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)

Школа _______________________инженерная школа ядерных технологий_____________
Направление подготовки ________14.03.02 Ядерные физика и технологии______________
Отделение школы_____________отделение ядерно-топливного цикла_________________

БАКАЛАВРСКАЯ РАБОТА

Тема работы
Влияние ливневых осадков на динамику гамма-фона и активности осажденных на земную поверхность ^{214}Pb и ^{214}Bi

УДК 539.122.16:551.577

Студент

Группа	ФИО	Подпись	Дата
0А7А	Епанчинцев Даниил Павлович		

Руководитель ВКР

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

Консультант

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

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

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

По разделу «Социальная ответственность»

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

ДОПУСТИТЬ К ЗАЩИТЕ:

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

Томск – 2021 г.

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«Национальный исследовательский Томский политехнический университет» (ТПУ)

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

BACHELOR WORK

Topic of research work
Influence of heavy rainfall on the dynamics of the gamma background and the activity of ^{214}Pb and ^{214}Bi deposited on the earth's surface

UDC 539.122.16:551.577

Student

Group	Full name	Signature	Date
0A7A	Daniil P. Epanchincev		

Scientific supervisor

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

Adviser

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

ADVISERS:

Section “Financial Management, Resource Efficiency and Resource Saving”

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

Section “Social Responsibility”

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

ADMITTED TO DEFENSE:

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

Tomsk – 2021

ПЛАНИРУЕМЫЕ РЕЗУЛЬТАТЫ ОБУЧЕНИЯ ООП

Код результата	**Результат обучения (выпускник должен быть готов)**
	Общекультурные компетенции
Р1	Демонстрировать культуру мышления, способность к обобщению, анализу, восприятию информации, постановке цели и выбору путей ее достижения; стремления к саморазвитию, повышению своей квалификации и мастерства; владение основными методами, способами и средствами получения, хранения, переработки информации, навыки работы с компьютером как средством управления информацией; способность работы с информацией в глобальных компьютерных сетях.
Р2	Способность логически, верно, аргументировано и ясно строить устную и письменную речь; критически оценивать свои достоинства и недостатки, намечать пути и выбирать средства развития достоинств и устранения недостатков.
Р3	Готовностью к кооперации с коллегами, работе в коллективе; к организации работы малых коллективов исполнителей, планированию работы персонала и фондов оплаты труда; генерировать организационно-управленческих решения в нестандартных ситуациях и нести за них ответственность; к разработке оперативных планов работы первичных производственных подразделений; осуществлению и анализу исследовательской и технологической деятельности как объекта управления.
Р4	Умение использовать нормативные правовые документы в своей деятельности; использовать основные положения и методы социальных, гуманитарных и экономических наук при решении социальных и профессиональных задач, анализировать социально-значимые проблемы и процессы; осознавать социальную значимость своей будущей профессии, обладать высокой мотивацией к выполнению профессиональной деятельности.
Р5	Владеть одним из иностранных языков на уровне не ниже разговорного.
Р6	Владеть средствами самостоятельного, методически правильного использования методов физического воспитания и укрепления здоровья, готов к достижению должного уровня физической подготовленности для обеспечения полноценной социальной и профессиональной деятельности.

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

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

PLANNED OOP LEARNING OUTCOMES

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

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

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

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«Национальный исследовательский Томский политехнический университет» (ТПУ)

Школа ______________________ инженерная школа ядерных технологий ____________
Направление подготовки ________ 14.03.02 Ядерные физика и технологии _____________
Отделение школы _____________ отделение ядерно-топливного цикла ________________

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

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

В форме:

Бакалаврская работа

Студенту:

Группа	ФИО
0А7А	Епанчинцев Даниил Павлович

Тема работы:

Численное исследование условий проявления влияния пород с повышенным содержанием урана на результаты измерения объемной активности радона в почвенном воздухе	
Утверждена приказом директора (дата, номер)	28.04.2021 г., №118-33/с

Срок сдачи студентом выполненной работы:	09.06.2021

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе	Активность осаждённых на земную поверхность ^{214}Pb и ^{214}Bi, мощность амбиентного эквивалента дозы гамма-излучения
Перечень подлежащих исследованию, проектированию и разработке вопросов	- обзор литературных источников; - источники атмосферного гамма-излучения; - методы и приборы измерения гамма-излучения в приземной атмосфере; - внутри суточные и сезонные особенности в динамике атмосферного гамма-излучения; - анализ полученных результатов; - финансовый менеджмент, ресурсоэффективность и ресурсосбережение; - социальная ответственность; - заключение по работе.
Перечень графического материала	Презентация для защиты ВКР

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

Названия разделов, которые должны быть написаны на русском и иностранном языках:
Введение
Обзор литературы
Провести эксперимент и анализ результатов измерений
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение
Социальная ответственность

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

Задание выдал руководитель / консультант (при наличии):

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А7А	Епанчинцев Даниил Павлович		

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«Национальный исследовательский Томский политехнический университет» (ТПУ)

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

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

ASSIGNMENT
for the Graduation Thesis completion

In the form:

Bachelor work

For a student:

Group	Full name
0A7A	Daniil P. Epanchincev

Topic of research work:

Numerical study of the conditions for the manifestation of the influence of rocks with an increased uranium content on the results of measuring the volumetric activity of radon in soil air	
Approved by the order of the Director of School of Nuclear Science & Engineering (date, number):	28.04.2021 г., №118-33/с

Deadline for completion of bachelor work:	09.06.2021

TERMS OF REFERENCE:

Initial date for research work	Activity of ^{214}Pb and ^{214}Bi deposited on the earth's surface, rate of ambient dose equivalent of gamma radiation
List of the issues to be investigated, designed and developed	- review of literary sources; - sources of atmospheric gamma radiation; - methods and instruments for measuring gamma radiation in the surface atmosphere; - within the daily and seasonal characteristics in the dynamics of atmospheric gamma radiation; - analysis of the results obtained; - financial management, resource efficiency and resource conservation; - Social responsibility; - conclusion on the work.
List of graphic material	Presentation to defend work

