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)

Инженерная школа ядерных технологий
Направление подготовки 14.04.02 Ядерные физика и технологии
ООП/ОПОП Ядерная и радиационная безопасность
Отделение школы (НОЦ) Отделение ядерного топливного цикла

ВЫПУСКНАЯ КВАЛИФИКАЦИОННАЯ РАБОТА МАГИСТРАНТА

Тема работы
Исследование вертикального профиля объемной активности изотопов радона в атмосфере при различных метеоусловиях

УДК 550.42:546.296.027:551.51

Обучающийся

Группа	ФИО	Подпись	Дата
0АМ13	Урманов Аслан Русланович		

Руководитель ВКР

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОЯТЦ	Яковлева В.С.	Д.т.н.		

Консультант

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОЯТЦ	Гоголев С.Ю.	К.ф-м.н.		

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОСГН	Спицина Л.Ю.	К.э.н.		

По разделу «Социальная ответственность»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОЯТЦ	Передерин Ю.В.	К.т.н.		

ДОПУСТИТЬ К ЗАЩИТЕ:

Руководитель ООП/ОПОП, должность	ФИО	Ученая степень, звание	Подпись	Дата
Ст. преподаватель ОЯТЦ	Семенов А.О.	К.т.н.		

Томск – 2023г.

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
MEP/MPEP Nuclear and radiation safety
Nuclear Fuel Cycle Division

GRADUATE QUALIFICATION WORK OF A MASTER STUDENT

Work theme
Study of the vertical profile of the volumetric activity of radon isotopes in the atmosphere under various weather conditions

UDC 550.42:546.296.027:551.51

Student

Group	**Full name**	**Signature**	**Date**
0AM13	Urmanov Aslan Ruslanovich		

Scientific supervisor

Position	**Full name**	**Academic degree, rank**	**Signature**	**Date**
Professor NFCD	Yakovleva V.S.	Doctor of technical sciences		

Scientific advisor

Position	**Full name**	**Academic degree, rank**	**Signature**	**Date**
Assistant professor NFCD	Gogolev S.Y.	Candidate of Physical and Mathematical Sciences		

ADVISERS:

Section “Financial Management, Resource Efficiency and Resource Saving”

Position	**Full name**	**Academic degree, rank**	**Signature**	**Date**
Assistant professor	Spitsina L.Y.	Ph.D.		

По разделу «Социальная ответственность»

Position	**Full name**	**Academic degree, rank**	**Signature**	**Date**
Assistant professor	Perederin Y.V.	Ph.D.		

ADMITTED TO DEFENSE:

Programme Director	**Full name**	**Academic degree, rank**	**Signature**	**Date**
Senior lecturer NFCD	Semenov A.O.	Ph.D.		

Tomsk – 2023г.

ПЛАНИРУЕМЫЕ РЕЗУЛЬТАТЫ ОСВОЕНИЯ ООП/ОПОП

Код компетенции	**Наименование компетенции**
Универсальные компетенции	
УК(У)-1	Способен осуществлять критический анализ проблемных ситуаций на основе системного подхода, вырабатывать стратегию действий
УК(У)-2	Способен управлять проектом на всех этапах его жизненного цикла
УК(У)-3	Способен организовывать и руководить работой команды, вырабатывая командную стратегию для достижения поставленной цели
УК(У)-4	Способен применять современные коммуникативные технологии, в том числе на иностранном (-ых) языке (-ах), для академического и профессионального взаимодействия
УК(У)-5	Способен анализировать и учитывать разнообразие культур в процессе межкультурного взаимодействия
УК(У)-6	Способен определять и реализовывать приоритеты собственной деятельности и способы ее совершенствования на основе самооценки
Общепрофессиональные компетенции	
ОПК(У)-1	Способен формулировать цели и задачи исследования, выбирать критерии оценки, выявлять приоритеты решения задач
ОПК(У)-2	Способен применять современные методы исследования, оценивать и представлять результаты выполненной работы
ОПК(У)-3	Способен оформлять результаты научно-исследовательской деятельности в виде статей, докладов, научных отчетов и презентаций с использованием систем компьютерной верстки и пакетов офисных программ
Профессиональные компетенции	
ПК(У)-1	Способность к созданию теоретических и математических моделей в области ядерной физики и технологий
ПК(У)-2	Готовность применять методы исследования и расчета процессов, происходящих в современных физических установках и устройствах в области ядерной физики и технологий
ПК(У)-3.	Готовность разрабатывать практические рекомендации по использованию результатов научных исследований
ПК(У)-4.	Способность оценивать риск и определять меры безопасности для новых установок и технологий, составлять и анализировать сценарии

	потенциально возможных аварий, разрабатывать методы уменьшения риска их возникновения
ПК(У)-5.	Способность к анализу технических и расчетно-теоретических разработок, к учету их соответствия требованиям законов РФ в области ядерной и радиационной безопасности, атомной энергии
ПК(У)-6.	Способность объективно оценить предлагаемое решение или проект по отношению к современному мировому уровню, подготовить экспертное заключение
ПК(У)-7.	Способность формулировать технические задания, использовать информационные технологии и пакеты прикладных программ при проектировании и расчете физических установок, использовать знания методов анализа эколого-экономической эффективности при проектировании
ПК(У)-8	Готовность применять методы оптимизации, анализа вариантов, поиска решения многокритериальных задач, учета неопределенностей при проектировании
ПК(У)-9.	Способность решать задачи в области развития науки, техники и технологии с учетом нормативного правового регулирования в сфере интеллектуальной собственности
ПК(У)-10.	Готовность к преподавательской деятельности по основным образовательным программам высшего образования и дополнительного профессионального образования (ДПО)
ПК(У)-11.	Способность к проектированию и экономическому обоснованию инновационного проекта, содержания, структуры и порядка его разработки

PLANNED RESULTS OF DEVELOPMENT OF MEP/MPEP

Code competencies	Name of competence
Universal competencies	
UK(U)-1	Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy
UK(U)-2	Able to manage a project at all stages of its life cycle
UK(U)-3	Able to organize and manage the work of the team, developing a team strategy to achieve the goal
UK(U)-4	Able to apply modern communication technologies, including in foreign language(s), for academic and professional interaction
UK(U)-5	Able to analyze and take into account the diversity of cultures in the process of intercultural interaction
UK(U)-6	Able to determine and implement the priorities of their own activities and ways to improve it based on self-assessment
General professional competencies	
OPK(U)-1	Able to formulate goals and objectives of the study, choose evaluation criteria, identify priorities for solving problems
OPK(U)-2	Able to apply modern research methods, evaluate and present the results of the work performed
OPK(U)-3	Able to draw up the results of research activities in the form of articles, reports, scientific reports and presentations using computer layout systems and office software packages
Professional competencies	
PK(U)-1	Ability to create theoretical and mathematical models in the field of nuclear physics and technology
PK(U)-2	Willingness to apply methods of research and calculation of processes occurring in modern physical installations and devices in the field of nuclear physics and technology
PC(U)-3.	Willingness to develop practical recommendations for the use of research results
PC(U)-4.	Ability to assess risk and determine safety measures for new installations and technologies, compose and analyze scenarios of potential accidents, develop methods to reduce the risk of their occurrence

PC(U)-5.	Ability to analyze technical and computational-theoretical developments, to take into account their compliance with the requirements of the laws of the Russian Federation in the field of nuclear and radiation safety, atomic energy
PC(U)-6.	The ability to objectively evaluate the proposed solution or project in relation to the modern world level, prepare an expert opinion
PC(U)-7.	The ability to formulate terms of reference, use information technology and application packages in the design and calculation of physical installations, use knowledge of methods for analyzing environmental and economic efficiency in design
PK(U)-8	Willingness to apply methods of optimization, analysis of options, search for solutions to multi-criteria problems, accounting for uncertainties in design
PC(U)-9.	Ability to solve problems in the field of development of science, engineering and technology, taking into account legal regulation in the field of intellectual property
PC(U)-10.	Readiness for teaching activities in the main educational programs of higher education and additional professional education (APE)
PK(U)-11.	Ability to design and economic justification of an innovative project, content, structure and procedure for its development

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)

Инженерная школа ядерных технологий
Направление подготовки (ООП/ОПОП) 14.04.02 Ядерные физика и технологии
Отделение школы (НОЦ) Отделение ядерного топливного цикла

УТВЕРЖДАЮ:
Руководитель ООП/ОПОП
_____ _______ Семенов А.О.
(Подпись) (Дата) (ФИО)

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

Обучающийся:

Группа	ФИО
0АМ13	Урманов Аслан Русланович

Тема работы:

Исследование вертикального профиля объемной активности изотопов радона в атмосфере при различных метеоусловиях	
Утверждена приказом директора (дата, номер)	*33-46/с*

Срок сдачи обучающимся выполненной работы:	25.05.2023

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе *(наименование объекта исследования или проектирования; производительность или нагрузка; режим работы (непрерывный, периодический, циклический и т. д.); вид сырья или материал изделия; требования к продукту, изделию или процессу; особые требования к функционированию (эксплуатации) объекта или изделия в плане безопасности эксплуатации, влияния на окружающую среду, энергозатратам; экономический анализ и т. д.)*	*Вертикальный профиль объемной активности радона в атмосфере*
Перечень разделов пояснительной записки подлежащих исследованию, проектированию и разработке *(аналитический обзор литературных источников с целью выяснения достижений мировой науки техники в рассматриваемой области; постановка задачи исследования, проектирования, конструирования; содержание процедуры исследования, проектирования, конструирования; обсуждение результатов выполненной работы; наименование дополнительных разделов, подлежащих разработке; заключение по работе)*	- обзор литературных источников - приборы и методы измерения объемной активнсоти радона в приземной атмосфере - моделирование вертикального профиля объемной активности радона в атмосфере - определение влияния метеоусловий на вертикальный профиль объемной активности радона - анализ полученных результатов - финансовая ответственность - социальная ответственность - заключение по работе
Перечень графического материала *(с точным указанием обязательных чертежей)*	Презентация для защиты ВКР

Консультанты по разделам выпускной квалификационной работы *(с указанием разделов)*	
Раздел	**Консультант**
Социальная ответственность	Передерин Юрий Владимирович
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	Спицина Любовь Юрьевна

Дата выдачи задания на выполнение выпускной квалификационной работы по линейному графику	13.03.2023

Задание выдал руководитель / консультант (при наличии):

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Профессор ОЯТЦ	Яковлева В.С.	Д.т.н.		
Доцент ОЯТЦ	Гоголев С.Ю.	К.ф-м.н.		

Задание принял к исполнению обучающийся:

Группа	**ФИО**	**Подпись**	**Дата**
0АМ13	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

APPROVE:
Head of MEP
_____ _______ Semenov A.O.
(Sign) (Date) (Full name)

TASK
for graduation qualification work

Student:

Group	Full name
0AM13	Urmanov Aslan Ruslanovich

Тема работы:

Study of the vertical profile of the volumetric activity of radon isotopes in the atmosphere under various weather conditions	
Approved by the order of the director (date, number)	*33-46/c*

Deadline for students to submit completed work:	25.05.2023

TECHNICAL TASK:

Initial data for work *(name of the object of study or design; performance or load; mode of operation (continuous, periodic, cyclic, etc.); type of raw material or material of the product; requirements for the product, product or process; special requirements for the functioning (operation) of the object or product in terms of operational safety, environmental impact, energy costs, economic analysis, etc.)*	*Radon volumetric activity in the surface atmosphere*
List of sections of the explanatory note to be researched, designed and developed *(analytical review of literary sources in order to clarify the achievements of the world science of technology in the area under consideration; setting the task of research, design, construction; content of the research, design, construction procedure; discussion of the results of the work performed; name of additional sections to be developed; conclusion on the work)*	*- review of literary sources* *- instruments and methods for measuring radon volumetric activity in the surface atmosphere* *- modeling of the vertical profile of radon volumetric activity in the atmosphere* *- determination of the influence of weather conditions on the vertical profile of radon volumetric activity- analysis of the obtained results* *- financial responsibility* *- Social responsibility* *- summary of the work*
List of graphic material *(with exact specification of required drawings)*	*Presentation for the defense of the FQW*
Consultants for the sections of the final qualifying work	

Chapter	Consultant
Social responsibility	Perederin Yuri Vladimirovich
Financial management, resource efficiency and resource saving	Spitsina Lyubov Yurievna

Date of issue of the assignment for the completion of the final qualification work according to the linear schedule	13.03.2023

The task was issued by the manager

Position	Full name	Academic degree	Sign	Date
Professor NFCD	Yakovleva V.S.	Doctor of technical sciences		
Assistant professor NFCD	Gogolev S.Y.	Candidate of Physical and Mathematical Sciences		

The task was accepted by the student:

Group	Full name	Sign	Date
0AM13	Urmanov Aslan Ruslanovich		

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)

Инженерная школа ядерных технологий
Направление подготовки (ООП/ОПОП) 14.04.02 Ядерные физика и технологии
Уровень образования Магистратура
Отделение школы (НОЦ) Отделение ядерного топливного цикла
Период выполнения (осенний / весенний семестр 2022/2023 учебного года)

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Обучающийся:

Группа	ФИО
0АМ13	Урманов Аслан Русланович

Тема работы:

Исследование вертикального профиля объемной активности изотопов радона в атмосфере при различных метеоусловиях

Срок сдачи обучающимся выполненной работы:	25.05.2023

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
10.04.2023	*Обзор литературных источников*	10
24.04.2023	*Методы измерения объемной активности радона*	15
25.04.2023	*Определение зависимости влияния различных метеоусловий на вертикальный профиль объемной активности радона*	20
26.04.2023	*Создание модели вертикального профиля объемной активности радона при различных метеоусловиях*	20
27.04.2023	*Анализ полученных результатов*	15
04.05.2023	*Финансовая ответственность*	10
05.05.2023	*Социальная ответственность*	10

СОСТАВИЛ:

Руководитель ВКР

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОЯТЦ	Яковлева В.С.	Д.т.н.		

СОГЛАСОВАНО:

Руководитель ООП/ОПОП

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Ст. преподаватель ОЯТЦ	Семенов А.О.	К.т.н.		

Обучающийся

Группа	ФИО	Подпись	Дата
0АМ13	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
Level of education: Master's degree
Nuclear Fuel Cycle Division
Period of work (fall/spring semester 2022/2023 academic year)

CALENDAR RATING PLAN
completion of the final qualifying work

Student:

Группа	ФИО
0AM13	Urmanov Aslna Ruslanovich

Study theme:

Study of the vertical profile of the volumetric activity of radon isotopes in the atmosphere under various weather conditions

The deadline for the student's completed work:	25.05.2023

Control date	Section name	Maximum score of a section (module)
10.04.2023	*Literature review*	10
24.04.2023	*Methods for measuring the volumetric activity of radon*	15
25.04.2023	*Determination of the dependence of the influence of various weather conditions on the vertical profile of radon volumetric activity*	20
26.04.2023	*Modelling of a vertical profile of radon volumetric activity under various weather conditions*	20
27.04.2023	*Analysis of the results*	15
04.05.2023	*Financial responsibility*	10
05.05.2023	*Social responsibility*	10

COMPOSED:
HEAD OF FQW

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Professor NFCD	Yakovleva V.S.	Doctor of technical sciences		

AGREED:
Head of BEP

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Senior lecturer NFCD	Semenov A.O.	Ph.D.		

Student

Группа	ФИО	Подпись	Дата
0AM13	Urmanov Aslan Ruslanovich		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

Группа	ФИО
0АМ13	Урманову Аслану Руслановичу

Школа	ИЯТШ	**Отделение школы (НОЦ)**	ОЯТЦ
Уровень образования	Магистратура	**Направление/специальность**	14.04.02 Ядерные физика и технологии

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. *Стоимость ресурсов научного исследования (НИ): материально-технических, энергетических, финансовых, информационных и человеческих*	*Бюджет проекта – не более 326530.74 руб., в т.ч. затраты по оплате труда – не более 158376.94 руб.*
2. *Нормы и нормативы расходования ресурсов*	*Значение показателя интегральной ресурсоэффективности – не менее 4.2 баллов из 5*
3. *Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования*	*Взносы во внебюджетные фонды – 30%*
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. *Оценка коммерческого и инновационного потенциала НТИ*	*Оценка конкурентоспособности SWOT анализ*
2. *Разработка устава научно-технического проекта*	*Структура работы, определение трудоемкости, разработка графика исследований*
3. *Планирование процесса управления НТИ: структура и график проведения, бюджет, риски и организация закупок*	*Расчет бюджета на выполнение исследования*
4. *Определение ресурсной, финансовой, экономической эффективности*	*Интегральный финансовый показатель. Интегральный показатель эффективности использования ресурсов. Интегральный показатель эффективности*
Перечень графического материала (с точным указанием обязательных чертежей):	
1. *«Портрет» потребителя результатов НТИ* 2. *Оценка конкурентоспособности технических решений* 3. *Матрица SWOT* 4. *Диаграмма Ганта* 5. *График проведения и бюджет НТИ* 6. *Оценка ресурсной, финансовой и экономической эффективности НТИ*	

Дата выдачи задания для раздела по линейному графику	13.03.23

Задание выдал консультант:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
доцент ОСГН ШБИП ТПУ	Спицына Любовь Юрьевна	к.э.н.		

