.13
3	Integral efficiency indicator	0,24

4.4 Conclusion on chapter 4

Comparison of the values of integral performance indicators allows us to understand and choose a more effective solution to the technical problem posed from the standpoint of financial and resource efficiency. In this case, it has only one solution to the problem. Hence, the option provided is also assumed to be the best.

Chapter 5 Social Responsibility

As part of the final qualification work, the contribution made by radioactive daughter products of radon decay ^{214}Pb and ^{214}Bi to the gamma background of the surface layer of the atmosphere was assessed. The main part of the work was carried out on a PC located in the laboratory room number 118 of the 10th TPU building.

The work consisted in modeling the dynamics of the gamma background and the activity of ^{214}Pb and ^{214}Bi deposited on the earth's surface.

5.1 Assessment of harmful and dangerous factors

This paragraph provides an analysis of all harmful and dangerous factors that may arise when working in the classroom. All harmful and hazardous factors typical for the laboratory environment are presented in table 5.1.

Table 5.1 – Possible harmful and dangerous factors

Factors (GOST 12.0.003-2015 [18])	Regulatory documentation
1. Microclimate	GOST 30494-96. Residential and public buildings. Indoor microclimate parameters [13]
2. Noise	GOST 12.1.003-83. Occupational safety standards system (SSBT). Noise. General safety requirements (with Amendment No. 1) [14]
3. Illumination of the working area	SNiP 23-05-95 *. Natural and artificial lighting (with Amendment N 1) [15]
4. Electromagnetic fields	SanPiN 2.2.4.1191-03 Electromagnetic fields in industrial conditions (as amended on March 2, 2009) [21]

5. Fire and explosion hazard	SP 12.13130.2009. Determination of categories of premises, buildings and outdoor installations for explosion and fire hazard (as amended by amendment No. 1, approved by order of the Ministry of Emergency Situations of Russia dated 09.12.2010 No. 643) [16] GOST 12.1.004-91 Occupational safety standards system. Fire safety. General requirements [17]
6. Electrical safety	GOST 12.1.009-76 Occupational Safety Standards System (SSBT) [18] GOST R12.1.019-2017 SSBT Electrical Safety [19] GOST R IEC 61140-2000 Protection against electric shock. General provisions on safety provided by electrical equipment and electrical installations in their relationship [20]
7. Radiation safety	SanPiN 2.6.1.2523-09 Radiation safety standards NRB-99/2009 [22]

5.1.1 Microclimate

The main factors characterizing the microclimate of the working environment are: temperature, air mobility and humidity. Deviation of these parameters from the norm leads to a deterioration in the employee's well-being, a decrease in his labor productivity and the occurrence of various diseases.

Working in high temperature conditions is accompanied by intense sweating, which leads to dehydration of the body, loss of mineral salts and water-soluble vitamins, serious changes in the activity of the cardiovascular system, an increase in respiratory rate, and also affects the functioning of other organs and systems (weakening of attention, deterioration coordination of movements, slowing down the reaction of the body, etc.).

High relative humidity at a high air temperature contributes to overheating of the body, while at a low temperature, heat transfer from the skin surface increases, which leads to hypothermia of the body. Low humidity causes discomfort in the form of dryness of the mucous membranes of the respiratory tract of the worker.

When standardizing meteorological conditions in industrial premises, the time of the year, the physical severity of the work performed, as well as the amount of excess heat in the room are taken into account. Optimal and permissible meteorological conditions of temperature and humidity are established according to [13] and are shown in Table 5.2.

For the convenience of working in the room, it is necessary to standardize the microclimate parameters, that is, it is necessary to carry out measures to control the methods and means of protection against high and low temperatures, heating, ventilation and air conditioning systems, artificial lighting, etc.