Advisors to the sections of Graduation Thesis	
Section	**Advisor**
Social Responsibility	Yuriy V. Perederin
Financial Management, Resource Efficiency and Resource Saving	Maharram A. Hasanov

The titles of the sections that must be written in Russian and foreign languages:
Introduction
Literature review
Conduct an experiment and analyze the measurement results
Financial management, resource efficiency and resource conservation
Social responsibility

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

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

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

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0A7A	Daniil P. Epanchincev		

TOMSK POLYTECHNIC UNIVERSITY | ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

Школа ___________________________инженерная школа ядерных технологий_____________
Направление подготовки________14.03.02 Ядерные физика и технологии ______________
Уровень образования __________бакалавриат____
Отделение школы _____________отделение ядерно-топливного цикла_________________
Период выполнения_____________весенний семестр 2020 /2021 учебного года___________

Форма представления работы:

Бакалаврская работа

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения бакалаврской работы

Срок сдачи студентом выполненной работы:	09.06.2021

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
10.05.2021	Обзор литературных источников	10
14.05.2021	Моделирование динамики радона и продуктов его распада в приземной атмосфере	15
20.05.2021	Моделирование динамики активности ^{214}Pb и ^{214}Bi, осаждённых на земную поверхность ливневыми осадками	15
24.05.2021	Расчёт мощности дозы гамма-излучения, создаваемой осаждёнными ^{214}Pb и ^{214}Bi	15
27.05.2021	Анализ полученных результатов	15
04.06.2021	Финансовая ответственность	10
04.06.2021	Социальная ответственность	10
08.06.2021	Заключение по работе	10

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Должность	ФИО	Ученая степень, звание	Подпись	Дата
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Руководитель ООП

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TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

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

Form of presenting the work:

Bachelor work

SCHEDULED ASSESSMENT CALENDAR
for the bachelor work completion

Deadline for completion of bachelor work:	09.06.2021

Assessment date	Title of section (module) / type of work (research)	Maximum score for the section (module)
10.05.2021	Review of literary sources	10
14.05.2021	Simulation of the dynamics of radon and its decay products in the surface atmosphere	15
20.05.2021	Modeling the dynamics of 214Pb and 214Bi activity deposited on the earth's surface by heavy rainfall	15
24.05.2021	Calculation of the dose rate of gamma radiation generated by the precipitated 214Pb and 214Bi	15
27.05.2021	Analysis of the obtained results	15
04.06.2021	Financial responsibility	10
04.06.2021	Social responsibility	10
08.06.2021	Conclusion on work	10

COMPILED BY:
Scientific supervisor:

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

Adviser

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

APPROVED BY:

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

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

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Уровень образования	бакалавр	**Направление/специальность**	14.03.02 Ядерные физика и технологии/ Радиационная безопасность окружающей среды

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. *Стоимость ресурсов научного исследования (НИ): материально-технических, энергетических, финансовых, информационных и человеческих*	– *Заработная плата – 46170 руб.;* – *Отчисления во внебюджетные фонды – 12512 руб.;* – *Накладные расходы – 7387руб.;* – *Бюджет затрат – 67000 руб.*
2. *Нормы и нормативы расходования ресурсов*	*Тариф на электроэнергию – 5,8 руб. за 1 кВт·ч.*
3. *Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования*	*Коэффициент отчислений во внебюджетные фонды – 27,1 %.*
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. *Оценка коммерческого потенциала, перспективности и альтернатив проведения НИ с позиции ресурсоэффективности и ресурсосбережения*	*Оценочная карта конкурентных технических решений*
2. *Планирование и формирование бюджета научных исследований*	*Иерархическая структура работ*
3. *Определение ресурсной (ресурсосберегающей), финансовой, бюджетной, социальной и экономической эффективности исследования*	*SWOT-анализ*
Перечень графического материала *(с точным указанием обязательных чертежей)***:**	
1. *Оценка конкурентоспособности технических решений* 2. *Матрица SWOT* 3. *График проведения и бюджет НИ* 4. *Оценка ресурсной, финансовой и экономической эффективности НИ*	

Дата выдачи задания для раздела по линейному графику	

Задание выдал консультант:

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

Задание принял к исполнению студент:

Группа	**ФИО**	**Подпись**	**Дата**
0А7А	Епанчинцев Даниил Павлович		

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

For a student:

Group	Full name
0A7A	Daniil P. Epanchincev

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

Initial data for the section "Financial Management, Resource Efficiency and Resource Saving":	
1. The cost of scientific research resources (SR): material and technical, energy, financial, informational and human	– Salary - 46170 rubles; – Contributions to off-budget funds - 12,512 rubles; – Overhead costs - 7387 rubles; – Cost budget - 67,000 rubles.
2. Norms and norms of resource consumption	Electricity tariff - 5.8 rubles. per 1 kW · h.
3. The used system of taxation, rates of taxes, deductions, discounting and crediting	The rate of deductions to extra-budgetary funds is 27.1%.
List of questions to be researched, designed and developed:	
1. Assessment of the commercial potential, prospects and alternatives of conducting research from the standpoint of resource efficiency and resource conservation	Competitive technical solutions scorecard
2. Planning and budgeting of scientific research	Work breakdown structure
3. Determination of resource (resource-saving), financial, budgetary, social and economic efficiency of the research	SWOT analysis
List of graphic material *(with exact indication of the required drawings)*:	
1. Assessment of the competitiveness of technical solutions *2. SWOT Matrix* *3. Schedule and budget of scientific research* *4. Assessment of the resource, financial and economic efficiency of scientific research*	

Date of issuance of the task according to the schedule	

Assignment issued by an advisor:

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

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0A7A	Daniil P. Epanchincev		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Студенту:

Группа	**ФИО**
0А7А	Епанчинцеву Даниил Павловичу

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

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

Дата выдачи задания для раздела по линейному графику	

Задание выдал консультант:

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

Задание принял к исполнению студент:

Группа	**ФИО**	**Подпись**	**Дата**
0А7А	Епанчинцев Даниил Павлович		

TASK FOR SECTION
"SOCIAL RESPONSIBILITY"

For a student:

Group	Full name
0A7A	Daniil P. Epanchincev

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

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

Date of issuance of the task according to the schedule	

Assignment issued by an advisor:

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

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0A7A	Daniil P. Epanchincev		

ABSTRACT

Final qualifying work 89 p., 25 figures, 20 tables, 34 sources.