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0АМ13	Урманов Аслан Русланович		

TASK FOR SECTION

"FINANCIAL MANAGEMENT, EFFICIENCY OF RESOURCES AND ECONOMY OF RESOURCES"

Student:

Group	Full name
0AM13	Urmanov Aslan Ruslanovich

School	**SNSE**	**Research and Education Centr**	**DNFC**
The level of education	Master's degree	**Direction/ specialty**	14.04.02 Nuclear physics and technology

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	The project budget is no more than 326530.74 rubles, incl. labor costs - no more than 158376.94 rubles.
2. Rates and rates of resource consumption	Electricity tariff 2.45 rubles. for 1 kW * h
3. The used system of taxation, rates of taxes, deductions, discounting and crediting	Contributions to extrabudgetary funds - 30%
List of questions to be researched, designed and developed:	
1. Assessment of the potential, prospects and alternatives to the NI position of resource efficiency and resource conservation	Calculation of competitiveness SWOT analysis
2. Formation of a plan and schedule for development and introducing NI	Work structure, determination of labor intensity, development of a research schedule
3. Drawing up the budget of the NI	Calculation of the budget for the implementation of research
4. Assessment of the resource, financial, budget efficiency of scientific research	Integral financial indicator. An integral indicator of resource efficiency. Integral efficiency indicator
List of graphic material (with exact indication of the required drawings)	
1. "Portrait" of the consumer *2. Assessment of the competitiveness of scientific research* *3. SWOT Matrix* *4. Gantt chart* *5. NI budget* *6. The main indicators of the effectiveness of research*	

Date of issue of the task for the section on a line chart	13.03.2023

The assignment was given by the consultant:

Position	ФИО	Academic degree, title	Signature	Data
Assistant professor	Spitsyna Lyubov Yurievna	Ph.D.		

The student accepted the assignment:

Group	Full name	Signature	Data
0AM13	Urmanov Aslan Ruslanovich		

ЗАДАНИЕ К РАЗДЕЛУ
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Обучающемуся:

Группа	ФИО
0АМ13	Урманову Аслану Руслановичу

Школа	ИЯТШ	Отделение (НОЦ)	ОЯТЦ
Уровень образования	Магистратура	**Направление/ООП/ОПОП**	Ядерная и радиационная безопасность

Исходные данные к разделу «Социальная ответственность»:	
1. Описание организационных условий реализации социальной ответственности − заинтересованные стороны (стейкхолдеры) программ социальной ответственности организации, проекта, инновационной разработки, на которых они оказывают воздействие; − стратегические цели организации, проекта, внедрения инновации, которые нуждаются в поддержке социальных программ; − цели текущих программ социальной ответственности организации	*Объект исследования: динамика плотности потока радона в приземной атмосфере. Заинтересованные стороны: службы радиационной безопасности.*
2. Законодательные и нормативные документы	
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. Правовые и организационные вопросы обеспечения безопасности: − специальные (характерные при эксплуатации объекта исследования, проектируемой рабочей зоны) правовые нормы трудового законодательства; − организационные мероприятия при компоновке рабочей зоны.	*− Трудовой кодекс Российской Федерации от 30.12.2001 N 197-ФЗ (ред. от 24.04.2020); − ГОСТ 22269-76. Система «человекмашина». Рабочее место оператора. Взаимное расположение элементов рабочего места. Общие эргономические требования.*
2. Производственная безопасность: 2.1. Анализ выявленных вредных и опасных факторов 2.2. Обоснование мероприятий по снижению воздействия	*Вредные и опасные факторы: − отклонение показателей микроклимата; − повышенный уровень электромагнитных излучений; − недостаточная освещенность рабочей зоны; − повышенный уровень шума; − опасность поражения электрическим током; − пожаровзрывоопасность*

Дата выдачи задания к разделу в соответствии с календарным учебным графиком	13.03.2023

Задание выдал консультант по разделу «Социальная ответственность»:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент	Передерин Ю.В.	к.т.н		

Задание принял к исполнению обучающийся:

Группа	ФИО	Подпись		Дата
0АМ13	Урманов Аслан Русланович			

TASK FOR SECTION
"SOCIAL RESPONSIBILITY"

To the student:

Group	Full name
0AM13	Urmanov Aslan Ruslanovich

School	SNSE	Research and Education Centr	DNFC
The level of education	Masters	**Direction/ specialty**	14.04.02 Radiological Safety

Subject FQW:

Investigation of seasonal trends in density dynamics radon flow from the earth's surface

Initial data for the section "Social responsibility":	
1. Characteristics of the research object (substance, material, device, algorithm, technique, working area) and its scope	*Object of research: dynamics of radon flux density in the surface atmosphere.* *Stakeholders: Radiation safety services.*
List of questions to be researched, designed and developed:	
1. Legal and organizational security issues: - special (typical for the operation of the research object, the projected working area) legal norms of labor legislation; -organizational measures for the layout of the working area.	*− Labor Code of the Russian Federation dated 12/30/2001 N 197-FZ (as amended on 04/24/2020);* *− GOST 22269-76. "man-machine" system. Operator's workplace;* *Mutual arrangement of elements of the workplace. General ergonomic requirements.*
2. Industrial safety: **2.1. Analysis of the identified harmful and dangerous factors** **2.2. Rationale for mitigation measures**	Harmful and dangerous factors: - deviation of microclimate indicators; - increased noise level; - insufficient illumination of the working area; - increased level of electromagnetic radiation; - danger of electric shock; - firesexplosion hazard.

Date of issue of the task for the section on a line chart	13.03.2023

The assignment was given by the consultant:

Position	Full name	Academic degree, title	Signature	date
Associate Professor	Perederin Yuriy Vladimirovich	Ph.D		

The student accepted the assignment:

Group	Full name	Signature	date
0AM13	Urmanov Aslan Ruslanovich		

Essay

The final qualifying work contains 109 pages, 39 figures, 26 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

DPD - Daughter products of the decay

VA - Volumetric activity

EEVA - Equivalent equilibrium volumetric activity

IR - Ionizing radiation

FD - 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.

The purpose of the work: To study the vertical profile of the volumetric activity of radon isotopes in the atmosphere under various weather conditions.

Tasks:

1. To study instruments and methods for measuring the volumetric activity of Rn^{222} and its DPD;

2. Simulate the vertical transport of Rn^{222} radionuclides and its DPD in the atmosphere under various atmospheric conditions;

3. To study the influence of the content of radium-226 and thorium-232 in the soil on the vertical profile of the VA of radon and DPD isotopes;

4. Analyze the results and draw 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.

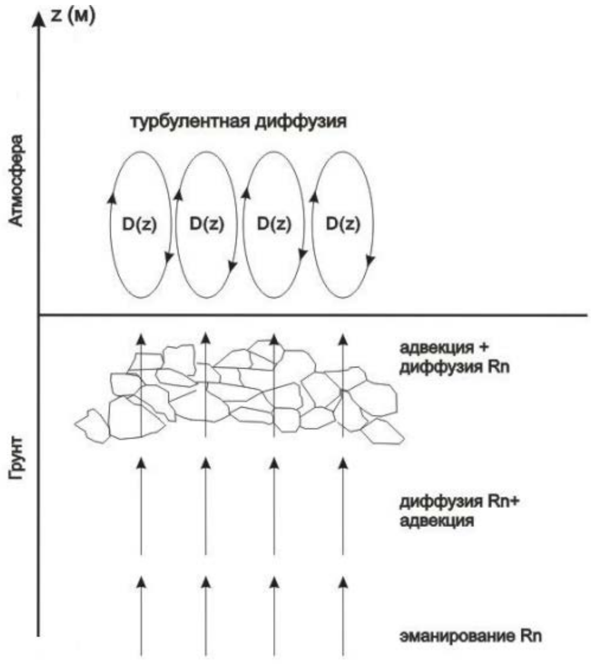


Figure 1 - Generalized scheme of radon transport in the "soil-atmosphere" system using the mechanisms of diffusion, advection and turbulent diffusion

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.

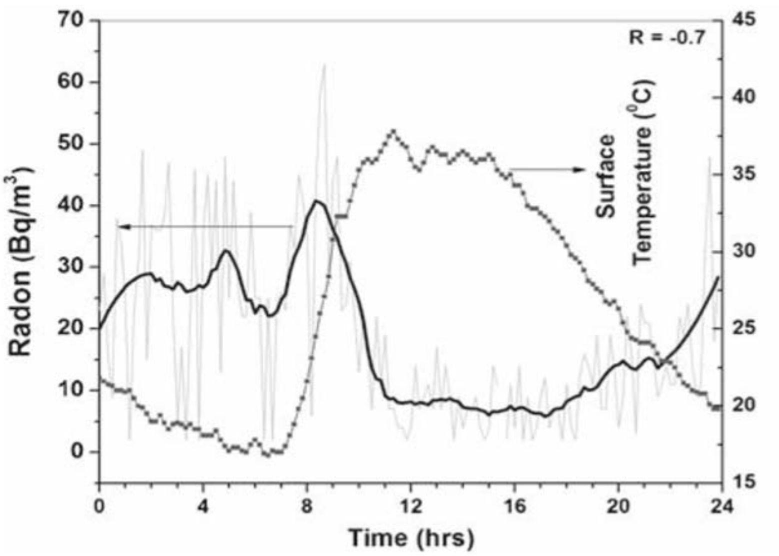


Figure 2 - Daily variations in hourly mean radon concentrations

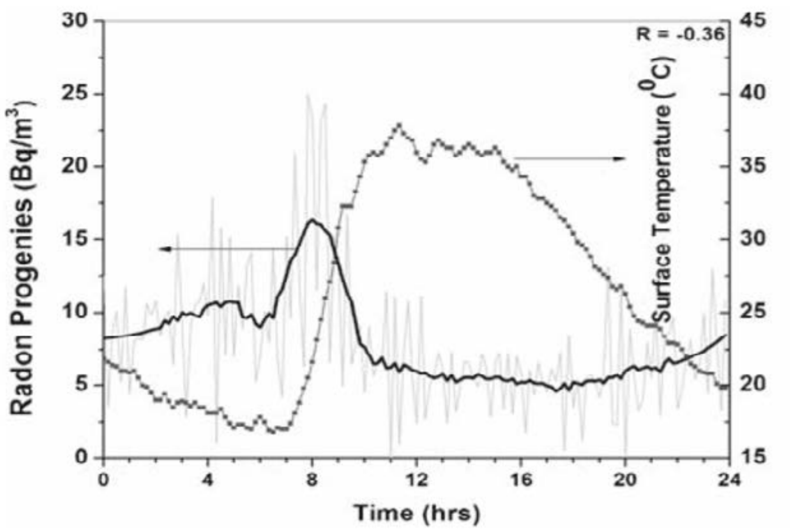


Figure 3 - Daily variations in the activity of radon DDP

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.

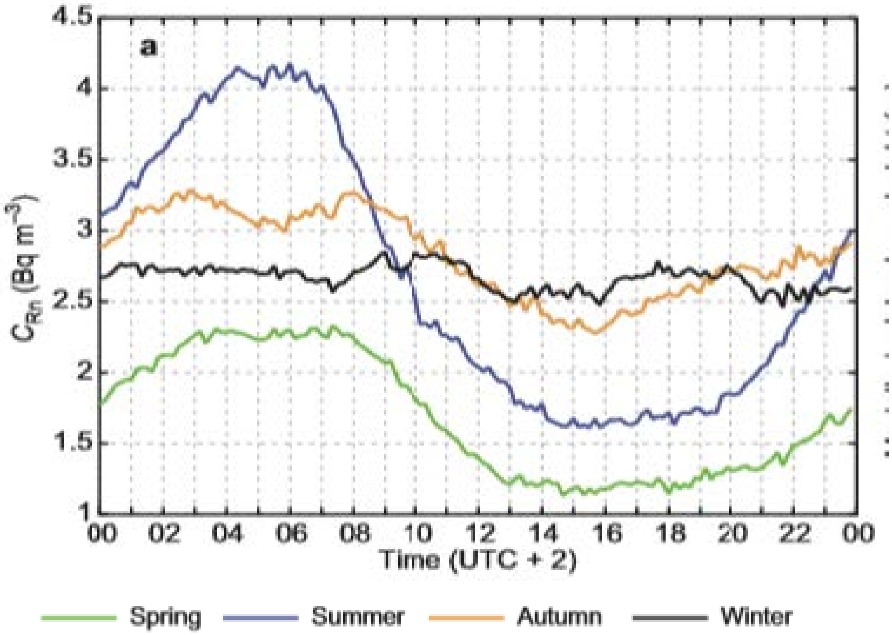


Figure 4 - Diurnal variations in different seasons in median radon concentrations (C_{Rn}) at a resolution of 10 minutes in 2000-2006

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].

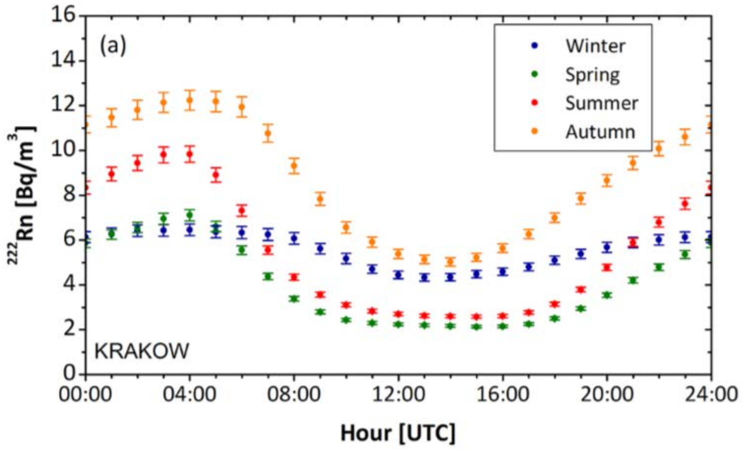


Figure 5 - Daily variations in the concentration of ^{222}Rn in the surface atmosphere over Krakow from January 2005 to December 2009 averaged over each hour and four seasons: winter (DJF), spring (MAM), summer (JJA) and autumn (SON)

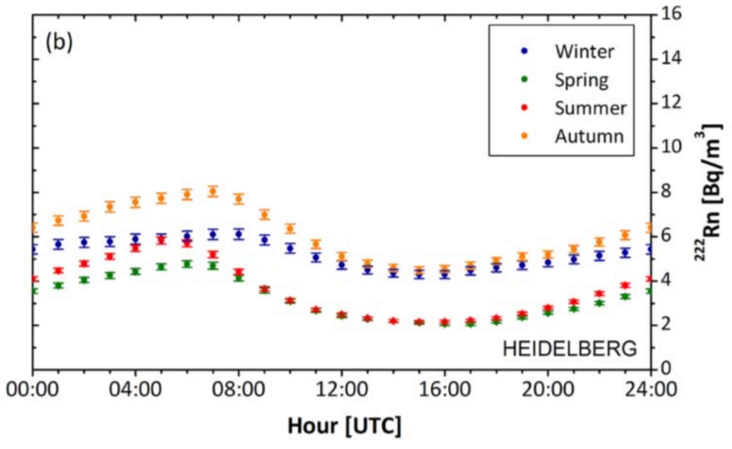


Figure 6 - Daily variations in the concentration of ^{222}Rn in the surface atmosphere over Heidelberg in the period from January 2005 to December 2009 averaged over each hour and four seasons: winter (DJF), spring (MAM), summer (JJA) and autumn (SON)

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].

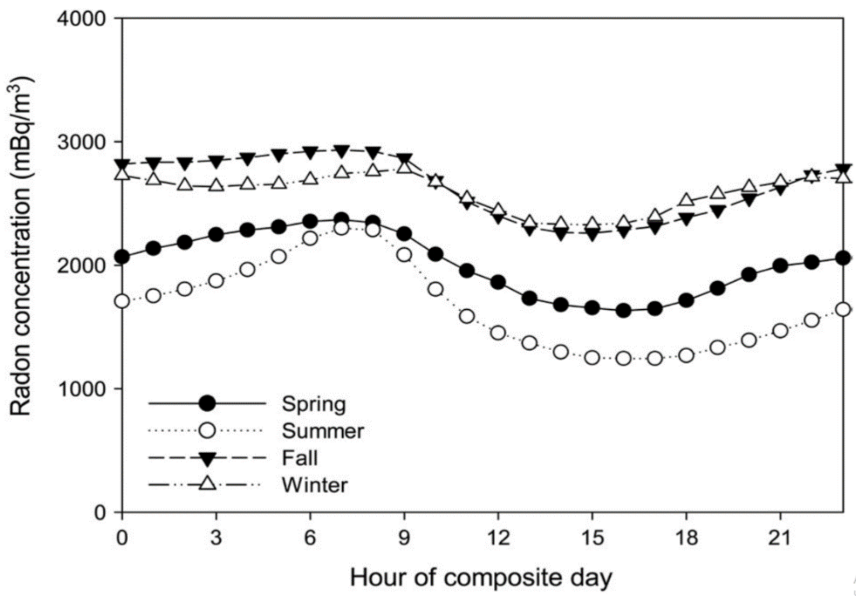


Figure 7 - Daily graph of hourly radon concentrations by season at Gosan station

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].

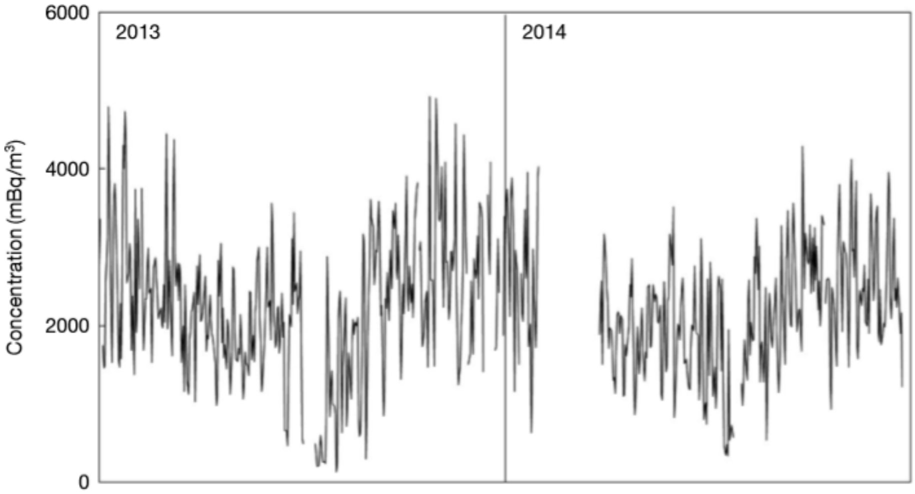


Figure 7 - Annual variation of atmospheric radon concentrations over time series measured at Gosan station in 2013-2014.