Table 5.2 – Optimal indicators of the microclimate in the workplaces of industrial premises

Period of the year	**Category of work by the level of energy consumption, W**	**Air temperature, °C**	**Surface temperature, °C**	**Relative humidity, %**	**Air speed, m/s**
Cold	Ia (up to 139)	22-24	21-25	60-40	No more than 0.1
Warm	Ia (up to 139)	23-25	22-26	60-40	No more than 0.1

To maintain these sanitary standards, it is enough to have a natural unorganized ventilation of the room and a local air conditioner of a complete air conditioning unit, which ensures the constancy of temperature, relative humidity, movement speed and air purity. A central heating system is required to provide a predetermined temperature level in winter according to [19]. In winter, a water heating system is used in the auditorium to maintain the required temperature. This system is reliable in operation and provides the ability to control temperature over a wide range. When installing a ventilation and air conditioning system in the auditorium, certain fire safety requirements must be observed. In winter, a heating system must be provided in the room. It must provide sufficient, constant and uniform heating of the air. In rooms with increased requirements for air purity, water heating should be used.

To protect the researcher from the harmful factor of deviation of microclimate indicators, microclimatic conditions are created by heating, exchange ventilation and air conditioning according to [13].

5.1.2 Noise

Excessive noise level. occurs during the operation of mechanical and electromechanical products.

To assess the noise environment, it is allowed to use a numerical characteristic called the sound level (measured in dB). In accordance with [14], the permissible noise level during work requiring concentration, work with increased requirements for monitoring processes and remote control of production cycles at workplaces in laboratory premises with noisy equipment is 75 dB. Areas with a sound level of 80 dB should be marked with safety signs according to [14].

In auditorium 118, the main sources of noise are air conditioning, computers (cooling inside the system unit, optical DVD-ROM drives).

In accordance with the specification for the DNS Office XL computer, the noise level of the computer's power supply is 5-10 dB, the noise level of the processor cooling device is 15-20 dB, the rest of the cooling elements are passive and their noise level is not taken into account. The noise caused by the operation of optical drives is also not taken into account, since they are used in operation for a very short time.

In the laboratory under consideration, additional sound insulation is not required, since the noise limit value is not reached.

To prevent the occurrence of harmful noise, computer system units should be regularly inspected (cleaning from dust and lubricating moving parts of cooling units, replacing unnecessarily noisy components).

Protection against increased noise levels is carried out by methods of its reduction in the source of formation and along the path of propagation, the device of screens and sound-absorbing facings, personal protective equipment according to [26].

5.1.3 Lighting

Insufficient illumination of the working area is also considered one of the factors affecting human performance. For industrial enterprises, optimal illumination of the territory and premises is an important and difficult technical task, the solution of which ensures normal hygienic conditions for the working personnel. Correctly selected light sources and their design create conditions for production work, correct execution of technological operations, compliance with safety rules and regulations.

The main task of lighting calculations for artificial lighting is to determine the required power of an electric lighting installation to create a given illumination.

Indoors, according to the way the lamps are placed and the distribution of illumination, the following artificial lighting systems are distinguished: general and combined.

General lighting is called lighting, the lamps of which illuminate the entire area of the room, both occupied by equipment or workplaces, and auxiliary. Depending on the location of the luminaires, a distinction is made between uniform and localized general illumination. With general uniform illumination, the luminaires are located evenly in the upper area of the room, thereby ensuring the same illumination of the entire room. It is used, as a rule, when the location of the working areas during the design is unknown, or with a flexible layout. With general localized lighting, the luminaires are placed taking into account the location of the technological equipment, creating the required level of illumination on individual surfaces.

The combined lighting system consists of general and local lighting. General lighting is designed to illuminate passages and areas where work is not being performed, as well as to equalize the brightness in the field of view of workers. Local lighting is provided by lamps located directly at the workplace. It should be preferred if different visual tasks are to be solved in several working areas of the room and therefore require different levels of illumination. It is also necessary when workplaces are geographically distant from each other. It should be borne in mind that the device only local lighting is unacceptable, since it creates a large difference in the illumination of the working surfaces and the surrounding space, which adversely affects vision [15].

Taking into account the peculiarities of the process of working on a computer, the use of a general uniform lighting system is allowed.