Key words: γ-radiation, rainfall, precipitation intensity, radon, surface layer of the atmosphere.

The object of research is the γ-background of the surface atmosphere.

The aim of this work is to investigate the relationship between the magnitude of the anomalous surge in the dose rate of γ-radiation during precipitation and the characteristics of rainfall.

In the course of the study, the spatial (in the vertical direction) and temporal dynamics of the activity of the DPR of radon contained in the surface atmosphere, as well as washed out by heavy rainfall on the ground, was simulated. The height distributions of the volumetric activity of short-lived daughter products of radon decay were calculated under various meteorological conditions. The contribution of each atmospheric radionuclide to the total dose rate was estimated at different atmospheric turbulence and the height of the lower edge of rain clouds.

The study revealed radionuclides that make the main contribution to the total γ-background. The dependence of the dynamics of volumetric activity and dose rate on various meteorological conditions is considered.

Implementation degree: research results can be used in calculations and estimates of gamma background dose rate.

Applications: meteorology, radiation safety, geophysics.

Economic efficiency / significance of the work lies in the use of the results to develop a cheaper method for measuring the characteristics of atmospheric precipitation in comparison with existing analogues.

Table of contents

Introduction

Tracking the background radiation in the surface atmosphere is a very important task. It is widely known that radon and its daughter decay products contribute more than half of the annual human dose to all-natural sources of radiation, both terrestrial and cosmic.

Over the past two decades, the scientific community has actively studied the issue of measuring and predicting changes in the concentrations of radon and its daughter decay products in the surface layers of the atmosphere.

At present, the radiation background of the surface layer of the atmosphere is monitored continuously. This is due to the fact that its value is not constant and depends on many factors: season of the year, time of day, temperature, humidity, etc. At the same time, the change in the radiation background, the main components of which are soil radioactive gases and atmospheric radionuclides, can speak about the course of various atmospheric and geophysical processes.

Thus, for example, on cool nights, radon for the most part remains at the earth's surface, and during the day, when the air is heated by the sun's rays, the turbulence of the atmosphere increases, which contributes to the fact that radon rises into the air, which leads to a decrease in its concentration at the earth's surface and lower background radiation.

An important fact is also the phenomenon of an increase in background radiation during rainfall. This is due to the washing out of the daughter products of radon decay from the atmosphere by the deposition of radioactive aerosols on the earth's surface together with water droplets.

The foregoing allowed us to determine the purpose and objectives of this work.

Purpose of the work: to study the effect of heavy rainfall on the dynamics of the γ-background and the activity of precipitated on the earth's surface ^{214}Pb and ^{214}Bi.

Tasks:

- literature review on the topic;
- modeling the spatial (in the vertical direction) and temporal dynamics of the volumetric activity and dose rate of daughter products of radon decay, formed in the surface atmosphere during rainfall, at different values of the duration of precipitation and atmospheric turbulence;
- analysis of results and conclusions.

Chapter 1 Literature review

1.1 Natural radiation background of the atmosphere

The radioactivity of the atmosphere depends on the surface layer of the air, which contains radionuclides of cosmogenic and terrestrial origin and undergoes various processes of radionuclides entering the earth's surface, into the aquatic environment and into living organisms.

The natural background of the atmosphere is determined by cosmic radiation and radiation of radioactive substances in the air and soil.

A large number of scattered radionuclides, which include radon, thoron and their DDP, are in the ground. Their entry into the atmosphere is associated with molecular and turbulent diffusion. It can be argued that the dose in the air is mainly determined by the background radiation of radon decay products [3].

The ancestors of radon and taron are radionuclides ^{238}U and ^{232}Th (Fig. 1.1).

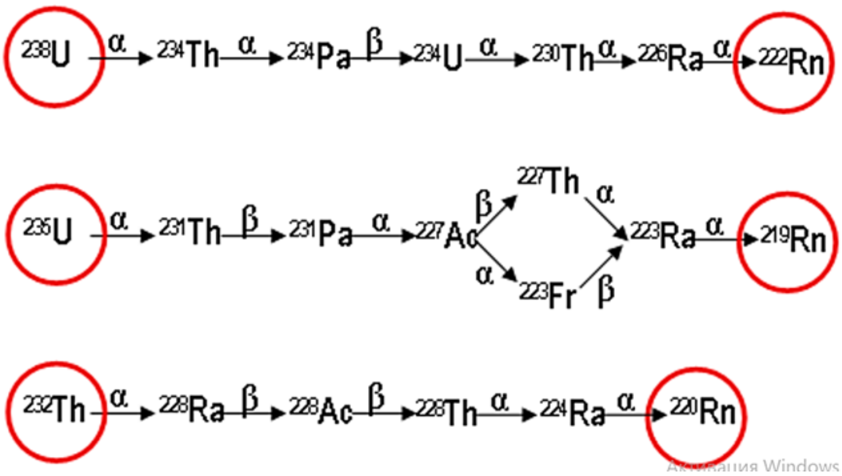

Figure 1.1 - Rows of natural radioactive families before the formation of radon [4]

Almost all radon is scattered in the depths of the earth and water. According to rough estimates, in the upper layer of the earth's crust, at a depth of 1.6 kilometers, there are almost 115 tons of radon. The content of radon in the atmosphere is much less than that of the earth's crust, only 4.6 kilograms. Radon is contained in almost everything that surrounds us: in the waters of oceans and rivers, the bowels of the earth's crust, soil, natural gases and even in humans. The only place where radon is practically absent is the air and glaciers of Antarctica.