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.

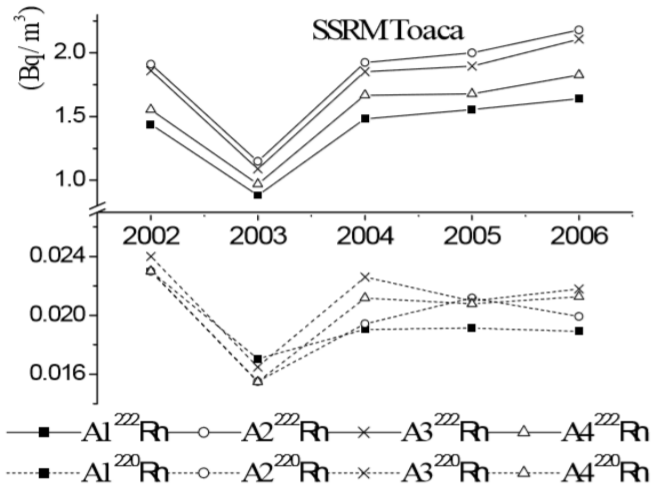


Figure 8 - Annual dynamics of the concentration of ^{222}Rn and ^{220}Rn DDP for aspirations

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.

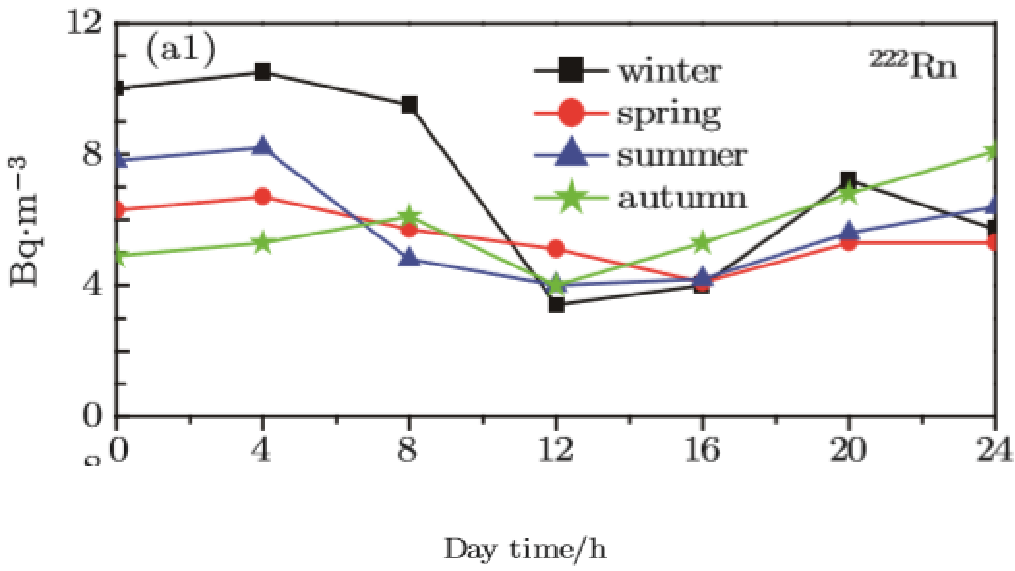


Figure 9 - Average daily variation of ^{222}Rn for each season over one year (November 2014 - October 2015) for surface air measurements in Jeddah, KSA.

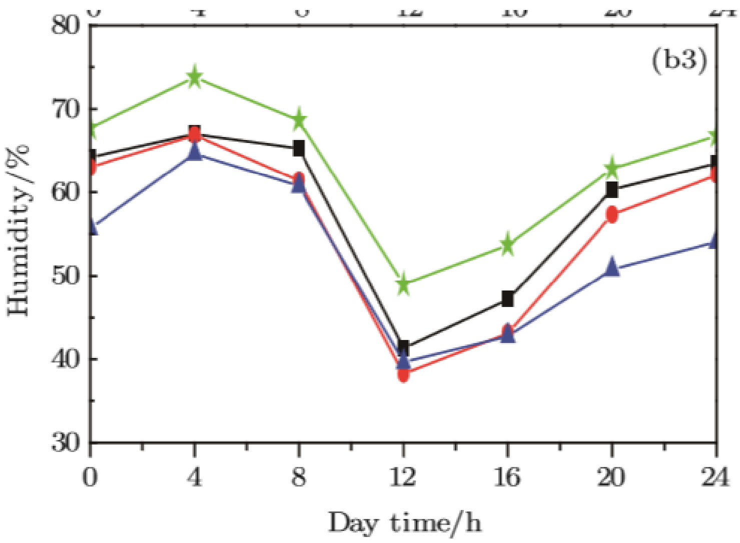


Figure 10 - Average daily change in relative humidity over one year (November 2014 - October 2015) for surface air measurements in Jeddah, KSA

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).

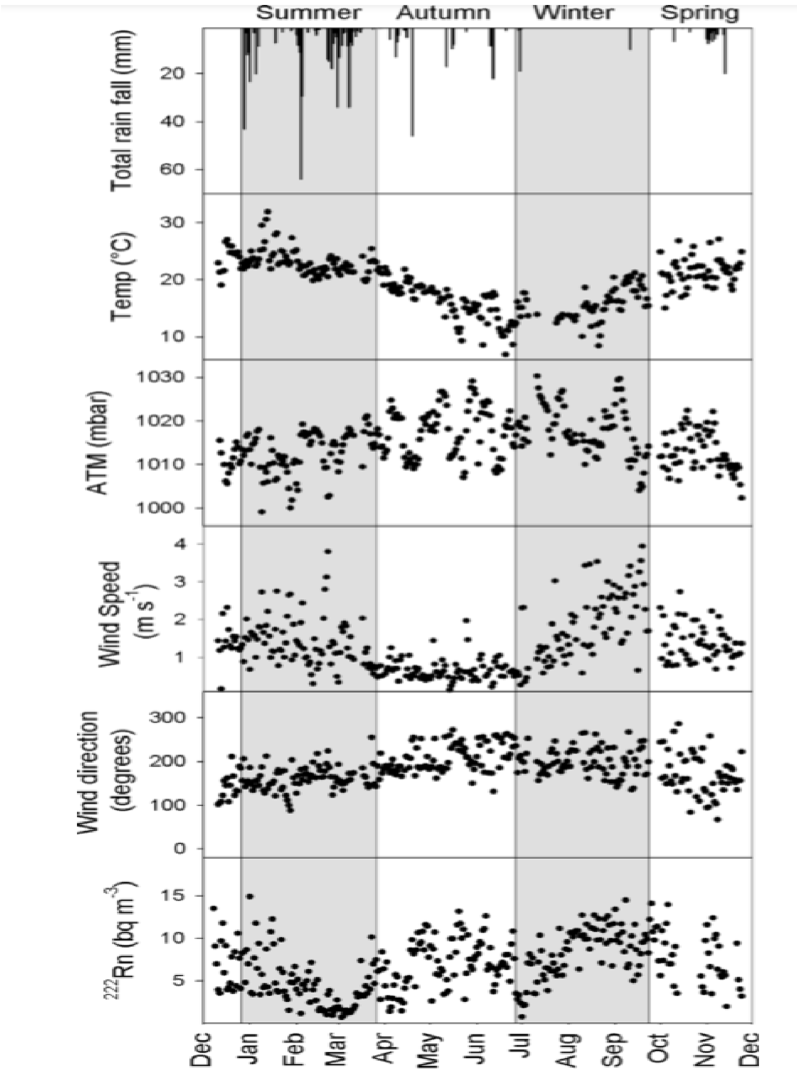


Figure 11 - Average daily precipitation (n = 353), temperature (n = 311), ATM (n = 327), wind speed / direction (n = 328) and ^{222}Rn concentration (n = 353) throughout the study.

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.

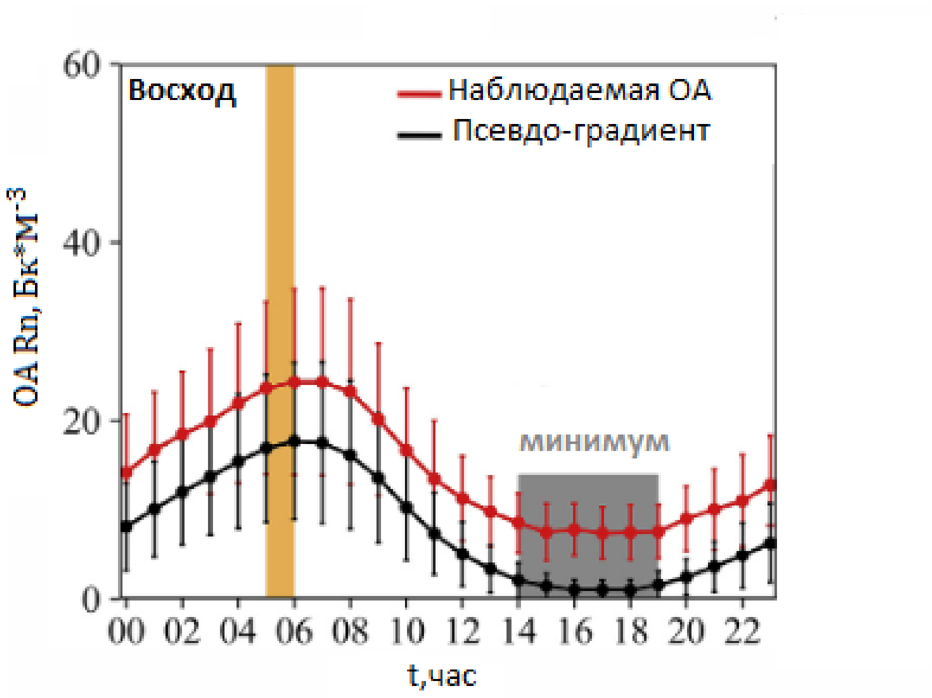


Figure 12 – Summer average value of hourly average daily composites of observed radon and local contribution to radon (pseudo-gradient) in the subalpine basin

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.

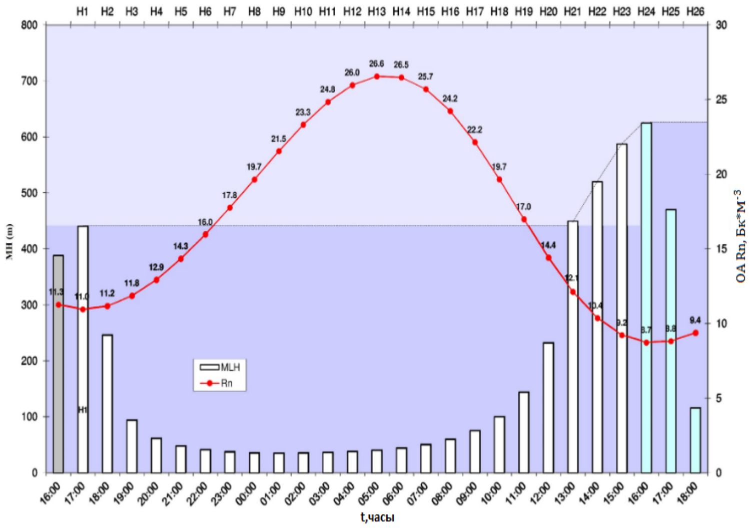


Figure 14 – An example of the equivalent time evolution of the mixing height. Red line and dots represent radon concentration.

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.

Designed for continuous environmental monitoring of the environment by 5 parameters simultaneously (radon, thoron, temperature, humidity, pressure) with the preservation of all measurement results and data output to an IBM PC with a graphical presentation of information. Can be used as an exemplary measuring instrument for verification of other radon radiometers.

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).

2.4 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.

2.5 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 18 and 19, respectively.

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

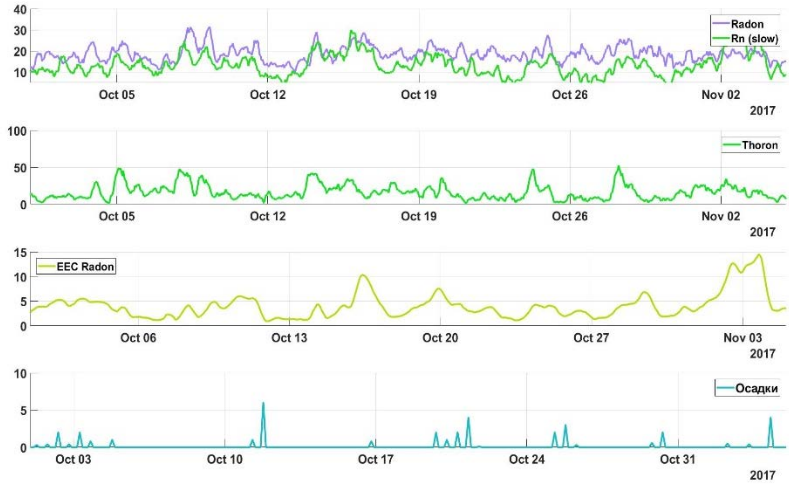


Figure 19 – Dynamics of radon and thoron VA in October at a height of 1 m (green line) and 25 m (purple line)

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.

2.6 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 Description of the traditional model

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;

$D_T(\mathrm{z,t})$ - 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

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

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

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, $м^2/с$	$1.2 \cdot 10^{-5}$
q	10-100
D_t	0,01-10 / K·φ, where φ- unknown function
λ	$2{,}1 * 10^{-6}$

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 20,21,22 respectively.

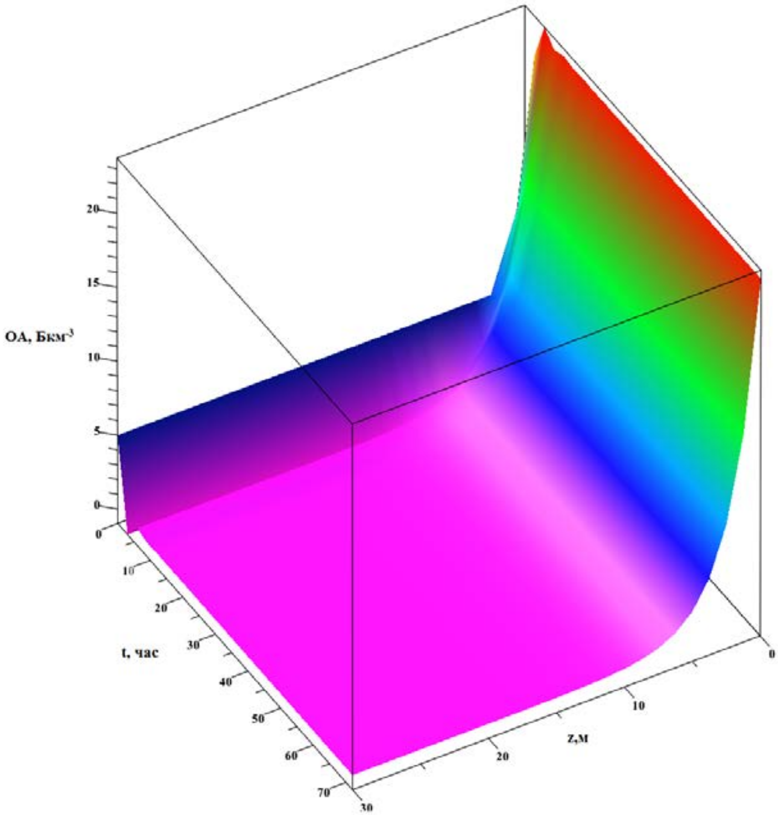


Figure 20 - Model of the vertical distribution of VA ^{222}Rn at D_t = 0.01, Bqm^{-3}

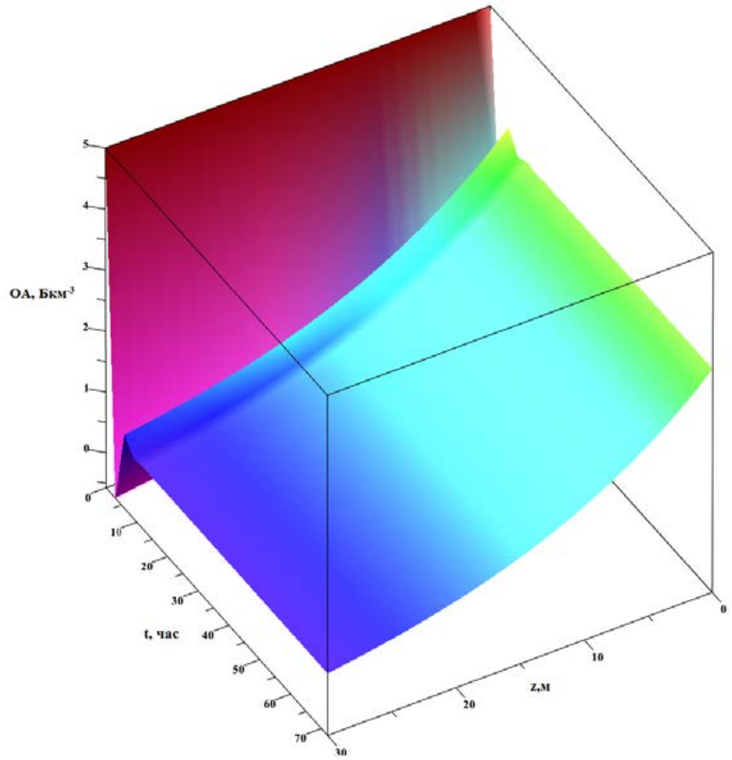


Figure 21 - Model of the vertical distribution of VA ^{222}Rn at D_t = 0.5, Bqm^{-3}

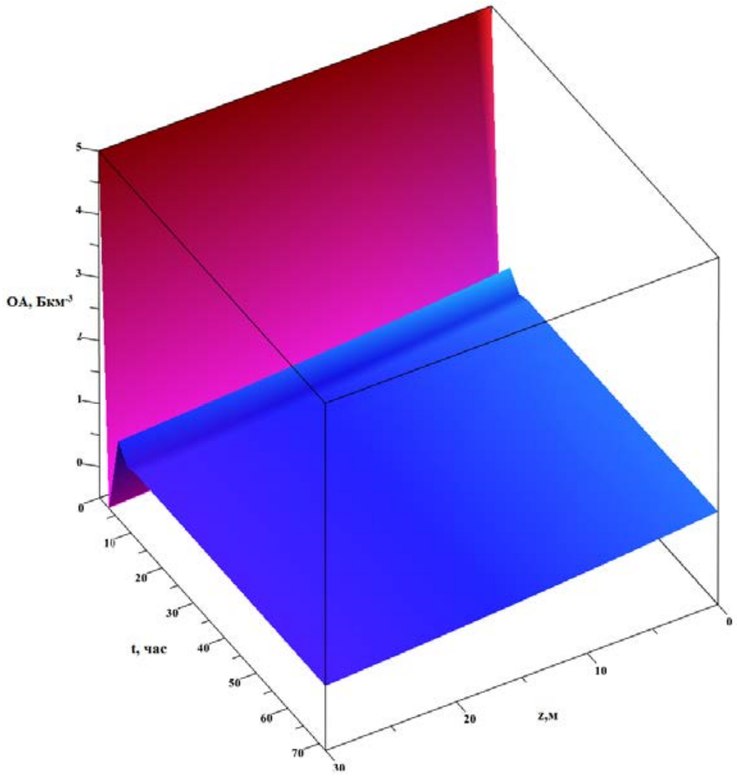


Figure 22 - Model of the vertical distribution of VA ^{222}Rn at D_t = 5, Bqm^{-3}

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 DDP value was chosen to be minimal and amounted to 10 $mBqm^2s^{-1}$ (since even at the minimum DDP 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 23,24,25 respectively.