For general lighting, gas-discharge lamps are used: daylight (LD), cold-white (LHB), warm-white (LTB) and white (LB). Determine the required number of light sources for full illumination of the classroom with a working computer with fluorescent ceiling lamps.

Luminous flux for fluorescent lamps, 56 W:

$$F = Ra \cdot P, \tag{5.1}$$

where Ra = 80Лм/Вт – minimum color rendering index for a fluorescent lamp.

$$F = 80 \cdot 56 = 4480 \text{ Лм}.$$

The required number of lamps to illuminate the laboratory classroom:

$$N = \frac{E \cdot S \cdot z \cdot k}{K \cdot F \cdot n}, \tag{5.2}$$

where E – illumination, Lx (with a general illumination system E = 300 Lx);

K – conversion factor, 4,5;

n – utilization factor of the luminous flux of the lighting installation, 45 %;

k – safety factor, 4,5;

S – illuminated area, 121 м^2;

z – correction factor for uneven lighting, 0,9.

$$N = \frac{300 \cdot 121 \cdot 0.9 \cdot 4.5}{4.5 \cdot 4480 \cdot 0.45} = 16{,}2 \text{ pieces.} \qquad (5.3)$$

The calculated value of the number of fixtures is rounded up to a whole number. We get that 17 lamps are needed for proper lighting of the audience.

To protect against insufficient illumination of the working area, natural lighting in its spectrum is the most acceptable, but it is not always sufficient. This is largely due to the mode of operation. General and combined lighting is generally recommended. Workplace illumination standards correspond to [15].

5.1.4 Electromagnetic fields

The main harmful factor when using a computer is electromagnetic radiation from the components of the computer. The norms of harmful permissible levels (VLU) of electromagnetic radiation of computers are established in the document [21], which are shown in table 5.3.

The propagation of an electromagnetic field (EMF) occurs with the help of electromagnetic waves, which in turn emit charged particles, molecules and atoms. The harm of electromagnetic radiation has been officially proven and confirmed by relevant research by scientists, therefore, as far as possible, its effect on the human body should be limited.

Table 5.3 – Temporary permissible levels of EMF generated by a PC

Parameter name		The value of the permissible level
Electric field strength	In the frequency range 5 Hz - 2 kHz	25 V / m
	In the frequency range 2 kHz - 400 kHz	2.5 V / m
Magnetic flux density	In the frequency range 5 Hz - 2 kHz	250 nT
	In the frequency range 2 kHz - 400 kHz	25 nT
Electrostatic potential of the video monitor screen		500 B

The screen and computer system units also emit electromagnetic radiation. Most of it comes from the system unit and video cable. The strength of the electromagnetic field at a distance of 50 cm around the screen in terms of the electrical component should correspond to [21].

An increased level of electromagnetic radiation can negatively affect the human body, namely, lead to nervous disorders, sleep disturbances, a significant deterioration in visual activity, a weakening of the immune system, and disorders of the cardiovascular system. There are the following methods of protection against EMI:

– increasing the distance from the source (the screen must be at least 50 cm away from the user);
– the use of screen filters, special screens and other personal protective equipment.

In this laboratory, the radiation meets the standards [21].

5.1.5 Fire and explosion safety

Depending on the characteristics of substances and materials in the room, according to the explosion and fire hazard, the premises are divided into categories A, B, C, D and E in accordance with [16]. The room in question belongs to category B, since it contains solid combustible substances in a cold state. Possible causes of fire:

– work with open electrical equipment;
– short circuits in power supplies;
– non-observance of fire safety rules.

In order to reduce the risk of fire and minimize possible damage, preventive measures are taken, which are subdivided into organizational, technical, operational and regime. Organizational and technical measures consist in conducting regular briefings of employees responsible for fire safety, training employees in the proper operation of equipment and the necessary actions in the event of a fire, certification of substances, materials and products in terms of ensuring fire safety, production and use of visual agitation tools to ensure fire safety [17]. Operational measures include preventive inspections of equipment. Regime measures include the establishment of rules for the organization of work and the observance of fire safety measures. To prevent a fire, the following fire safety rules must be observed:

- maintenance of premises in accordance with fire safety requirements;
- proper operation of equipment (correct connection of equipment to the power supply network, control of equipment heating);
- training of production personnel in fire safety rules;
- availability, correct placement and use of fire extinguishing equipment.