Thoron, in turn, is found in small quantities in the atmospheric air. [4].

1.2 Washout radon, thoron and their DDP by rainfall

Figure 1.2 shows an illustration of the process of washout of radon and thoron DDP by rainfall.

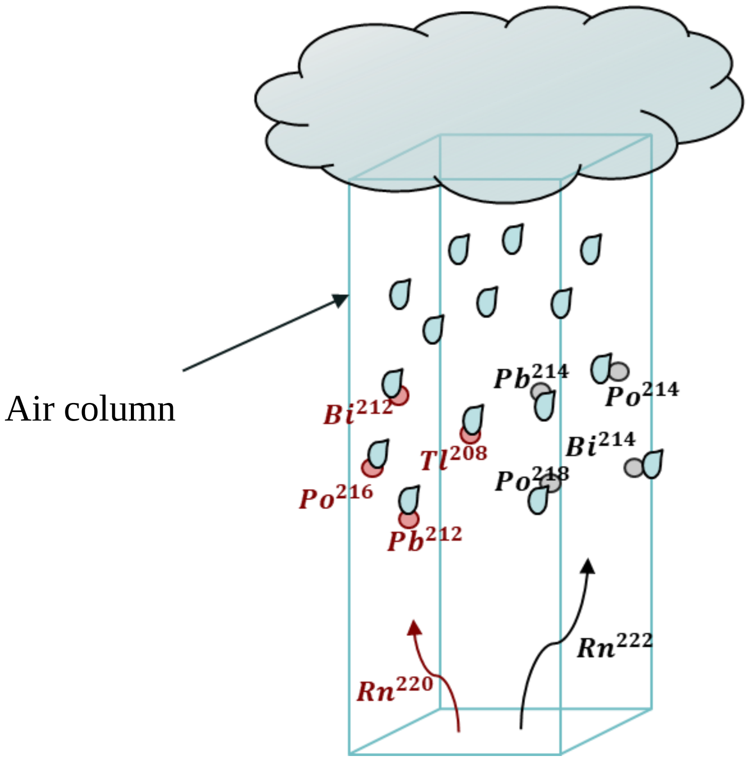

Figure 1.2 - An illustration of the washout of the DDP of radon and thoron by rainfall

From the soil, through molecular and turbulent diffusion, radioactive gases radon and thoron enter the atmosphere. Being in the atmosphere, they undergo radioactive decay and their DDP fall into the air. As a result, radioactive aerosols are formed, that is, aerosols containing particles that are fully or partially composed of radionuclides, which either enter the particle material or attach to inactive particles.

When rain falls, radioactive aerosols, together with water droplets, settle on the surface of the earth. Thus, we can say that the characteristics of the transfer of the decay products of radon and thoron in the surface atmosphere strongly depend on their physical state, as well as on the state and variability of the surface atmosphere, lithosphere, and space weather factors.

The washout process of the DDP of radon and thoron contributes to abnormal bursts of the radiation dose rate and the greater the intensity of rainfall, the more the dose rate increases [5].

The effect of precipitation on the radiation background of the atmosphere is being studied by scientists from different countries.

The dependence of the increase in the γ-background on various precipitation was found in low latitudes of the tropical zone. [6].

At the Ranger uranium mine in Australia, the factors influencing the γ-background of the atmosphere were soil moisture and porosity, since with an increase in soil moisture, as a result of precipitation, the release of radon increased, and hence the background of the surface atmosphere [7].

Observations of the γ-background in the surface layer of the atmosphere of the Arctic regions also confirm the influence of precipitation, such as rain or snowfall, on the increase in γ-radiation level. The reason for this effect in these regions is the X-ray bremsstrahlung of energetic electrons accelerated by electric fields inside rain (snow) clouds, since no characteristic lines of any radionuclides were found in the γ-background during the period of increases and there were no radionuclides in the rainwater. Although one should not forget about short-lived atmospheric radionuclides, which are difficult to detect, since they can significantly decay during sample preparation [8]. So, in the Oak Ridge laboratory it was found that it is the short-lived radionuclides that make the main contribution to the increase in the γ-background of the near-ground atmosphere. [9].

The connection between precipitation and an increase in the background radiation in the atmosphere was questioned by scientists from the UK, who, after studying this dependence at various stations, could not determine whether precipitation affects an increase in background or air masses carrying radon fluxes. Moreover, after the expiration of 1 - 2 hours, the radiation background of the surface atmosphere decreased again. [10]. Most likely, the short-lived DDP of radon were not taken into account, since the half-life of such nuclei is less than one hour.

On the surface of the earth, the number of cosmogenic radionuclides also increases during precipitation, such as ^{7}Be, which can contribute to an increase in the radioactivity of the surface atmosphere. In Japan, since 1991, the increase in the amount of ^{7}Be and ^{214}Pb on the earth's surface has been studied. This happens in winter and summer during the period of precipitation. It was found that this phenomenon is not temporary, but stationary in nature. [11]. Similar studies carried out in Spain also confirm an increase in the amount of these radionuclides during the period of precipitation.

It should be noted that the cosmogenic component of radiation also depends on precipitation and increases the γ-background of the near-ground atmosphere. [6].

Thus, the effect of rainfall has been repeatedly confirmed by research, and a number of scientists have noted that precipitation plays an important role in changes in atmospheric γ-radiation during one day and causes short-term sharp increases (bursts) of some characteristics of γ-radiation fields by tens and even hundreds of percent.