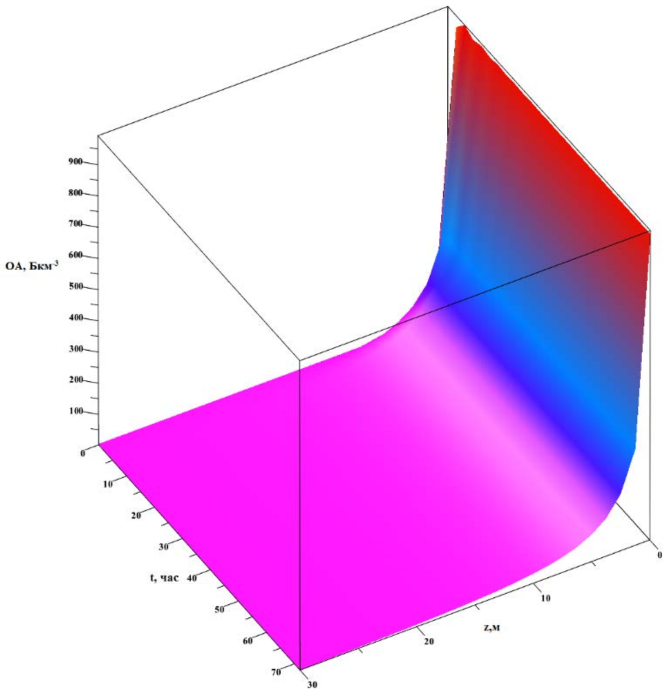
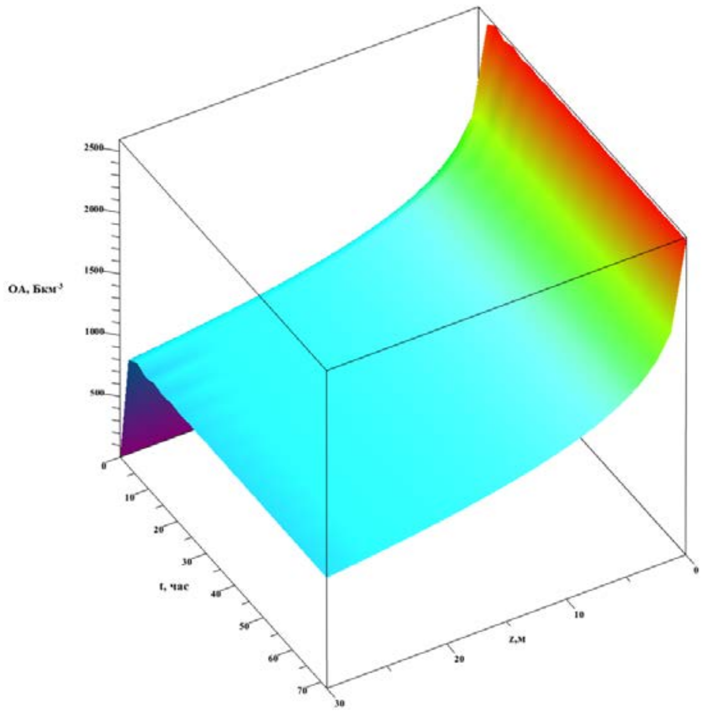


Figure 23 - Model of the vertical distribution of VA Rn222 at Dt = 0.01·z, Bq m^{-3}

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



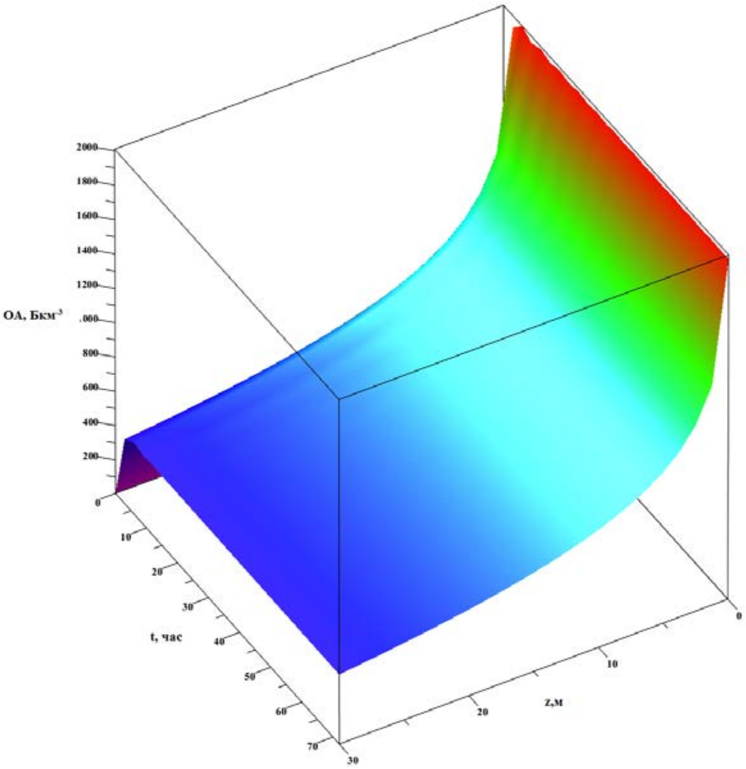


Figure 25 - Model of the vertical distribution of VA ^{222}Rn at Dt = 5·z, Bqm^{-3}

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

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

With an increase in the coefficient of turbulent diffusion, an exponential dependence of VA is observed. Also, with an increase in Dt, the value of VA 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 DDP value was 10 mBqm^{2}s^{-1}. K takes the following values: 0.01. The model obtained for a given value of the turbulent diffusion coefficient is shown in Figure 26. Previously, 4 values for

K were considered, however, with this model, with an increase in K, the equation has a unique solution.

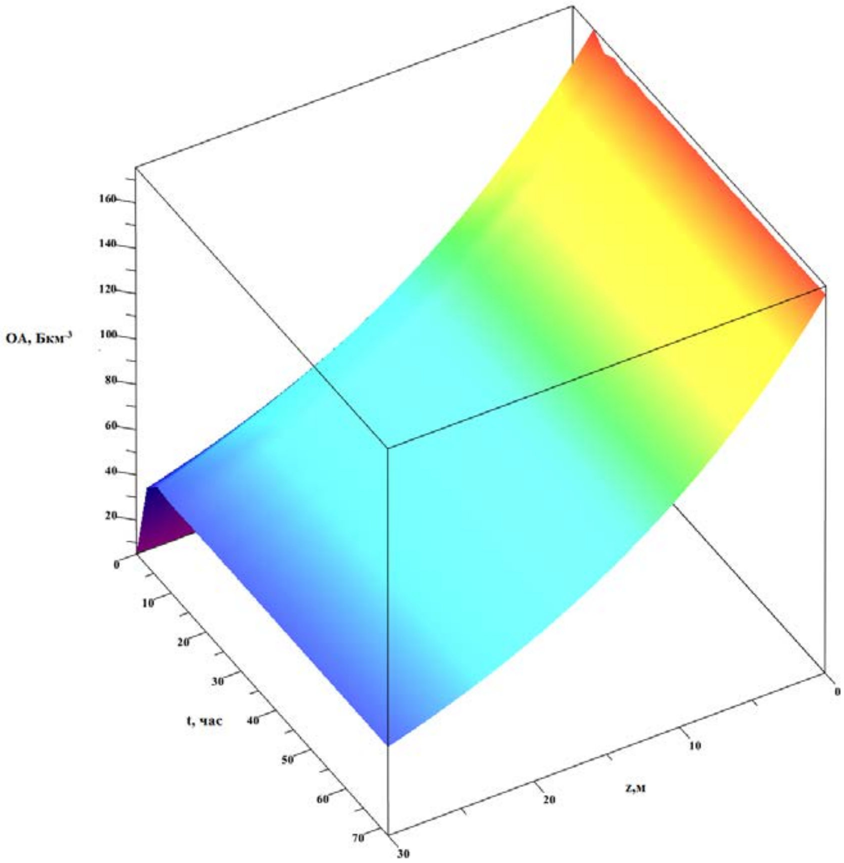


Figure 26 - Model of the vertical distribution of VA ^{222}Rn at Dt = exp (0.01 * z), Bqm^{-3}

Analyzing the figure, we can conclude that with an increase in the height, VA decreases exponentially. As in the previous models, there is no connection similar to experiment in the dependence of VA 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 DDP 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 27, 28, 29 respectively.

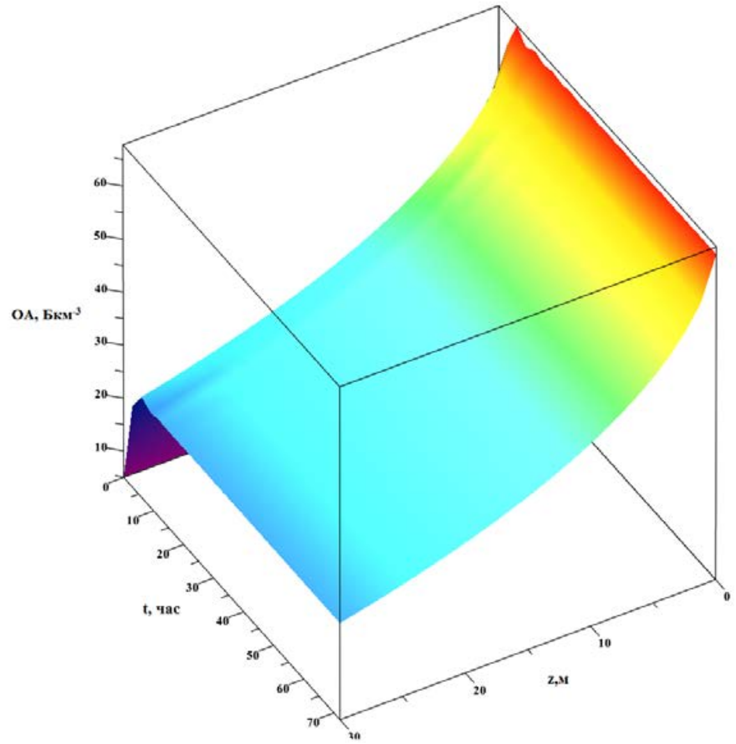


Figure 27 - Model of vertical distribution of VA ^{222}Rn at Dt = 0.01, Bqm^{-3}

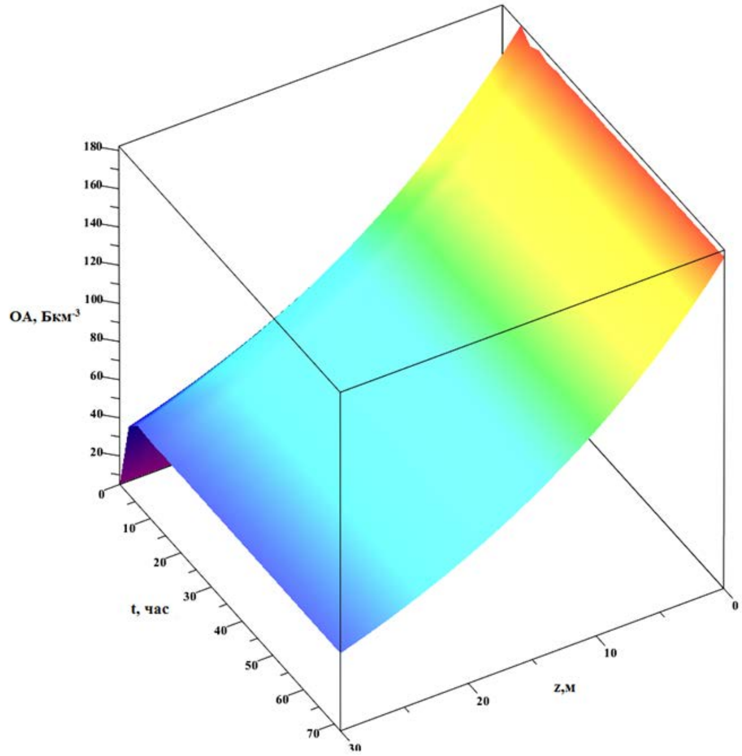


Figure 28 - Model of the vertical distribution of OA ^{222}Rn at Dt = 0.5, Bqm^{-3}

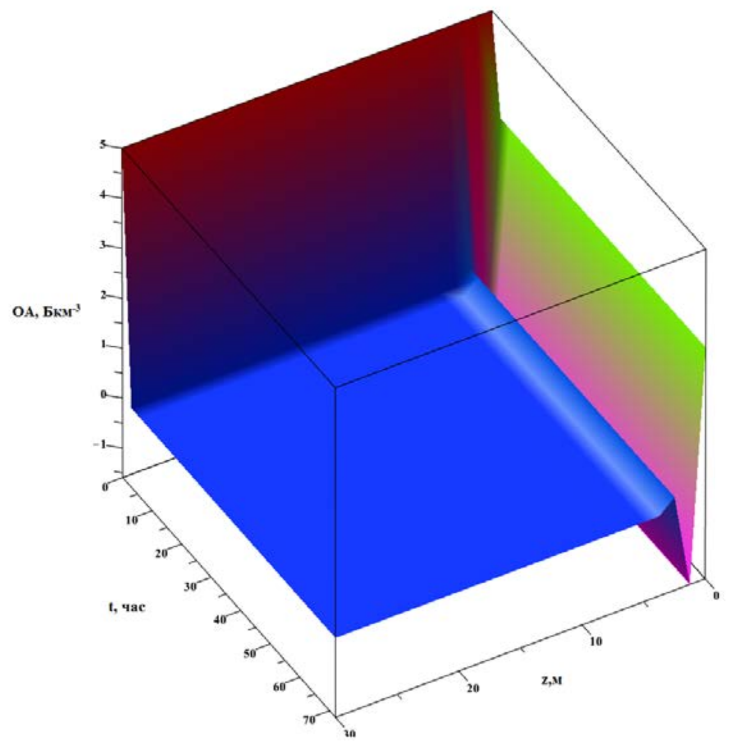


Figure 29 - Model of the vertical distribution of OA ^{222}Rn at Dt =0.5, Bqm^{-3}

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 VA is observed at K less than 1, at K more than 1, it can be observed that VA changes only at a height of less than five meters, while at some values of the VA height it acquires negative values, which contradicts the experiment. At an altitude of more than 5 m, VA 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 ($7{,}2921\cdot 10^{-5} c^{-1}$). 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 DDP 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 30,31 respectively.