In a room with electrical equipment, in order to avoid electric shock, it is advisable to use carbon dioxide or dry powder fire extinguishers. These fire extinguishers are designed to extinguish fires of various substances and materials, electrical installations under voltages up to 1000 V, flammable liquids. Chemical and foam extinguishers are not permitted. Fire extinguishers should be located at the protected object in accordance with the requirements so that they are protected from direct sunlight, heat flows, mechanical influences and other adverse factors (vibration, aggressive environment, high humidity, etc.). They must be clearly visible and easily accessible in the event of a fire. It is preferable to place fire extinguishers near the places where fire is most likely to occur, along the paths of the passage, as well as near the exit from the premises. Fire extinguishers should not interfere with the evacuation of people during a fire. According to fire safety requirements [16,17], there are 2 Powder fire extinguisher 3 fire extinguishers on the floor (portable powder fire extinguishers), staircases are equipped with hydrants, there is a fire alarm button.

5.1.6 Electrical safety

Electrical safety is a system of organizational and technical measures and means to protect people from harmful and dangerous effects of electric current, electric arc, electromagnetic field and static electricity in accordance with [19]. Electric current passing through the human body produces thermal, chemical and biological effects, thereby disrupting normal life activity. Employees hired to perform work in electrical installations must have professional training appropriate to the nature of the work.

Electric shock occurs when it comes into contact with an electrical circuit in which there are voltage sources and / or current sources that can cause current to flow through the part of the body that is under voltage. It is usually sensitive for humans to pass a current of more than 1 mA. In addition, in high voltage installations, an electric shock is possible without touching current-carrying elements, as a result of current leakage or breakdown of an air gap with the formation of an electric arc.

As part of the current work, no contacts were made with open sources of electric current. The current flowing in the computer peripherals (computer mouse, keyboard) does not pose a significant danger to human health. According to the classification, this laboratory is suitable for class 1 premises in which operating voltages do not exceed 1,000 V [18, 19].

5.1.7 Radiation safety

Increased level of ionizing studies in the work area. Dangerous and harmful production factors associated with an increased level of ionizing radiation include the following types of radiation [22]:

a) short-wave electromagnetic radiation (fluxes of high-energy photons) - X-rays and gamma radiation;

b) particle flows:

– beta particles (electrons and positrons);

– alpha particles (nuclei of an atom of helium-4);

– neutrons;

– protons, other ions, muons, etc.;

– fission fragments (heavy ions arising from nuclear fission);

c) radiation caused by radioactive contamination (above the natural background), including contamination with man-made radionuclides:

– radioactive contamination of the air in the working area (due to the presence of radioactive gases radon, thoron, actinon, products of their radioactive decay, aerosols containing radionuclides);

– radioactive contamination of surfaces and materials of the working environment, including protective equipment for workers and their skin.

As a result of the impact of ionizing radiation on the human body, the normal course of biochemical processes and metabolism are disrupted. Depending on the size of the absorbed dose of radiation and on the individual characteristics of the organism. The changes caused can be reversible or irreversible. Any type of ionizing radiation causes biological changes in the body both during external irradiation, when the radiation source is outside the body, and during internal irradiation, when radioactive substances enter the body.

In the course of scientific research, involving theoretical calculations using a computer and no more, work with sources of ionizing radiation was not carried out [22].

5.2 Justification and development of measures to reduce the levels of hazardous and harmful effects and eliminate their influence when working on a PC

5.2.1 Organizational arrangements

All personnel are obliged to know and strictly follow the safety regulations. Personnel training in safety and industrial sanitation consists of induction and on-the-job instruction by the responsible person.

An employee's knowledge of safety regulations is tested by a qualification commission after training at the workplace. Subsequently, the employee is assigned a safety qualification group corresponding to his knowledge and work experience and a special certificate is issued.