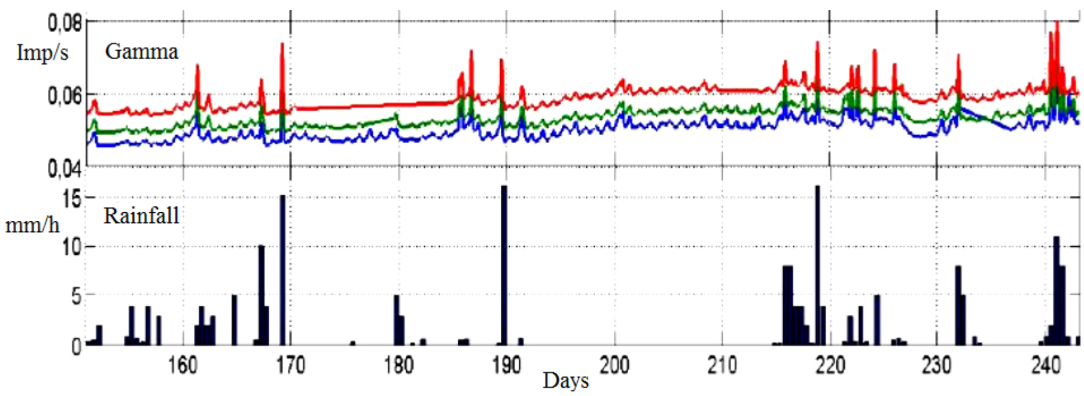

Figure 1.3 - Dependence of the amount of precipitation and the dose rate of γ-radiation on time (summer 2013)

To describe this phenomenon, a special term “radon washout” was even invented abroad, meaning the washing out of γ-emitting DDP of radon and thoron by precipitation onto the earth's surface [12]. TPU scientists also carried out seasonal studies of this effect and noticed bursts of γ-radiation during precipitation. Measurements were carried out at different heights from 10 cm to 25 m. The effect lasts from several hours to half a day.

A detailed review and analysis of the 2009-2011 data was also carried out for the presence of bursts during precipitation. During the analysis, it was noted that the best dependence of the bursts of the dose rate of gamma radiation with the time of precipitation is observed in the summer season.

1.3 Conclusion on the first chapter

The main contribution to the radiation background of the surface layer of the atmosphere is made by the natural background, which includes soil and atmospheric radionuclides.

An increase in the γ-background of the surface layer of the atmosphere occurs at the time of rainfall, which is explained by the washing out of the DDP of radon and thoron.

The penetration of the DDP into the atmosphere is due to radioactive decay in the atmosphere of radon and thoron, penetrating through turbulent and molecular diffusion into the air.

Chapter 2 Methods for measuring rainfall intensity

The intensity of rainfall is understood as the layer of precipitation that falls per unit of time. There are many different instruments available to measure the intensity of rainfall. But, like all devices, there are drawbacks associated with the technical performance and the method of measuring the intensity, which affect the result.

2.1 Pluviograph

One of the instruments that measure the intensity of rainfall is the Pluviograph.

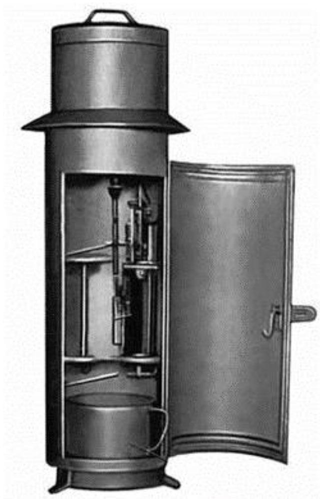

Figure 1.4 - Pluviograph [13]

The pluviograph consists of a sediment collection chamber with a receiving funnel, a siphon and a float connected with a recorder and a unit for forced discharge. The unit of the forced start of draining is made in the form of a tipping tank mounted on a pivot axis, and a stop rigidly connected to the sludge collection chamber, the float is rigidly attached to the bottom of the tipping tank, and the center of gravity of the float and the stop are located on opposite sides of the pivot axis.

Each turn ("somersault") of this container is recorded on the diagram. The density of the location of the drawn diagram for a certain period of time is used to judge the total amount and intensity of the incoming liquid through the receiving funnel.

But when using a pluviograph, the time of the beginning of rain is not known, that is, the time of the beginning of filling the overturning container is not recorded on the drawn diagram, but only the time of draining the first portion of the overturning container is recorded, thus, the exact time of the beginning of rain is not known, which can lead to an increase in the determination error precipitation intensity and decrease in the reliability of the measurement result.

The use of a large number of mechanical and kinematic links leads to a decrease in the reliability of the method and the service life.

2.2 Sectional winding rain gauge with distributed capacity

A known method for determining the intensity of rainfall in the surface layer of the atmosphere using a rain gauge containing a sectional winding with a distributed capacity formed by two insulated conductors, the ohmic resistance of which depends on temperature, as well as a signal processing unit and a recorder. Under the influence of precipitation falling inside the winding, the capacitance of the capacitor changes, which is converted into a sequence of electrical impulses, the repetition rate of which is proportional to the intensity of precipitation.

The main disadvantage of this method is the high measurement error of the precipitation intensity, since it is determined only by the variable repetition rate of electrical pulses of equal duration, and does not depend on the size of the drops.

2.3 Optical-acoustic-electronic device

Determination of the intensity of rainfall in the surface layer of the atmosphere can be carried out using an opto-acoustic-electronic device, in which the number of precipitation drops is converted into the number of electrical impulses due to the interruption of the laser beam by drops, as well as the conversion of an audio signal using a membrane and a microphone into an electrical signal.

The main disadvantages of this method:

– low reliability due to clouding of optics with prolonged exposure to precipitation;
– the influence of random noise leads to an increase in the error in determining the intensity of precipitation;
– complexity of measuring units and power consumption of power supply with different voltages.