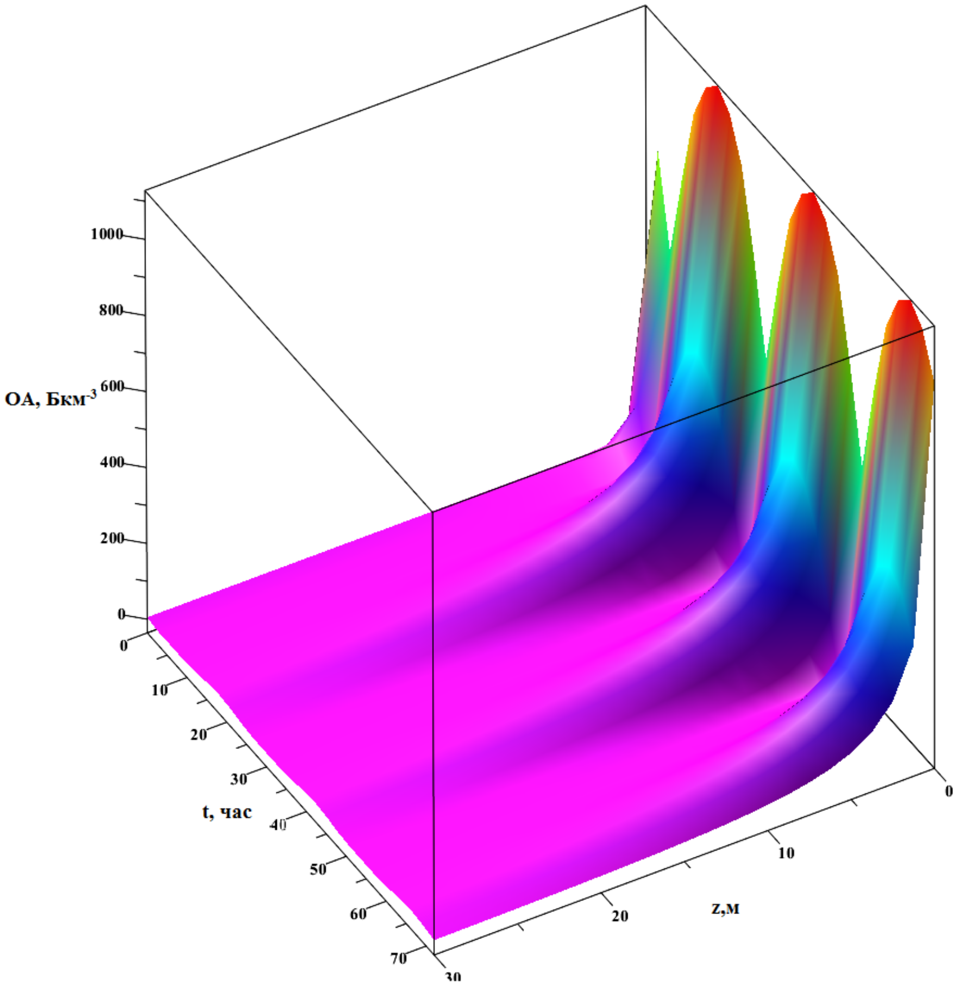


Figure 30 - Model of the vertical distribution of VA ^{222}Rn at $Dt=(1-\sin(\omega\cdot t))\cdot z\cdot 0.01$, Bqm^{-3}

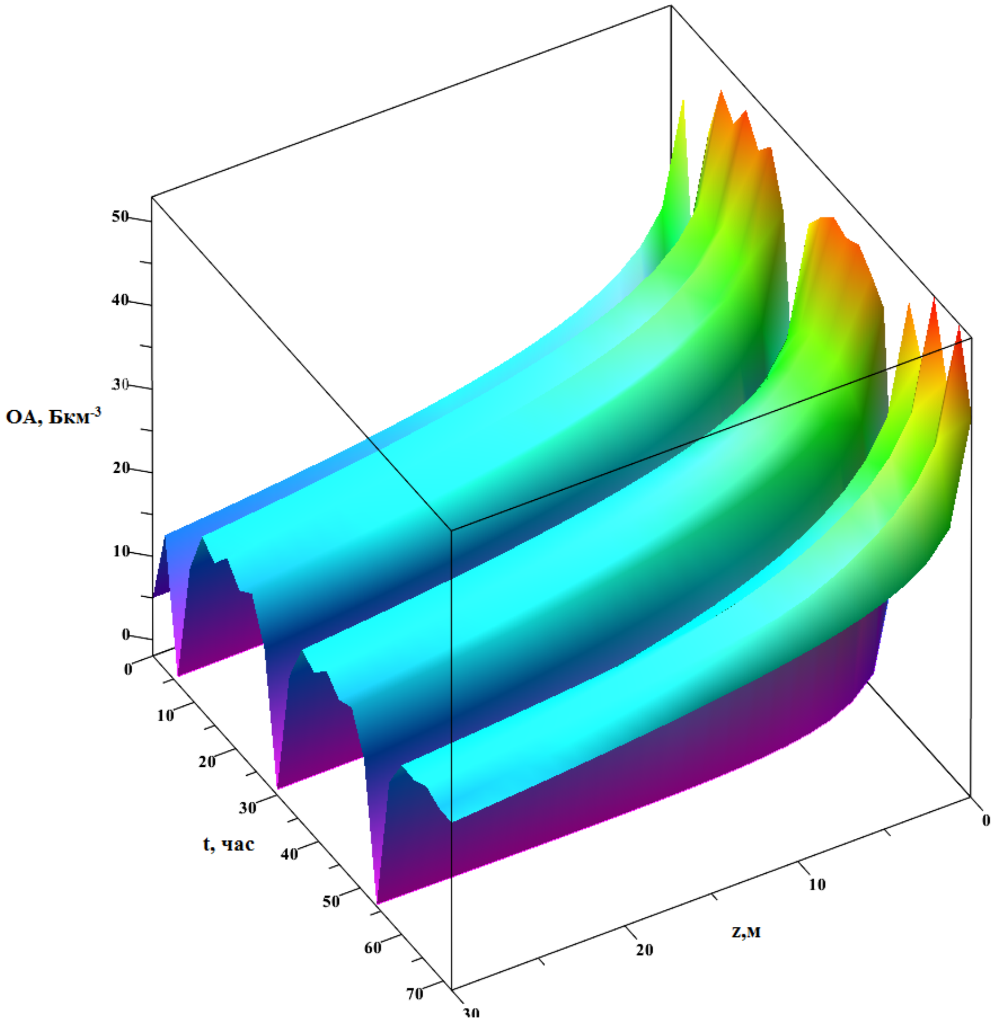


Figure 31 - Model of vertical distribution of VA ^{222}Rn at $Dt=(1-\sin(\omega\cdot t))\cdot z\cdot 10$, Bqm^{-3}

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 VA decreases, which contradicts the experimental data.

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

None of the functions considered above allows one to describe the relationship between VA 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

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

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

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

Table 3.2 - Meaning of simulation parameters

	Radon
Dm, m^2/s	$1.2{\cdot}10^{-5}$
q	10-100
D	0,01-10 / K(1–sinωt)z, K=0,15-5
ω, s^{-1}	$7{,}2921{\cdot}10^{-5}$
λ	$2{,}1{*}10^{-6}$
ν	|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 $mBqm^2s^{-1}$. For speed, let's take values equal to: 0.001; 0.005; 0.01. The simulation results are shown in Figure 32,33 respectively.

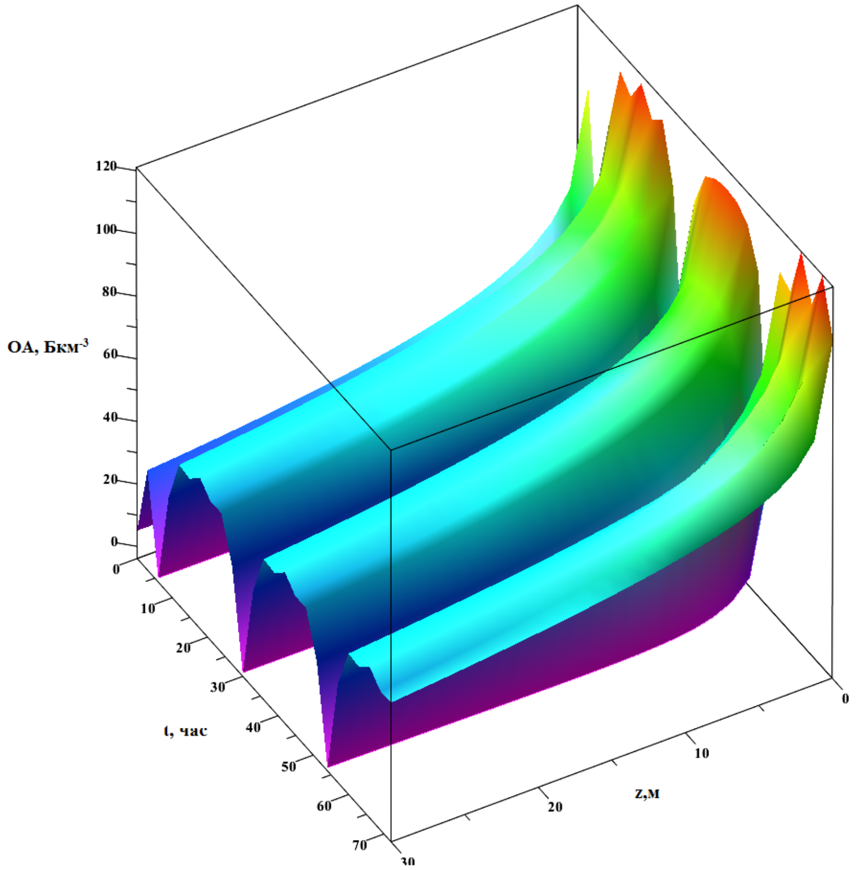


Figure 32 - Model of vertical distribution of OA ^{222}Rn at Dt=(1–sin(ω·t))·z·5 and speed v = 0.001, Bqm^{-3}

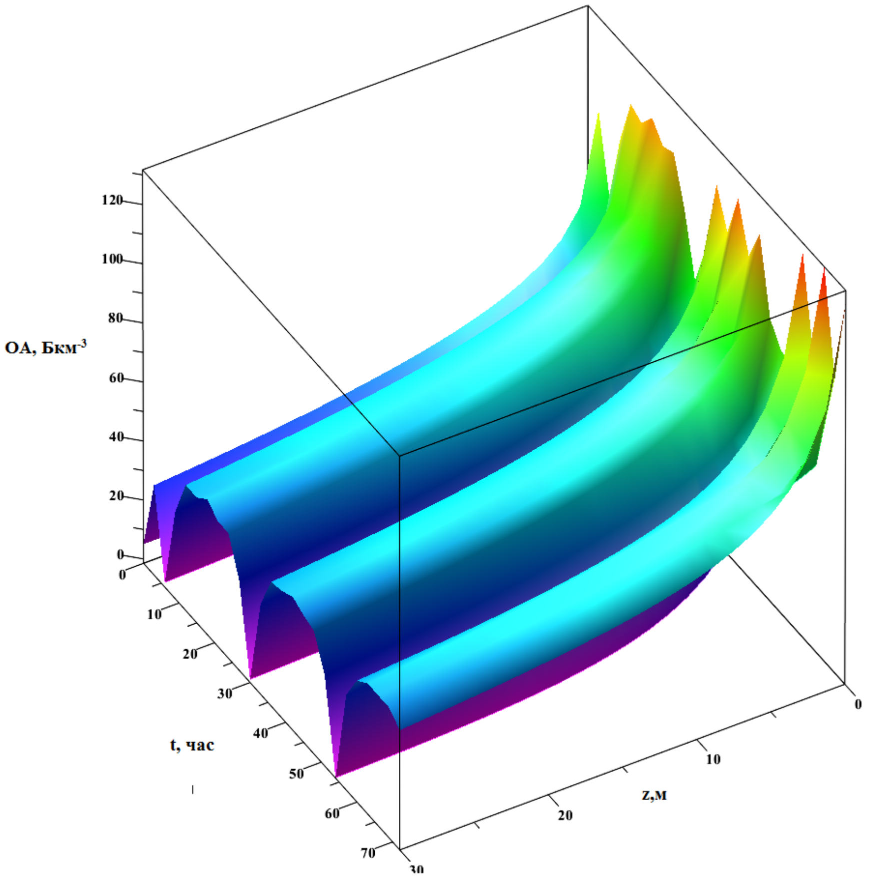


Figure 33 - Model of vertical distribution of OA ^{222}Rn at, Bkm-3Dt=(1–sin(ω·t))·z·5 и скорости v=0,005, Bqm^{-3}

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.

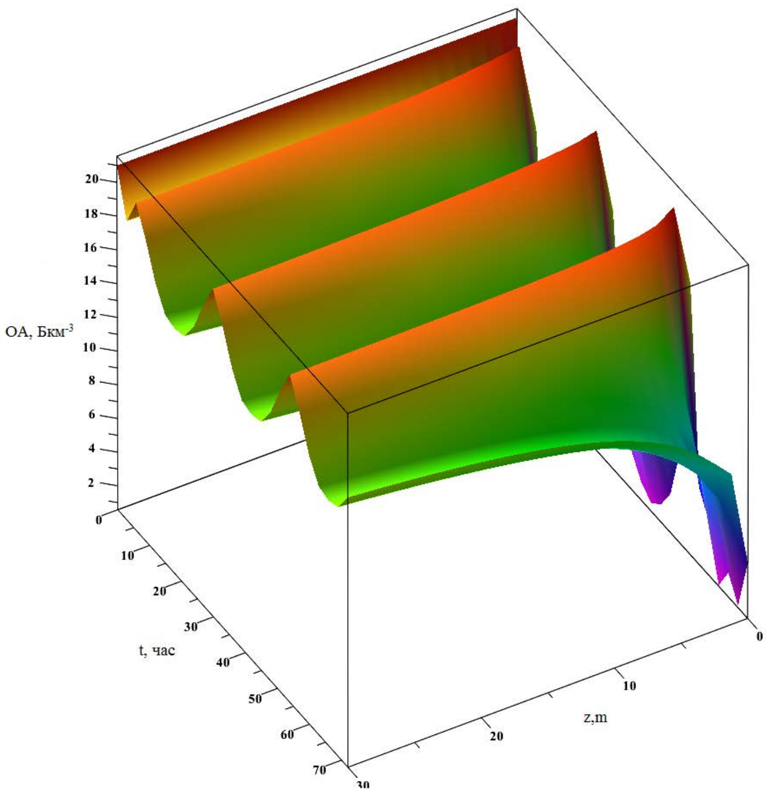


Figure 34 - Model of vertical distribution of VA ^{222}Rn at Dt=(1−sin(ω·t))·z·5 and speed v = – 0,001, Bqm^{-3}

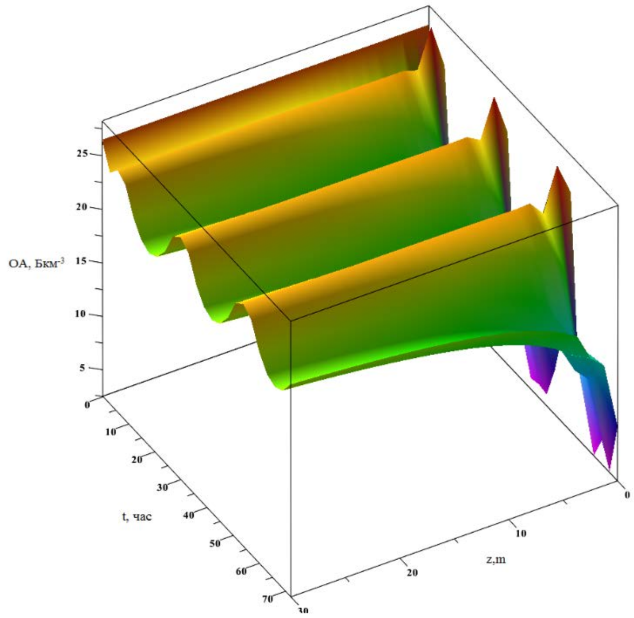


Figure 35 - Model of vertical distribution of VA ^{222}Rn at Dt=(1−sin(ω·t))·z·5 v = - 0.01, Bqm^{-3}

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 36.

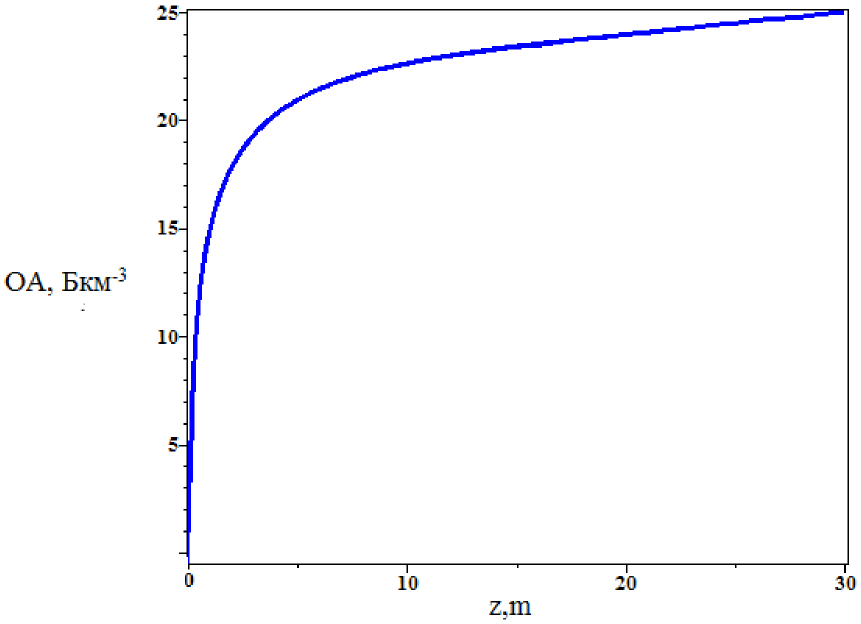


Figure 36 - Projection of the model of the vertical distribution of OA ^{222}Rn at at Dt=(1–sin(ω·t))·z·5 and speed v = – 0,001, Bqm^{-3}

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, VA increases, which confirms the experimental data obtained in October.

As the speed increases, VA increases. However, it can be seen that the spread between the VA 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%.