Persons serving electrical installations should not have injuries and diseases that interfere with production work. Before employment, the state of health is established by a medical examination.

5.2.2 Technical measures

For the rational organization of the workplace, it is necessary to have order, the constancy of finding objects, documents and means of labor. Items that are used to perform various works should be in the area of easy reach of the workspace, as shown in figure 47.

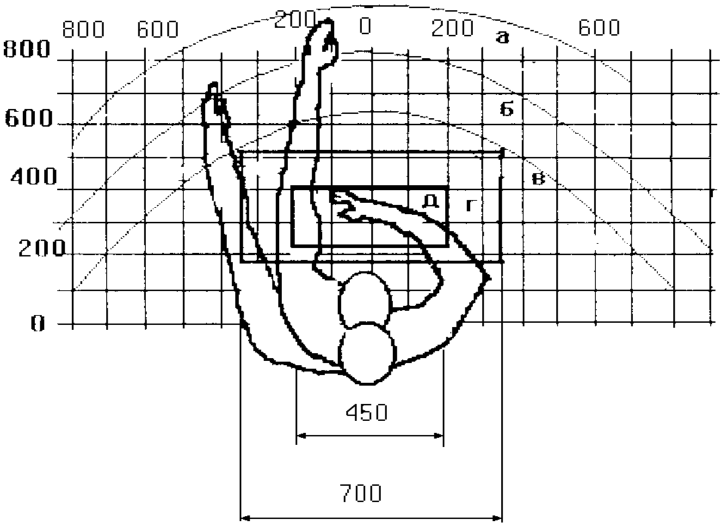


Figure 47 - Areas of reach of hands in the horizontal plane: a - area of maximum reach of hands; b - the reach of the fingers with an outstretched hand; c - zone of easy palm reach; d - optimal space for rough manual work; d - optimal space for delicate handwork

Optimal placement of objects of work and documentation in the reach of the hands:

– the display is located in zone a (in the center);

– keyboard - in the g / d zone;

– the system unit is located in zone b (left);

– the printer is in area a (right);

– literature and documentation required during work is placed in the easy reach of the palm - in (left);

– literature that is not used is constantly placed in the drawers of the table.

When designing a writing desk, the following requirements should be taken into account.

The height of the working surface of the table should be 680-800 mm. If the working surface of the table has a computer keyboard, its height should be 650 mm. The working table itself must be at least 700 mm wide and at least 1400 mm long. It is also necessary to have space for legs, the height of which should be at least 600 mm, and the width - at least 500 mm, the depth at the knee level - not less than 450 mm, and at the level of the outstretched legs - at least 650 mm.

It is necessary to have a working chair of the lifting-swivel type with the ability to adjust the height and angles of the seat and backrest, as well as the distance of the backrest to the front edge of the seat. The recommended seat height in relation to the floor is 420-550 mm. By design, the seat must have a minimum width and depth of 400 mm of the seat surface and the seat surface must have a recessed front edge.

The eye level of the computer operator should be located at a distance of 500-600 mm from the monitor, and according to the standards, the viewing angle in the horizontal plane to the normal of the monitor screen should not exceed 45º, and the best angle is 30 º. It is also necessary to be able to select the level of contrast and brightness of the screen image.

You must be able to adjust the screen:

– in height +3 cm;

– tilt from 10 to 20 degrees relative to the vertical;

– in the left and right directions.

The keyboard should be placed on the table at a distance of 100-300 mm from its edge, and the normal placement of the keyboard is the level of the operator's elbow with an angle of inclination to the horizontal plane of 15º. A keyboard in which the keys have a rectangular shape with rounded corners and a concave surface is more comfortable to work with. The keyboard should be designed to provide a clickable feel when pressing its keys. It is necessary that the color of the keys is significantly different from the color of the panel.

If mental work is monotonous, requires strong nervous tension and concentration, then it is necessary to choose shades that do not distract or scatter attention (low-saturated shades of cold green or blue colors). For work that requires intense and mental tension, you need to take shades of warm tones, since they excite a person's activity [24,25].