2.4 Shuttle rain gauge

Shuttle type rain gauges work on the shuttle principle. They imply the presence of a drain hole at the bottom of the container that collects precipitations. Through this small hole, water drops dropwise into a container (ladle, spoon), which, when filled, overturns, and the water is drained from the device to the ground. The empty bucket is returned to its original state with the help of a reed switch magnet.

Sometimes, in the device there are two buckets paired with a partition, one of which, when filled, falls on one side for draining, substituting, due to its weight, a second bucket under the hole. When the second bucket is filled, it, in turn, falls on the other side, freeing up space for the first. The movement of the spoons - buckets resembles the movement of a shuttle or a swing, which is why this mechanism was called shuttle or swing. The capacity of the spoon - the bucket is known, and each tipping means the discharge of a certain amount of measured precipitation. Thus, knowing the number of rollovers, you can easily calculate the amount of precipitation. Just like other devices, the shuttle rain gauge has a number of disadvantages:

– the time of the beginning of rainfall is not recorded;

- the influence of random noise leads to an increase in the error in determining the intensity of precipitation;
- demagnetization of the magnetic device leads to a measurement error.

2.5 Radar sounding of the atmosphere

A method for determining the intensity of rainfall, including radar sounding of the atmosphere with subsequent identification of the type of cloudiness according to known criteria and determination of the desired parameters of precipitation using correlation functions and data of radar reflectivity of clouds.

On the controlled territory, at least one control zone with an increased probability of precipitation is allocated and a precipitation gauging station is placed on it. With the help of this station, for various types of clouds moving over it, precipitation measurements are made, while radar sounding of the clouds over the station is simultaneously carried out and the levels of radar reflectivity corresponding to the obtained precipitation are found. Using the data obtained, the radar station is calibrated, and then the corresponding radar measurements of precipitation in the controlled area.

The main disadvantage of this method is that for each case of precipitation it is necessary to determine its own coefficients, which depend on the spectrum of drops, the type and microstructure of precipitation, as well as orographic features.

2.6 Carrying out several measurement cycles

A known method for determining the intensity of rainfall, based on carrying out n-cycles of measurements, each of which includes the accumulation of precipitation over time τ_i (i = 1, 2, 3,…, n), s, in a receiver with an inlet, determining the increment m_i of their mass and the value of the intensity R_i, mm/h (m/s). There are pauses between the accumulation modes, the duration of each of which is not less than the calming time of the mass meter. The value of the increment m_i of the accumulated mass of precipitation is measured during the corresponding pause.

Disadvantages of this method:

– The time of the beginning of rain is not known for certain, since in this method the time of precipitation accumulation in the first cycle is set based on a visual assessment of the meteorological situation. If it rains outside of working hours, a visual assessment is not possible. When a short accumulation time is established in the event of high-intensity precipitation, excessive precipitation can pour out of the measuring chamber. And, conversely, when a long accumulation time is established in the first cycle with low-intensity precipitation, it is impossible to reliably determine the time of the beginning of rain. All these possible cases can lead to an increase in the error in determining the intensity of precipitation and a decrease in the reliability of the measurement result.;

– the use of a large number of mechanical and kinematic links leads to a decrease in the reliability of the method and the service life.

2.7 Chapter Conclusion

When developing the method, the values of the γ-radiation dose rate and volumetric activity were taken into account only for two radionuclides. The possibility of the influence of other radionuclides included in the chain of radioactive decay of radon and thoron is assumed. Therefore, it becomes necessary to study three other radionuclides in order to check their effect on the dose rate of γ-radiation of the surface layer of the atmosphere during rainfall.

Chapter 3 Simulation

To calculate the distribution of the volumetric activity and dose rate, it was necessary to determine the radionuclides that make the greatest contribution to the γ-radiation dose rate, for which the spatial (in the vertical direction) and temporal dynamics of the γ-radiation dose rate formed in the surface atmosphere during rainfall were modeled. , taking into account different values of the height of rain clouds, density and turbulence of the atmosphere.

3.1 Selection of radionuclides

To further study the effect of precipitation on the γ-background, it was determined which DPR of radon isotopes make the greatest contribution to the atmospheric γ-background.

Emitting α - particles, radon isotopes are converted into solid radioactive isotopes that are no longer related to the group of inert gases (Fig. 3.1).

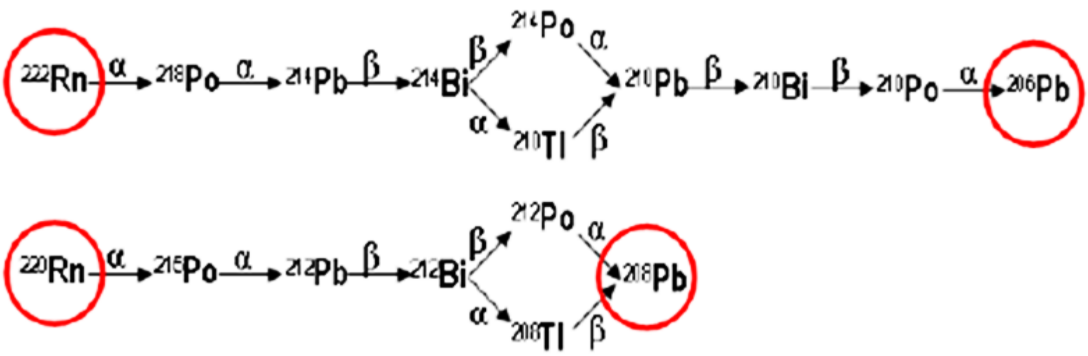

Figure 3.1 – Chains of decay of radon isotopes [4]

The sample was made on the basis of the nuclear-physical characteristics of radon, thoron and short-lived products of their decay (Table 3.1). Attention was drawn to such characteristics as the type of radiation, half-life and radiation yield per decay [15].