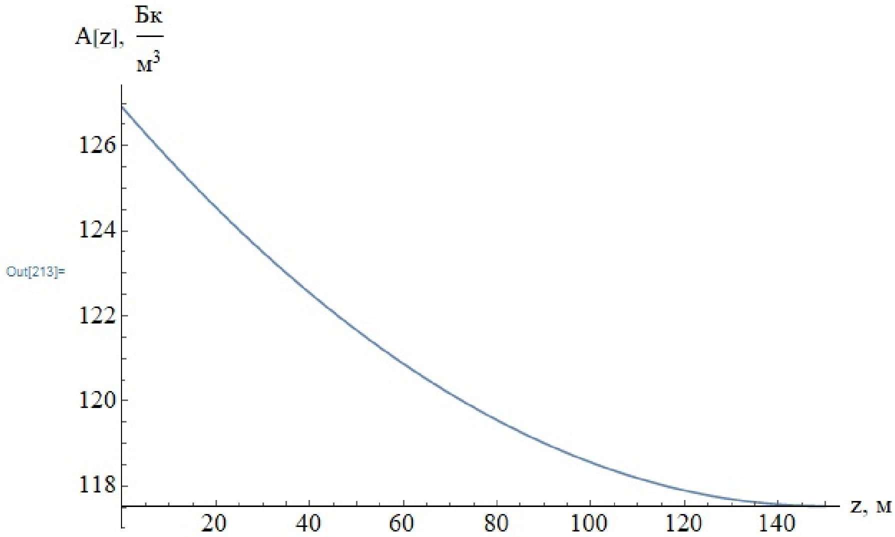


Figure 37 - Dependence of the volumetric activity of the radon flux taking into account the temperature inversion in summer.

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.

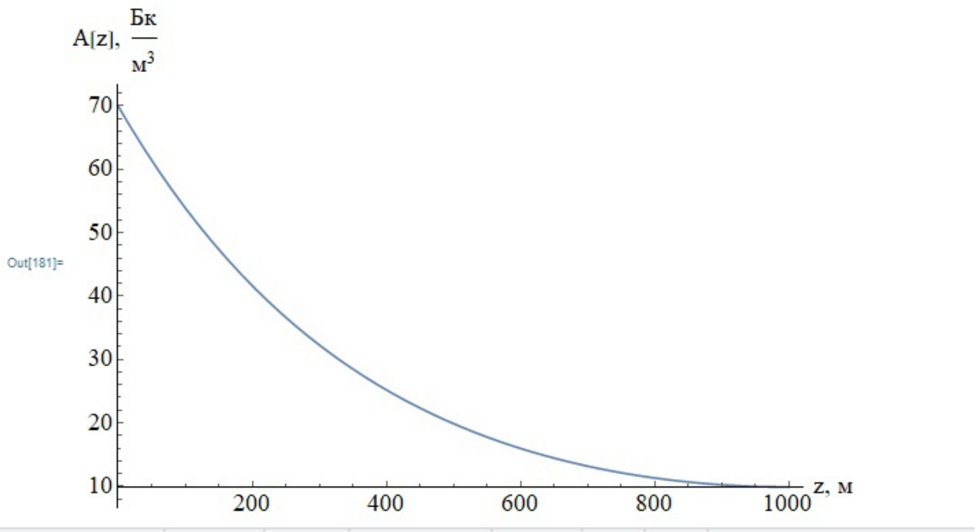


Figure 38 - Dependence of the volumetric activity of the radon flux, taking into account the temperature inversion.

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 saving

One of the most essential features in any research work is financial management. For every project or research to be started and completed successfully, one has to have a fair knowledge about financial management. Financial management can basically be defined as the process of organizing, directing, controlling, monitoring and strategic planning of financial resources of an institute or an organization, in order to achieve a set of goals and objectives. Application of management principles to financial resources of the institute or organisation plays a very vital part in financial management. Finance or money plays an essential role when it comes to the management of a business because it is needed in order to meet the requirements of the economic world and in addition, every business requires money in order to survive. No matter how small or big a business is, money needs to be put into it so as to keep it running, achieve a set of goals and gain more profit. The main aim of every businessman is to gain lots of profit, no one wants to do a business that would fail or would not generate profits hence to achieve this, one has to manage his or her finance properly.

The purpose of this section "Financial Management, Resource Efficiency and Resource Saving" discusses the issues of competitiveness, resource efficiency and resource saving, as well as financial costs regarding the object of study of Master's thesis. Competitiveness analysis is carried out for this purpose. SWOT analysis helps to identify strengths, weaknesses, opportunities and threats associated with the project, and give an idea of working with them in each particular case. For the development of the project requires funds that go to the salaries of project participants and the necessary equipment, a complete list is given in the relevant section. The calculation of the resource efficiency indicator helps to make a final assessment of the technical decision on individual criteria and in general.

In addition, it would help determine the accomplishment of the research work so as to develop a mechanism for managing and supporting specific project solutions at the implementation stage of the project lifecycle to increase productivity. The financial management solves the following objectives:

1. Planning and preparation of research work.
2. Budget calculation for research work.
3. Development of evaluation of commercial potential.

4.1 Consumer portrait

To date, various companies, including private accredited ones, provide radiation monitoring services. They monitor soil radon and the density of radon flux from the earth's surface, mainly for the purpose of predicting earthquakes, or, occasionally, in radioecological and geoecological surveys before construction begins.

At the moment, radiation monitoring includes synchronous continuous automated high sampling rate (1–10 min.) measurements of the characteristics of ionizing radiation fields. the density of radon and thoron fluxes from the ground surface, as well as the volumetric activity of radon, thoron and their daughter decay products at depths up to 5 m and heights up to 35 m. This method requires expensive equipment, such as the Alfaradplus measuring complex, MKS-08P dosimeters-radiometers and other measuring instruments.

4.2 Competitiveness analysis of technical solutions

In order to find sources of financing for the project, it is necessary, first, to determine the commercial value of the work. Analysis of competitive technical solutions in terms of resource efficiency and resource saving allows to evaluate the comparative effectiveness of scientific development. This analysis is advisable to carry out using an evaluation card.

The monitoring ad measuring of radiation level in the environment has become a very important factor in our world today and this can be achieved by using an appropriate device or equipment known as the radiation detector. Scintillation detectors are mostly used for measuring radiation outdoor and are mostly affected by environmental conditions such as temperature. Since radiation detectors are been developed most often, it is important to find the most effective and accurate method for estimating the correct algorithm for calculating dose rate under different environmental condition, especially at different temperature range, taking into consideration low cost. This algorithm must be able to calculate radiation dose rate at both low and high levels. In this work, a method with a very low cost was chosen to investigate the effect of current temperature on the readings of flux density of radon to the surface atmosphere and to obtain a temperature correction factor that can be used to calculate the results of flux density These methods include:

1. The use of climatic chamber to depict the environmental conditions for different temperature range.
2. The use of an inorganic scintillation detector and laptop to measure dose rate and count rate at low background gamma radiation.
3. The use of excel software to analysis the results.

The scintillation detector (BDKG-03) was used because that is the radiation detector used in TPU for gamma radiation monitoring. An experiment conducted showed that the scintillation detector (BDKG-03) is the best Dosimetric method sensitive to background radiation because it had a smaller standard deviation compared to the gas discharge counter.

There are different sources of low background radiation that can be used as a source to calibrate radiation detectors that are used for monitoring in the environment. For this research, two sources can be considered:

1. Gamma background radiation – P_f.
2. Low radioactive source – P_i.

First of all, it is necessary to analyze possible technical solutions and choose the best one based on the considered technical and economic criteria.

Evaluation map analysis presented in Table 1. The position of your research and competitors is evaluated for each indicator by you on a five-point scale, where 1 is the weakest position and 5 is the strongest. The weights of indicators determined by you in the amount should be 1. Analysis of competitive technical solutions is determined by the formula:

$$C = \sum W_i \cdot P_i , \qquad (4.1)$$

C - the competitiveness of research or a competitor;

Wi– criterion weight;

Pi – point of i-th criteria.

You can use the following criteria for the model of expert evaluation:

1. noise immunity;
2. set of terminals relay protection;
3. reliability of relay protection;
4. smart interface quality;
5. energy efficiency;
6. ease of operation;
7. ability to connect to PC;
8. estimated lifetime;
9. safety;
10. etc.

Table 4.1 Evaluation card for comparison of competitive technical solutions

Evaluation criteria ***Example***	**Criterion weight**	**Points**		**Competitiveness** Taking into account weight coefficients	
		P_{f1}	P_i	C_f	C_i
1	2	3	4	7	8
Technical criteria for evaluating resource efficiency					
1. Energy efficiency	0.1	4	3	0.4	0.3
2. Reliability	0.2	5	4	1	0.8
3. Safety	0.2	5	4	1	0.8
4. Functional capacity	0.1	5	5	0.5	0.5
Economic criteria for performance evaluation					

1. Development cost	0.1	5	4	0.5	0.4
2. Market penetration rate	0.1	3	4	0.3	0.4
3. Expected lifecycle	0.2	5	4	1	0.8
Total	**1**	**32**	**28**	**4.7**	**4.0**

The results of the competitiveness analysis shows that gamma background radiation have the highest value of competitiveness. This shows that they are the best option to choose when investigating the effect of ambient temperature on the readings of low gamma background radiation in order to obtain a temperature correction factor that can be used to calculate the results of low gamma background radiation.

4.3 SWOT analysis

Complex analysis solution with the greatest competitiveness is carried out with the method of the SWOT analysis: Strengths, Weaknesses, Opportunities and Threats. The analysis has several stages. The first stage consists of describing the strengths and weaknesses of the project, identifying opportunities and threats to the project that have emerged or may appear in its external environment. The second stage consists of identifying the compatibility of the strengths and weaknesses of the project with the external environmental conditions. This compatibility or incompatibility should help to identify what strategic changes are needed.

Table 4.2 SWOT analysis

	Strengths: S1. Low cost. S2. Simplicity of method. S3. Reliability of results obtained.	**Weaknesses:** W1. Taking measurement and analyzing takes lots of time.

	S4.Small relative error for both the dose rate and the count rate. S4. Very safe. S5. Very important factor for all radiation detectors.	W2. Difficulty in getting data the actual temperature in different places. W3. Need to know how to operate the detector and climatic chamber technically. W4. Software sometimes take long to open.
Opportunities: O1.Data can be used to calculate dose rate for low background radiation in BDKG -03 scintillation detector. O2. Research institute could use the method to find the influence of ambient temperature on gamma background radiation of any radiation detector used outdoor. O3. Researchers can use the method can be used to estimate the algorithm for calculating dose rate under the influence of different temperature range.	***Strategy which based on strengths and opportunities:*** 1. Obtained a method, which can be used to calibrate dose rate in radiation detectors.	***Strategy which based on weaknesses and opportunities:*** Using open sources with data of temperature for measurement.
Threats: T1. Lack of financial support in purchasing of equipment. T2. Lack of demand since it is needed only after development of a radiation detector. T3. Need of a climatic chamber to depict the environmental weather conditions.	***Strategy which based on strengths and threats:*** Finding another equipment that can replace the climatic chamber to depict the environmental condition accurately.	***Strategy which based on weaknesses and threats:*** Not being able to complete project due to lack of financial support and lack weather data.

Analyzing the SWOT-analysis table, we can say that the proposed set of activities has enough strengths and opportunities.

The main weakness is the dependence on third-party sources of information about the climatic conditions of the area.

At the same time, it is worth talking about the need for constant modernization of technologies and equipment. In addition, compliance with environmental legislation is an important task.

4.4 Project Initiation

The initiation process group consists of processes that are performed to define a new project or a new phase of an existing one. In the initiation processes, the initial purpose and content are determined and the initial financial resources are fixed. The internal and external stakeholders of the project who will interact and influence the overall result of the research project are determined.

4.4.1 Project Stakeholders

Table 4.3 Stakeholders of the project

Project stakeholders	**Stakeholder expectations**
Tomsk Polytechnic University (TPU)	Supervision and approval of research work came from TPU. The acquired results can be used to calculate the dose rate of low gamma background radiation in the environment when using scintillation detector (BDKG-03).
Radiation Safety Service	Development of a method for modeling of radon flux density based on current atmospheric temperature

4.4.2 Objectives and Outcomes of Project

Table 4.4 Purpose and results of the project

Purpose of project:	To investigate the effect climate changes such as temperature, pressure, air humidity on the readings of flux density of radon in surface atmosphere
Expected results of the project:	• Creation of a model of radon flux density in the surface atmosphere. • Identification of seasonal patterns in the dynamics of radon SPR into the surface atmosphere based on experimental data
Criteria for acceptance of the project result:	Validation of results by using the obtained model of flux density of radon with the experimental data.
Requirements for the project result:	Agreement between the results of project and the results of other authors on similar works.
	Industrial application. The results would help conducting radiation monitoring in different industries.
	Technical specification: To be able to calculate the correct flux density of radon an area with created model based on climatic data.

4.4.3 Project Participants

The organizational structure of the project involves all participants or people who participated in the research work, the number of hours they spent and the roles they played in the research. In this research work, there were two participants.

- Scientific supervisor
- Engineer

Table 4.5 Structure of the project

№	Participant	Role in the project	Functions	Labor time, hours (working days (from table 7) × 6 hours)

1	Scientific Supervisor – A professor and a lecture of the Nuclear Science and Technology department at TPU.	Head of project	Formulating of research topic and giving directions of how to achieve the main aim. Ensuring that all task pertaining to the main objectives are done on time. Verification of results obtained.	48×6 = 288
2	Engineer – A student of the Nuclear Science and Technology department at TPU.	Executor	Performing of task and researching of literature review. Collecting of data and analysing of results.	82×6 = 492

4.4.4 Project limitations and Assumptions

Project limitations are all factors that can be as a restriction on the degree of freedom of the project team members.

Table 4.6 Project limitations

Factors	**Limitations / Assumptions**
3.1. Project's budget, rubles	326530.74
3.1.1. Source of financing	TPU
3.2. Project timeline:	25/05/2022 to 25/05/2023
3.2.1. Date of approval of plan of project	25/05/2022
3.2.2. Completion date	25/05/2023

4.4.5 Project Schedule

As part of planning a science project, you need to build a project timeline and a Gantt Chart.

Table 4.7. Project Schedule

Job title	**Duration, working days**	**Start date**	**Date of completion**	**Participants**
Development of the technical task	6	1/02/2023	7/02/2023	Scientific Supervisor
Drafting and approval of terms of reference	11	7/02/2023	21/02/2023	Scientific Supervisor
Choosing of a research direction	2	21/02/2023	24/02/2023	Scientific Supervisor, Engineer
Collection and study of literature	24	24/02/2023	24/03/2023	Engineer
Choosing of experimental method	2	24/03/2023	25/03/2023	Scientific Supervisor, Engineer
Choosing of a place to conduct research	2	25/03/2023	26/03/202	Scientific supervisor
Conducting of experiment to collect data of count rate and dose rate of gamma radiation using the BDKG-03 and climatic chamber	3	26/08/2023	29/03/2023	Engineer

Analysis of results obtained	16	29/03/2023	16/04/2023	Engineer, Scientific supervisor
Summary of results	4	16/04/2023	20/04/2023	Scientific Supervisor, Engineer
Checking and assessment of results	4	20/04/2023	23/04/202	Scientific supervisor, Engineer
Compilation of results for report	7	23/04/2023	2/04/2023	Engineer
Preparation of report	4	2/05/2023	6/05/2023	Engineer
Defence preparation	16	6/05/2023	25/05/2023	Engineer

A Gantt chart, or harmonogram, is a type of bar chart that illustrates a project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervals on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity.

Table 4.8 A Gantt chart

№	Activities	Participants	T_c, days	Duration of the project											
				February			March			April			May		
				1	2	3	1	2	3	1	2	3	1	2	3
1	Development of the technical task	Scientific Supervisor	6												
2	Drafting and approval of terms of reference	Scientific Supervisor	11												
3	Choosing of a research direction	Scientific Supervisor, Engineer	2												
4	Collection and study of literature	Engineer	24												
5	Choosing of experimental method	Scientific Supervisor, Engineer	2												
6	Choosing of a place to conduct research	Scientific supervisor	2												
7	Conducting of experiment to collect data of count rate and dose rate of gamma radiation using the BDKG-03 and climatic chamber	Engineer	3												
8	Analysis of results obtained	Engineer, Scientific supervisor	16												
9	Summary of results	Scientific Supervisor, Engineer	4												

10	Checking and assessment of results	Scientific supervisor, Engineer	4												
11	Compilation of results for report	Engineer	7												
12	Preparation of report	Engineer	4												
13	Defence preparation	Engineer	16												

Scientific Supervisor   Engineer

4.5 Scientific and technical research budget

The amount of costs associated with the implementation of this work is the basis for the formation of the project budget. This budget will be presented as the lower limit of project costs when forming a contract with the customer.

To form the final cost value, all calculated costs for individual items related to the manager and the student are summed.

In the process of budgeting, the following grouping of costs by items is used:

- Material costs of scientific and technical research;
- costs of special equipment for scientific work (Depreciation of equipment used for design);
- basic salary;
- additional salary;
- labor tax;
- overhead.

4.5.1 Calculation of material costs

The calculation of material costs is carried out according to the formula:

$$C_m = (1 + k_T) \cdot \sum_{i=1}^{m} P_i \cdot N_{consi} \qquad (4.2)$$

where

m – the number of types of material resources consumed in the performance of scientific research;

N_{consi} – the amount of material resources of the i-th species planned to be used when performing scientific research (units, kg, m, m^2, etc.);

P_i – the acquisition price of a unit of the i-th type of material resources consumed (rub./units, rub./kg, rub./m, rub./m^2, etc.);

k_T – coefficient taking into account transportation costs.

Prices for material resources can be set according to data posted on relevant websites on the Internet by manufacturers (or supplier organizations).