5.3 Emergency situations

Emergency situation (ES) - a situation in a certain territory resulting from an accident, a dangerous natural phenomenon, catastrophe, natural or other disaster, which may or did entail human casualties, damage to human health or the environment, significant material losses and disruption living conditions of people [29]. There are two types of emergencies:

– technogenic;
– natural.

Man-made emergencies include fires, explosions, sabotage, emissions of toxic substances. Natural disasters include natural disasters. The most likely man-made emergencies are fires.

Accident hazards include a sudden and uncontrollable source of energy: a moving object, uncontrollable movement or energy.

Let's consider possible emergencies in the classroom laboratory No. 118 of the educational building No. 10 of TPU, namely:

– occurrence of a fire;
– electric shock;
– falling from the height of one's own growth;
– falling from a ladder.

Measures to prevent and eliminate the above emergencies are presented in Table 5.4.

Table 5.4 – Emergency situations, measures to prevent emergencies and eliminate the consequences of an emergency

№	Emergency situation	Emergency prevention measures	Measures to eliminate the consequences of an emergency
1	Falling from height	1. Maintenance of the premises in proper order. 2. Limitation of working space. 3. Timely briefing.	1. Examine or interview the victim; 2.if necessary - call an ambulance; 3. stop bleeding, if any; 4. if there is a suspicion that the victim has a broken spine (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.
2	Corresponding growth	1. Covering stair steps with anti-slip coating. 2. Timely briefing.	1. Call an ambulance; 2. stop bleeding, if any; 3. if there is a suspicion that the victim has a broken spine (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.
3	Falling down the stairs	1. Grounding of all electrical installations. 2. Limitation of working space. 3. Ensuring the inaccessibility of live parts of the equipment. 4. Timely briefing.	1. Quickly release the victim from the action of the electric current [26]; 2. call an ambulance; 3. if the victim has lost consciousness, but breathing is preserved, he should be laid down comfortably, unbuttoned tight clothing, create an influx of fresh air and ensure complete rest;

			4. the victim should be allowed to smell ammonia, sprinkle water on his face, rub and warm the body; 5. In the absence of breathing, artificial respiration and heart massage should be done immediately.
4	Electric shock	1. Timely briefing. 2. Establishment of means of automatic fire extinguishing in premises. 3. Installation of smoke and fire detectors. 4. Providing evacuation routes and maintaining them in proper condition. 4. Control of the work of electrical appliances.	1. De-energize the room, cut off the air supply; 2. immediately report the fire to the duty officer or to the guard post; 3. If possible, take measures to evacuate people, extinguish a fire and save material assets.

This section discusses potential emergencies that may arise when working in laboratory classroom No. 118 of educational building No. 10. Measures to prevent and eliminate the consequences of these situations are considered, according to [23].

5.4 Chapter Conclusions

The chapter discusses harmful and dangerous factors:

– microclimate [13];
– noise [14];
– illumination [15];
– fire hazard [16, 17];
– electrical safety [18, 19,20];
– electromagnetic radiation [21];
– radiation safety [22].

The audience in question is assigned to class B for fire hazard [16] and 1 for electrical safety [18,19].

Also considered are the causes and means of protection, emergencies and emergencies, measures to prevent them, measures to eliminate their consequences. The radiation safety of work and the potential hazard from electromagnetic radiation were considered separately.

Conclusion

A change in the coefficient of turbulence of the atmosphere strongly changes the profile of the volumetric activity of radon, especially at the earth's surface.

It was experimentally found that at heights of 1 and 25, radon VA decreases with altitude in the summer. In the autumn period, OA at a height of 1 and 25 m are practically equal, however, in some areas, VA is higher at an altitude of 25.

It was experimentally established that the best convergence with real measurements was obtained with the coefficient of turbulent diffusion as a function of height and time.

When simulating using the traditional model, no convergence with the experimental data was found. It is concluded that the traditional model does not describe the real research results.

Modeling with the modified model showed a good relationship with experimental data. It is concluded that when modeling the vertical component of radon VA, it is necessary to take into account the wind speed.

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