Table 3.1 – Nuclear-physical characteristics of radionuclides [4]

Source	Half life	Type of radiation	Radiation yield per decay	Energy (MeV)
Pb^{214}	26.8 minutes	β	1,622	1,024
		γ	1,025	0,352
Bi^{214}	19.9 minutes	β	0,987	3,27
		γ	1,289	1,765
Tl^{208}	3.7 minutes	β	0,994	1,795
		γ	2,28	2,615
Bi^{212}	60.55 minutes	β	0,64	2,24
		γ	0,283	0,727
Pb^{212}	10.64 h	β	1,775	0,1
		γ	0,993	0,15

In this regard, only γ-emitting radionuclides were selected by the type of radiation. In the ^{222}Rn chain, this is ^{210}Pb, the half-life of which is 22 years, and it cannot reach an equilibrium concentration in the atmosphere. Therefore, it and the subsequent elements can be neglected.

As a result, five γ-emitting radionuclides were selected: ^{212}Bi, ^{214}Bi, ^{208}Tl and ^{214}Pb, ^{212}Pb.

3.2 Modeling atmospheric gamma-ray fields

The simulation of this process was carried out using the Monte Carlo method in the Computer Laboratory program (CL/PCLab). Tables 3.2 and 3.3 show the composition of water and atmosphere used in the modeling.

Table 3.2 – Composition of water for modeling

Element	Atomic number Z	Mass number A	Weight share %
O	8	16	88,9
H	1	1,008	11,1

Table 3.3 – Composition of the atmosphere for modeling

Element	Z	A	W, Weight fraction of substance elements
N	7	14,00	0,755
O	8	16,00	0,232
Ar	18	39,95	$1{,}92 \cdot 10^{-2}$

The air density for modeling was selected based on the experimental data presented in Figure 3.2.

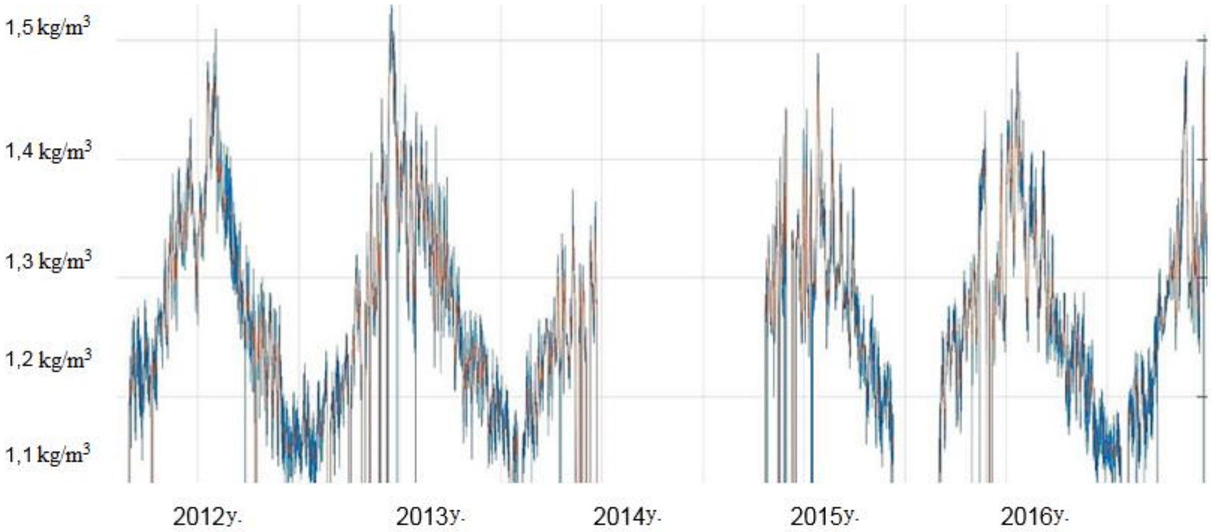

Figure 3.2 – Air density

For the calculations, a cylindrical geometry was specified (Fig. 3.3). A radius of 400 m was chosen to take into account the penetrating power of photons in the air. To get rid of the influence of edge effects on the final result, an inner cylinder with a radius of 20 m was formed. The water layer was taken 1 mm thick to take into account only those radionuclides that settled after precipitation on the soil surface.

The altitude at which the calculations were carried out was taken 400 m.

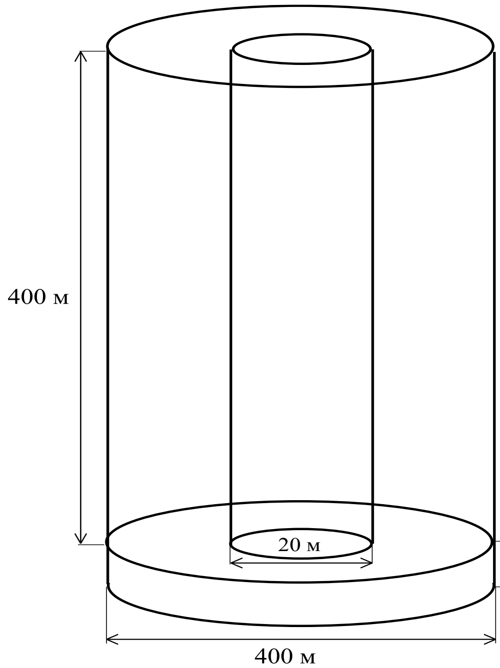

Figure 3.3 – Geometry of modeling the dose rate created at different altitudes per unit activity of a radionuclide

The simulation results are shown in Figures 3.4 – 3.7.