Table 4.9 Material costs

Name	**Unit**	**Amount**	**Price per unit, rub.**	**Material costs, rub.**
Office supplies	-	1	1000	1000.00
Transportation	Unit	8	100	800.00
Printing	Unit	200	4	800.00
Total				2600.00

4.5.2 Calculation of the depreciation.

Depreciation is not charged if an equipment cost is less than 40 thousand rubles, its cost is taken into account in full.

If you use available equipment, then you need to calculate depreciation:

$$A = \frac{C_{перв} * H_a}{100} \qquad (4.3)$$

A - annual amount of depreciation;

$C_{перв}$ - initial cost of the equipment;

$H_a = \frac{100}{T_{сл}}$ - rate of depreciation;

$T_{сл}$ - life expectancy.

For this research, a gamma radiation detector (BDKG-03), a climatic chamber and a laptop, which cost 118000 rubles, 400000 and 30000 respectively, were used. The gamma detector and the laptop both had a life expectancy of 5 years whiles that of the climatic chamber was 10 years. The depreciation for the gamma detector, climatic chamber and laptop can be calculated as follows:

Radiometer:

$$D = \frac{\text{Cost}}{\text{Time}} \tag{4.4}$$

$$D = \frac{118000}{5 \times 365} = 64.66 \, \frac{\text{rubles}}{\text{day}} \tag{4.5}$$

Since the equipment was used for 3 days

$$A = 64.66 \times 3 = 193.97 \text{ rubles} \tag{4.6}$$

Storage chamber:

$$D = \frac{\text{Cost}}{\text{Time}} \tag{4.7}$$

$$D = \frac{400000}{10 \times 365} = 109.589 \, \frac{\text{rubles}}{\text{day}} \tag{4.8}$$

Since the equipment was used for 3 days

$$A = 109.589 \times 3 = 328.767 \text{ rubles} \tag{4.9}$$

Table 4.10 Depreciation of special equipment (+software)

№	**equipment identification**	**Quantity of equipment**	**Total cost of equipment, rub.**	**Life expectancy, year**	**Depreciation for the duration of the project, rub.**
1.	Radiometer Alpharad	1	118000	10	193.97
2.	Climatic chamber	1	400000	10	328.77
3	Laptop	1	30000	-	30000

Total	30522.74

4.5.3 Basic salary

This point includes the basic salary of participants directly involved in the implementation of work on this research. The value of salary costs is determined based on the labor intensity of the work performed and the current salary system

The basic salary (S_b) is calculated according to the formula:

$$S_{\text{b}} = S_a \cdot T_{\text{w}}, \tag{4.10}$$

where S_b – basic salary per participant;

T_{w} – the duration of the work performed by the scientific and technical worker, working days;

S_d - the average daily salary of an participant, rub.

The average daily salary is calculated by the formula:

$$S_d = \frac{S_m \cdot M}{F_{\text{v}}}, \tag{4.11}$$

where,

S_m – monthly salary of a participant, rubles;

M – the number of months of work without leave during the year:

at holiday in 48 days, M = 11.2 months, 6 day per week;

F_{v} – valid annual fund of working time of scientific and technical personnel (251 days).

Table 4.11 The valid annual fund of working time

Working time indicators	
Calendar number of days	365

The number of non-working days - weekend - holidays	 52 14
Loss of working time - vacation - isolation period - sick absence	 48
The valid annual fund of working time	251

Monthly salary is calculated by formula:

$$S_{month} = S_{base} \cdot (k_{premium} + k_{bonus}) \cdot k_{reg} , \quad (4.12)$$

where, S_{base} – base salary, rubles;

$k_{premium}$ – premium rate;

k_{bonus} – bonus rate;

k_{reg} – regional rate.

Table 4.12 Calculation of the base salaries

Performers	**S_{base}, rubles**	**$k_{premium}$**	**k_{bonus}**	**k_{reg}**	**S_{month}, rub.**	**W_d, rub.**	**T_p, work days (from table 7)**	**W_{base}, rub.**
Scientific Supervisor	40000	-	-	1,3	52000	1784.86	48	85673.28
Engineer	19870				25831	886.63	82	72703.66
Total								158376.94

4.5.4 Additional salary

This point includes the amount of payments stipulated by the legislation on labor, for example, payment of regular and additional holidays; payment of time associated with state and public duties; payment for work experience, etc.

Additional salaries are calculated on the basis of 10-15% of the base salary of workers:

$$W_{add} = k_{extra} \cdot W_{base}, \qquad (4.13)$$

where,

W_{add} – additional salary, rubles;

k_{extra} – additional salary coefficient (10%);

W_{base} – base salary, rubles.

Table 13. Additional Salary

Participant	**Additional Salary, rubles**
Scientific Supervisor	8567.32
Engineer	7270.37
Total	15837.69

4.5.5 Labor tax

Tax to extra-budgetary funds are compulsory according to the norms established by the legislation of the Russian Federation to the state social insurance (SIF), pension fund (PF) and medical insurance (FCMIF) from the costs of workers.

Payment to extra-budgetary funds is determined of the formula:

$$P_{social} = k_b \cdot (W_{base} + W_{add}) \qquad (4.14)$$

where,

k_b – coefficient of deductions for labor tax.

The rate of deductions to off-budget funds for institutions engaged in scientific and educational activities for 2023 is 30%

Table 4.14 Labor tax

	Project leader	**Engineer**
Coefficient of deductions	30%	
Salary (basic and additional), rubles	94240.60	79974.03
Labor tax, rubles	25444.96	21672.96
Total		47117.92

4.5.6 Overhead costs

Overhead costs include other management and maintenance costs that can be allocated directly to the project. In addition, this includes expenses for the maintenance, operation and repair of equipment, production tools and equipment, buildings, structures, etc.

Overhead costs account from 30% to 90% of the amount of base and additional salary of employees.

Overhead is calculated according to the formula:

$$C_{ov} = k_{ov} \cdot (W_{base} + W_{add}) \quad (4.15)$$

where,

k_{ov} – overhead rate.

Table 4.15 Overhead

	Project leader	**Engineer**
Overhead rate	40%	
Salary, rubles	94240.60	79974.03
Overhead, rubles	37696.24	31989.61
Total, rubles		69685.85

4.5.7 Other direct costs

Energy costs for equipment are calculated by the formula:

$$C = P_{el} \cdot P \cdot F_{eq}, \quad (4.16)$$

where,

P_{el} – power rates (5.8 rubles per 1 kWh);

P – power of equipment, kW;

F_{eq} – equipment usage time, hours.

Table 4.16 Other direct costs

	Power rates, kWh	**Power of equipment, kW**	**Equipment usage time, hr**	**Energy cost, rubles**
Climatic chamber	5.8	0.5	24	69.60
Laptop	5.8	0.5	492	1426.80
Gamma radiation detector (BDKG-03)	5.8	0.5	24	69.60
Total				1566.00

4.5.8 Formation of budget costs

The calculated cost of research is the basis for budgeting project costs.

Determining the budget for the scientific research is given in the table 4.17.

Table 4.17 Items expenses grouping

Name	**Cost, rubles**
1. Material costs	2600.00
2. Equipment costs	30522.74
3. Basic salary	158376.94
4. Additional salary	15837.69
5. Labor tax	47117.92
6. Overhead	69685.85
7. Other direct costs	1566.00
Total planned costs	**325707.14**

4.6 Evaluation of the comparative effectiveness of the project

Determination of efficiency is based on the calculation of the integral indicator of the effectiveness of scientific research. Its finding is associated with the definition of two weighted average values: financial efficiency and resource efficiency.

The integral indicator of the financial efficiency of a scientific study is obtained in the course of estimating the budget for the costs of three (or more) variants of the execution of a scientific study. 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 for all the options are correlated.

The integral financial measure of development is defined as:

(4.17)

where,

– integral financial measure of development;

C_i – the cost of the i-th version;

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

As an analogue, the method of temperature stabilization of a radiation detector is done by placing the detector in the climatic chamber and measuring the dose rate and count rate of a gamma ray source.

The integral financial measure of development can be calculated as:

$$I^d{}_f = \frac{C_i}{C_{max}} \qquad (4.18)$$

where,

C_i – the cost of the research work using gamma background radiation = 325707.14

And C_{max} – the maximum cost of execution of research project using a gamma radioactive source = 400,000.00

$$I^d{}_f = \frac{325707.14}{400000.00} \quad (4.19)$$

$$I^d{}_f = 0.814 \quad (4.20)$$

$$I^a{}_f = \frac{C_i}{C_{max}} \quad (4.21)$$

$$I^a{}_f = \frac{400000.00}{400000.00} \quad (4.22)$$

$$I^a{}_f = 1 \quad (4.23)$$

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

Since the development has one performance, then = 1.

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

$$I_m^a = \sum_{i=1}^{n} a_i b_i^a \qquad I_m^p = \sum_{i=1}^{n} a_i b_i^p \quad (4.24)$$

where,

I_m – integral indicator of resource efficiency for the i-th version of the development;

a_i – the weighting factor of the i-th version of the development;

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

n – number of comparison parameters.

The calculation of the integral indicator of resource efficiency is presented in the form of table 4.18.

Table 4.18 – Evaluation of the performance of the project

Criteria	Weight criterion	Points	
		I_m^a	I_m^p
1. Energy efficiency	0.2	5	3
2. Reliability	0.1	4	4
3. Safety	0.2	5	5
4. Functional capacity	0.1	4	4
Economic criteria for performance evaluation			
1. The cost of development	0.1	4	4
2. Market penetration rate	0.1	5	5
3. Expected life	0.1	4	4
4. After-sales service	0.1	4	5
Total	**1**	**4.5**	**4.2**

$$I^a{}_m = \sum_{i=1}^{n} a_i b_i^a \quad (4.25)$$

$$I^a{}_m = (0.2 \times 5) + (0.1 \times 4) + (0.2 \times 5) + (0.1 \times 4) + (0.1 \times 4) + (0.1 \times 5) + (0.1 \times 4) + (0.1 \times 4) \quad (4.26)$$

$$I^a{}_m = 4.5 \quad (4.27)$$

$$I^p{}_m = \sum_{i=1}^{n} a_i b_i^a \quad (4.28)$$

$$I^p{}_m = (0.2 \times 3) + (0.1 \times 4) + (0.2 \times 5) + (0.1 \times 4) + (0.1 \times 4) + (0.1 \times 5) + (0.1 \times 4) + (0.1 \times 5) \quad (4.29)$$

$$I^p{}_m = 4.2 \quad (4.30)$$

The integral indicator of the development efficiency (I_e^P) is determined on the basis of the integral indicator of resource efficiency and the integral financial indicator using the formula:

$$I_e^P = \frac{I_m^P}{I_f^d} \quad (4.31)$$

$$I_e^a = \frac{I_m^a}{I_f^a} \quad (4.32)$$

$$I_e^P = \frac{I_m^P}{I_f^d} = \frac{4.5}{0.877} = 5.13 \quad (4.33)$$

$$I_e^a = \frac{I_m^a}{I_f^a} = \frac{4.2}{1} = 4.2 \quad (4.34)$$

Comparison of the integral indicator of the current project efficiency and analogues will determine the comparative efficiency. Comparative effectiveness of the project:

$$E_C = \frac{I_e^P}{I_e^a} \quad (4.35)$$

$$E_c = \frac{5.13}{4.2} = 1.221 \quad (4.36)$$

Thus, the effectiveness of the development is presented in table 4.19.

Table 4.19 Efficiency of development

№	**Indicators**	**Points**	
		P	a
1	Integral financial measure of development	0.814	1
2	Integral indicator of resource efficiency of development	4.5	4.2
3	Integral indicator of the development efficiency	1.221	1

Comparison of the values of integral performance indicators allows us to understand and choose a more effective solution to the technical problem from the standpoint of financial and resource efficiency.

4.7 Conclusion on chapter 4

Thus, in this section was developed stages for design and create competitive development that meet the requirements in the field of resource efficiency and resource saving.

These stages include:

- development of a common economic project idea, formation of a project concept;
- organization of work on a research project;
- identification of possible research alternatives;
- research planning;
- assessing the commercial potential and prospects of scientific research from the standpoint of resource efficiency and resource saving;
- determination of resource (resource saving), financial, budget, social and economic efficiency of the project.

5. Social responsibility

5.1 Introduction

At present, one of the main directions for improving preventive work to reduce occupational injuries and occupational morbidity is the introduction of a labor protection management system.

Occupational safety is a system of legislative, socio-economic, organizational, technological, hygienic and therapeutic and preventive measures and means that ensure safety, health and performance of a person in the process of work.

A hazardous production factor is such a production factor, the impact of which, under certain conditions, leads to injury or other sudden, sharp deterioration in health.

A harmful production factor is such a production factor, the impact of which on a worker, under certain conditions, leads to illness or a decrease in working capacity.

The purpose of this section of the WQR is to develop and analyze industrial safety issues in room 123 10 of the TPU building.

5.2. Legal and organizational issues of security

5.2.1. Organizational events

Persons who have reached the age of 18, of both sexes, who have passed a preliminary and periodic medical examination, introductory briefing, primary briefing at the workplace, a training course in safe working methods, an internship for at least 2 shifts and a test of knowledge of labor protection requirements, who have passed the briefing, are allowed to work. for 1 group on electrical safety and knowing this manual. The frequency of re-briefing is at least 1 time in 6 months.

Conducting all types of briefing should be recorded in the Instruction Log of the established form, with the obligatory signatures of the person who received and conducted the briefing, indicating the date of the briefing, the name and numbers of the briefing, the name and numbers of the instructions for the types of work for which the briefing is carried out.

5.2.2. Technical measures

The document that establishes the most general requirements for the organization of the workplace when performing work while sitting is GOST 12.2.032-78. According to this document, a workplace for performing work while sitting is organized for light work that does not require free movement of the worker. The design of the workplace and the relative position of all its elements (seat, controls, information display tools, etc.) must comply with anthropometric, physiological and psychological requirements, as well as the nature of the work. So, for example, the performance of labor operations "often" and "very often" should be provided within the zone of easy reach and the optimal zone of the motor field.

When choosing a desk, the following requirements should be taken into account. The height of the working surface of the table is recommended within 680 - 800 mm. The height of the working surface on which the keyboard is installed must be 650 mm. The working table must be at least 700 mm wide and

not less than 1400 mm long. Legroom must be at least 600 mm high, at least 500 mm wide, at least 450 mm deep at the knees and at least 650 mm at the level of the outstretched legs.

The height of the seat of the working chair above the floor level is 420 - 550 mm. There should be a work chair. The design of the work chair should provide: the width and depth of the seat surface is at least 400 mm; seat surface with recessed front edge. The monitor should be located at the level of the operator's eyes at a distance of 500 - 600 mm.

It should be possible to adjust the screen:

- height +3 cm;
- tilted from 10 to 20 degrees relative to the vertical;
- in left and right directions.

The keyboard should be placed on the table surface at a distance of 100-300 mm from the edge. The normal position of the keyboard is its placement at the level of the operator's elbow with an angle of inclination to the horizontal plane of 15 degrees. It is more convenient to work with keys that have a concave surface, a quadrangular shape with rounded corners. The design of the key should provide the operator with a clicky feel. The color of the keys should contrast with the color of the panel.

With monotonous mental work that requires significant nervous tension and great concentration, it is recommended to choose soft, low-contrast floral shades that do not scatter attention (low-saturated shades of cold green or blue colors). When working, requiring intense mental or physical tension, shades of warm tones are recommended that excite human activity.

5.3 Industrial safety

5.3.1 Analysis of harmful and dangerous factors

Calculations are carried out at the workplace at a personal computer. Identified hazardous and harmful factors are shown in Table 5.1.

Table 5.1 – Harmful and dangerous factors

Factors (according to GOST 12.0.003-2015)	Этапы работ			Regulations
	Design	Evaluation of the results	Create a report	
1. Deviation of microclimate indicators	+	+	+	1. SanPiN 1.2.3685-21.2. 2. SP 52. 13330.2016 3. ПУЭ 4. ГОСТ 12.1.038-82
2. Absence or deficiencynecessary artificial lighting	+	+	+	
3. Increased voltage in the electrical circuit, the closure of which can occur through the human body	+	+	+	
4. Mental overstrain, monotony of work	+	+	+	
5. Fire safety	+	+	+	
6. Noise and vibration	+	+	+	
7. Static electricity	+	+	+	

5.3.2. Microclimate

In accordance with SanPiN 1.2.3685-21, hygienic requirements are established for the indicators of the microclimate of workplaces in industrial premises, taking into account the intensity of energy consumption of workers, the time of work and periods of the year. The indicators characterizing the microclimate of the room are:

- air temperature;
- surface temperature;
- relative humidity;
- speed of air movement;
- intensity of thermal radiation.

These indicators of the microclimate should ensure the preservation of the thermal balance of a person with the environment and the maintenance of an optimal or acceptable level of the thermal state of the body. Optimal and permissible microclimate parameters are presented in tables 5.2, 5.3.

Table 5.2 – Optimal values of microclimate indicators

Period of the year	Category of work	Air temperature, °C	Surface temperature, °C	Relative humidity, %	Air speed
Cold	Ia	22-24	21-25	60-40	0,1
Warm	Ia	23-25	22-26	60-40	0,1

Optimal microclimatic conditions provide a general and local sensation of thermal comfort during an 8-hour working day, with a minimum stress of thermoregulation mechanisms, do not cause deviations in health, create the prerequisites for a high level of efficiency and are preferred at workplaces.

Table 5.3 – Permissible values of microclimate indicators

Period of the year	Category of work	Air temperature, °C		Surface temperature, °C	Relative humidity, %	Air speed	
		T°< T°опт.	T°> T°опт.			T°< T°опт.	T°< T°опт.
Cold	Ia	20,0-21,09	24,1-25,0	19,0-26,0	15-75	Cold	Ia
Warm	Ia	21,0-22,9	25,1-28,0	20,0-29,0	15-75	Warm	Ia

Acceptable microclimatic conditions do not cause damage or health disorders, but can lead to general and local sensations of thermal discomfort, tension in thermoregulation mechanisms, deterioration of well-being and decreased performance.

To select a suitable exhaust fan for room 123 of housing 10 with an area of 25 m^3, we use the following formula

$$L = S \cdot h \cdot k$$

Where L is the fan capacity, m^3/hour; S is the area of the room, m^2; h - ceiling height, m; k is the rate of air exchange, then we get:

$$L = 25 \cdot 3 \cdot 2 = 150 \text{ m}^3\text{/hour}$$

Fan "Event 150C" is able to provide the required air extraction performance for a given room. [16].

Table 5.4 Fan specifications of “Эвент 150C”.

Type of instalation:	wall
Channel type:	circular
Voltage:	220 V
Power (W)	22
Efficiency:	320 m^3/h
Number of speeds:	1
Duct diameter:	150 mm

In room 123 of building 10, all microclimate standards are met in accordance with SanPiN 2.2.4.548-96.

5.3.3 Artificial lighting

Artificial lighting is divided into working, emergency, security and duty.

The standardized characteristics of indoor and outdoor lighting are provided both by general lighting fixtures and by their joint action with emergency lighting fixtures.

Work lighting should be provided for all premises of buildings, as well as for areas of open spaces intended for work, the passage of people and traffic. For rooms with zones with different natural lighting conditions and different operating modes, separate control of the lighting of such zones is necessary.

Standard lighting indicators for office premises are shown in Table 5.4.

Table 5.3 - Standard lighting indicators for the main premises of public, residential and auxiliary buildings.

Premises	The plane of normalization of illumination and KEO, the height of the plane above the floor, m	Category and sub-category of visual work	Artificial lighting				
			Illumination of working surfaces, lx		UGR combined discomfort score, no more	Illumination ripple coefficient,	Light source color rendering index Ra
			With the combined	In general			
Cabinets and work rooms, offices, representative offices	Г-0,8	Б-1	400/200	300	21	15	80

The total illumination in a room with personal computers should be 300 lux.

As sources of artificial lighting at the workplace, 4 office LED lamps are used, the location of which is shown in Figure 5.1.

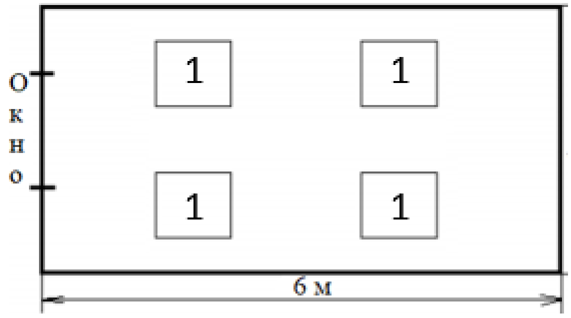


Figure 5.1 - Layout of fixtures at the workplace of a lighting engineer: 1-fixtures.

Let's calculate the artificial illumination of the room using the utilization factor method. The characteristics of the LED luminaire used in office space are as follows:

- power 40 W;
- luminous flux 4240 lm;
- light temperature 4000 K;

- IP 40.

$$i = \frac{A \cdot B}{h \cdot (A + B)}$$

where: A is the length of the room, m; B is the width of the room, m; h is the height of the luminaire suspension above the working surface, m.

$$i = \frac{A \cdot B}{h \cdot (A + B)} = \frac{6 \cdot 4}{2 \cdot (6 + 4)} = 1{,}2$$

The reflection coefficient of the walls is taken ρ = 50%.

According to SP 52.13330.2016, the minimum illumination on the working surface must be at least Emin = 300 lux.

Let's calculate the luminous flux of the lamp. There are 4 lighting devices in the room, N = 2; safety factor of LED luminaires k = 1.1; the numerical ratio of uneven illumination z = 1; the index of the room determines the utilization factor of the luminous flux, η = 0.51. Then the luminous flux is:

$$\Phi = \frac{E \cdot k \cdot S \cdot z}{N \cdot \eta} = \frac{300 \cdot 1{,}1 \cdot 24 \cdot 1}{4 \cdot 0{,}51} = 3882\ lm$$

We compare the calculated value of the luminous flux with the value of the selected light fixture, 4240 lm.

$$-10 \le \frac{\Phi_{\text{станд.}} - \Phi_{\text{расч.}}}{\Phi_{\text{станд.}}} \cdot 100\% \le 20$$

$$-10 \le \frac{4240 - 3882}{4240} \cdot 100\% \le 20$$

$$-10 \le 8.44 \le 20$$

We get that the luminous flux of the selected lighting device is suitable for lighting rooms where computers with an illumination of 300 lux are installed.

Many types of industrial and scientific activities are characterized by an increased load on the visual system and attention processes. In combination with physical inactivity, neuro-emotional stress, long-term preservation of a non-optimal basic working posture leads to the development of visual and general fatigue and a decrease in working capacity.

In the prevention of general and visual fatigue in representatives of a number of professions, an important role belongs to the provision of visual comfort. This includes general illumination, room color, light distribution, etc. The optimal location of objects of the labor process at a distance of 30-100 cm from the eyes.

When working for a long time at a personal computer, regulated breaks during which gymnastics is performed must be taken into account. It consists of general strengthening and special exercises for the eyes. The latter should be based on the principles of training and relaxation of accommodation, as well as manipulations that improve the blood supply to the eyes.

Also, correctly designed and executed lighting ensures a high level of efficiency, reduces the load on the organs of vision, has a positive psychological effect on workers, and helps to increase labor productivity.

5.3.4 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.

The premises for electrical safety are divided into 3 groups:

1. A room without increased danger (dry, well-heated, room with non-conductive floors, with a temperature of 18–20 °, with a humidity of 40–50%).

2. A room with increased danger (where there is one of the following signs: high temperature, humidity 70-80%, conductive floors, metal dust, the presence of grounding, a large amount of equipment).

3. Premises are especially dangerous, in which there are two signs from the second group or there are caustic or poisonous explosive substances in the room.

According to [1], electrical safety must be ensured by the design of electrical installations, technical methods and means of protection. Electrical installations and their parts are designed in such a way that workers are not exposed to dangerous and harmful effects of electric current and electromagnetic fields, and comply with electrical safety requirements.

First of all, safety is ensured by the use of collective protective equipment, and then, if it cannot be ensured, personal protective equipment is used.

The means of collective protection against electric shock include: protective devices, which can be stationary and portable. Fences can be interlocked with devices that cut off the operating voltage when removed; insulating devices and coatings; protective grounding, neutralization and protective shutdown devices; remote control devices; safety devices, etc.

Also, personal protective equipment is divided into basic and additional. The main protective insulating means include insulating rods, insulating pliers and electrical voltage indicators, dielectric gloves, fitting and assembly tools with insulating handles. Additional insulating protective equipment includes means that supplement the main ones, and can also serve to protect against touch voltage and step voltage. Dielectric galoshes, dielectric rugs, insulating supports [2] serve as additional protective equipment.

5.3.5 Noise

Industrial noise is the noise in workplaces, on sites or on the territory of enterprises, which occurs during the production process. Noise and vibration worsen working conditions, have a harmful effect on the human body, namely, on the hearing organs and on the entire body through the central nervous system. As a result, attention is weakened, memory deteriorates, reaction decreases, and the number of errors during work increases. Noise can be generated by operating equipment, air conditioning units, daylight fixtures, and can also be emitted from outside.

In accordance with SanPiN 1.2.3685-21 [3], the standardized indicators in the workplace are:

- equivalent sound level per work shift;

- maximum sound level;

- peak sound level.

The standard equivalent sound level in the workplace is 80 dB. At noise levels above the permissible level, it is necessary to provide RMS and PPE.

Collective protection means [4]:

- elimination of the causes of noise or its significant attenuation in the source of education;

- isolation of noise sources from the environment by means of sound vibration isolation, sound and vibration absorption;

- the use of means that reduce noise and vibration along the path of their propagation.

Personal protective equipment [4]:

- the use of overalls, footwear and hearing protection: headphones, earplugs, antiphones.

5.3.6 Static electricity

All conductive parts of process equipment and other objects that generate or store static electricity must be grounded, regardless of whether other ESD devices are used. An ESD grounding device must have a maximum resistance of 100 ohms. According to [SanPin 1.2.3685-21] collective protection means against static electricity are: anti-electrostatic substances, humidifying devices, neutralizers, shielding substances. Anti-static footwear, gowns, and anti-electrostatic hand protection should be used as personal protective equipment.

5.4 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 subdivided into categories A, B, C, D and F in accordance with [12]. The room in question belongs to category C, 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 [12]. Operational measures include preventive inspections of equipment.

Regime measures include the establishment of rules for organizing work and compliance with 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 the 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.[12] 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, there are 2 OP 3 fire extinguishers (portable powder fire extinguishers) on the floor, stairwells are equipped with hydrants, and there is a fire alarm button[12].

5.4 Safety in emergencies

Emergency situation - a situation in a certain area resulting from an accident, dangerous natural phenomenon, catastrophe, natural or other disaster that may or have resulted in human casualties, damage to human health or the environment, significant material losses and disruption of the living conditions of people.

The most common emergencies in the building where the bachelor's job was developed are intrusion and fire.

Table 5.5 - 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.

First case: penetration of unauthorized persons. To ensure the safety of the employee and prevent the entry of unauthorized persons into the enterprise, a number of security measures should be used:

1. Organize a checkpoint.

2. Hire a security guard to bypass the building.

3. Install video surveillance systems in production halls, as well as at all entrances and exits from the building.

4. Install warning security systems in case of unauthorized entry into the enterprise outside of working hours.

Second case: fire. Possible causes of sunburn:

- malfunction of current-carrying parts of installations;
- work with open electrical equipment;
- short circuits in the power supply;
- non-observance of fire safety rules;
- presence of combustible components: documents, doors, tables, cable insulation, etc.

Fire prevention measures are divided into: organizational, technical, operational and regime.

Organizational measures provide for the correct operation of equipment, the correct maintenance of buildings and territories, fire-prevention instructions for workers and employees, training of production personnel in fire safety rules, the publication of instructions, posters, and an evacuation plan.

Technical measures include: compliance with fire regulations, norms in the design of buildings, in the installation of electrical wires and equipment, heating, ventilation, lighting, proper placement of equipment.

Regime measures include the establishment of rules for organizing work, and compliance with fire safety measures. To prevent a fire from short circuits, overloads, etc., the following fire safety rules must be observed:

- elimination of the formation of a combustible environment (equipment sealing, air control, working and emergency ventilation);
- the use of non-combustible or hardly combustible materials in the construction and decoration of buildings; correct operation of equipment (correct connection of equipment to the power supply network, control of equipment heating);
- correct maintenance of buildings and territories (exclusion of the formation of an ignition source - prevention of spontaneous combustion of substances, limitation of hot work);
- training of production personnel in fire safety rules;
- publication of instructions, posters, availability of an evacuation plan;
- observance of fire safety rules, norms in the design of buildings, in the installation of electrical wires and equipment, heating, ventilation, lighting;
- correct placement of equipment;
- timely preventive inspection, repair and testing of equipment.

In the event of an emergency it is necessary to: Inform the management (duty officer);

Call the appropriate emergency service or the Ministry of Emergency Situations - tel. 112;

Take measures to eliminate the accident in accordance with the instructions.

5.5 Conclusion on chapter 5

The industrial safety technique has been developed and analyzed in the course of this scientific and technical research.

Measures to create the necessary microclimate conditions have already been introduced in this room. The noise in the room is in accordance with the established norms. Electrical safety measures are also carried out in this laboratory.

The chapter discusses harmful and dangerous factors:

- microclimate [5];
- noise [4];
- illumination [8];
- fire hazard [12];
- electrical safety [15];

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 danger from electromagnetic radiation were considered separately.

The audience in question is assigned to class B for fire hazard [13] and 1 for the electrical safety [9].

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, VA 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.

List of references

1. Zahorowski, W., Chambers, S.D., Henderson-Sellers, A., 2004. Ground based radon-222observations and their application to atmospheric studies. J. Environ. Radioact. 76,3–33. https://doi.org/10.1016/j.jenvrad.2004.03.033.

2. Rudakov VP Dynamics of subsoil radon fields in seismically active regions of the CIS: Author's abstract. doctor. dis. M. 1992.56 p. (in Russian).

3. Leonova A.V. Fundamentals of hydrogeology and engineering geology: textbook / comp .: A.V. Leonova; Tomsk Polytechnic University. - 2nd ed. - Tomsk: Publishing house of the Tomsk Polytechnic University, 2013 .-- 149 p. (in Russian).

4. Firstov P.P., Ponomarev E.A., Cherneva N.V., Buzevich A.V. Subsoil radon and the gradient of the potential of the atmospheric electric field in the Petropavlovsk-Kamchatka geodynamic testing area in 1998-2005. (Kamchatka) // Bulletin of KRAUNTS. Earth Science Series, 2006. No. 1. (issue 7.). S. 102-109. (in Russian).

5. Brief Geographical Encyclopedia, Volume 4 / ed. A.A. Grigoriev M .: Soviet encyclopedia, 1964 .-- 448 p. (in Russian).

6. Dafina Kikaj, Scott D. Chambers, Janja Vaupotič Radon-based atmospheric stability classification in contrasting sub-Alpine and subMediterranean environments, Journal of Environmental Radioactivity, Volume 203, 2019, Pages 125-134, ISSN 0265-931X, https://doi.org/10.1016/j.jenvrad.2019.03.010.

7. K Charan Kumar, T Rajendra Prasad, M Venkat Ratnam, Kamsali Nagaraja Activity of radon (222Rn) in the lower atmospheric surface layer of a typical rural site in south India.

8. Chen, Xuemeng & Paatero, Jussi & Kerminen, Veli-Matti & Riuttanen, Laura & Hatakka, J & Hiltunen, V & Paasonen, Pauli & Hirsikko, A & Franchin, Alessandro & Manninen, H.E. & Petäjä, T & Viisanen, Y & Kulmala, M. (2016). Responses of the atmospheric concentration of radon-222 to the vertical mixing and spatial transportation. 21. 299-318.

9. Factors controlling temporal variability of near-ground atmospheric 222Rn concentration over central Europe M. Zimnoch, P. Wach, L. Chmura, Z. Gorczyca, K. Rozanski, J. Godlowska, J. Mazur, K. Kozak, and A. Jeričević.

10. Bu, J.-O & Song, J.-M & Kim, W.-H & Kang, C.-H & Song, S.-K & Williams, Alastair & Chambers, Scott. (2017). Temporal variation of atmospheric Radon-222 and gaseous pollutants in background area of Korea during 2013-2014. Asian Journal of Atmospheric Environment.

11. 114-121. 10.5572/ajae.2017.11.2.114. 11. Mohery, M & M Abdallah, A & Ali, A & S Baz, S. (2016). Daily variation of radon gas and its short-lived progeny concentration near ground level and estimation of aerosol residence time. Chinese Physics B. 25. 050701. 10.1088/1674-1056/25/5/050701.

12. R. Vecchi, F.A. Piziali, G. Valli, M. Favaron, V. Bernardoni Radonbased estimates of equivalent mixing layer heights: A long-term assessment, Atmospheric Environment, Volume 197, 2019, Pages 150-158, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2018.10.020.

13. GOST 30494-96. Zdanija zhilye i obshhestvennye. Parametry mikroklimata v pomeshhenijah;

14. GOST 12.1.003-83. Sistema standartov bezopasnosti truda (SSBT). Shum. Obshhie trebovanija bezopasnosti (s Izmeneniem N 1);

15. SNiP 23-05-95*. Estestvennoe i iskusstvennoe osveshhenie (s Izmeneniem N 1);

16. SP 12.13130.2009. Opredelenie kategorij pomeshhenij, zdanij i naruzhnyh ustanovok po vzryvopozharnoj i pozharnoj opasnosti (v red. izm. № 1, utv. prikazom MChS Rossii ot 09.12.2010 № 643);

17. GOST 12.1.004-91 Sistema standartov bezopasnosti truda. Pozharnaja bezopasnost'. Obshhie trebovanija;

18. GOST 12.1.009-76 Sistema standartov bezopasnosti truda (SSBT);

19. GOST R12.1.019-2017 SSBT Jelektrobezopasnost';

20. GOST R MJeK 61140-2000 Zashhita ot porazhenija jelektricheskim tokom. Obshhie polozhenija po bezopasnosti, obespechivaemoj jelektrooborudovaniem i jelektroustanovkami v ih vzaimosvjazi;

21. SanPiN 2.2.4.1191-03 Jelektromagnitnye polja v proizvodstvennyh uslovijah (s izmenenijami ot 2 marta 2009 g.);

22. SanPiN 2.6.1.2523-09 Normy radiacionnoj bezopasnosti NRB-99/2009;

23. GOST 22.0.02-94 Bezopasnost' v chrezvychajnyh situacijah. Terminy i opredelenija osnovnyh ponjatij;

24. Ob osnovah ohrany truda v Rossijskoj Federacii: Federal'nyj zakon ot 17 ijulja 1999 № 181 – FZ // Rossijskaja gaz. – 1999 – 24.07. – S.4;

25. Kukin P.P., Lapin V.L. Bezopasnost' tehnologicheskih processov i proizvodstv: ucheb. posobie. M., Vysshaja shkola. 1999. S.318;

26. SNiP 23-03-2003 s SP 51.13330.2011 Zashhita ot shuma.