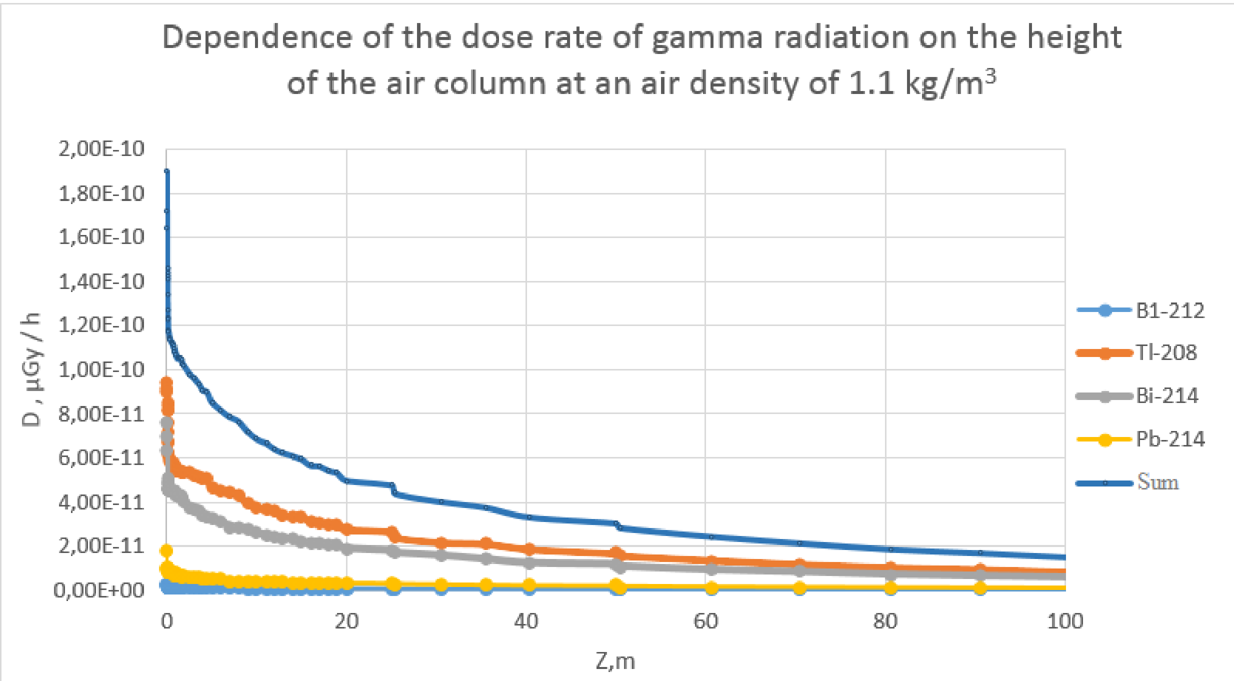

Figure 3.4 – Change with height Dγ at an air density of 1.1 kg / m^3

The dose rate of γ-radiation decreases exponentially with an increase in the height of the air column.

The top graph is the sum of the dose rate from each radionuclide. It can be noted that the greatest contribution to the dose rate of γ-radiation is made by two radionuclides ^{214}Bi and ^{208}Tl, however, their values are almost comparable. Other radionuclides make a smaller contribution to the total dose rate, but they can also ultimately affect the result of calculating the intensity of rainfall by the developed method.

The following are graphs of the dose rate dynamics depending on the air density.

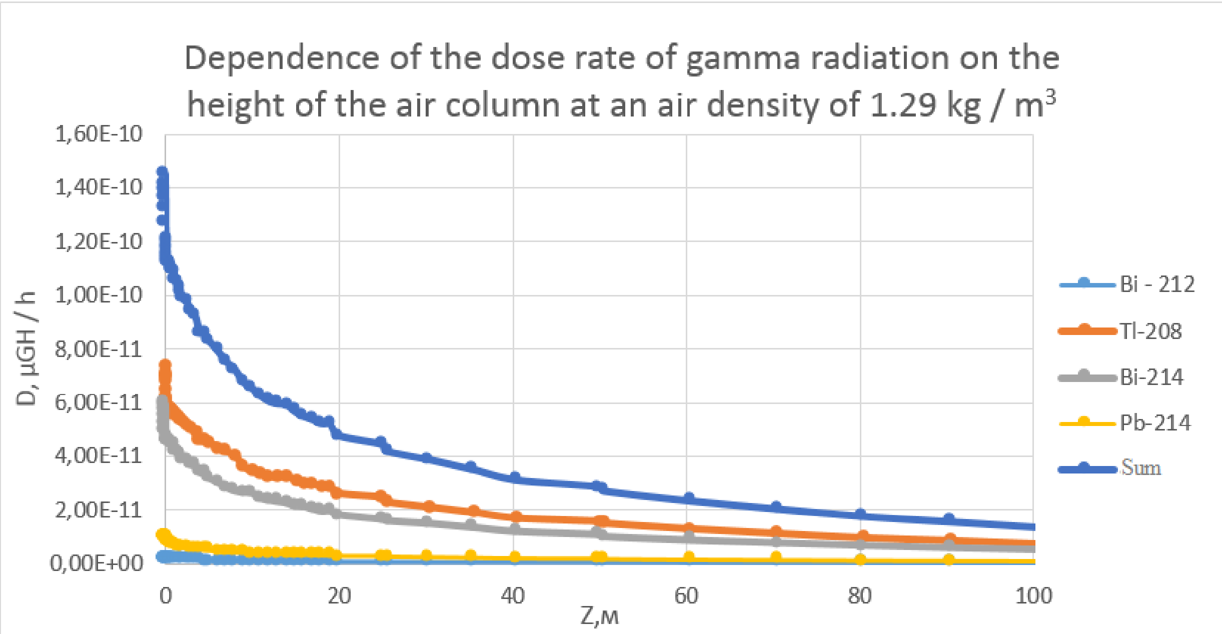

Figure 3.5 – Change with height Dγ at air density 1.29 kg / m^3

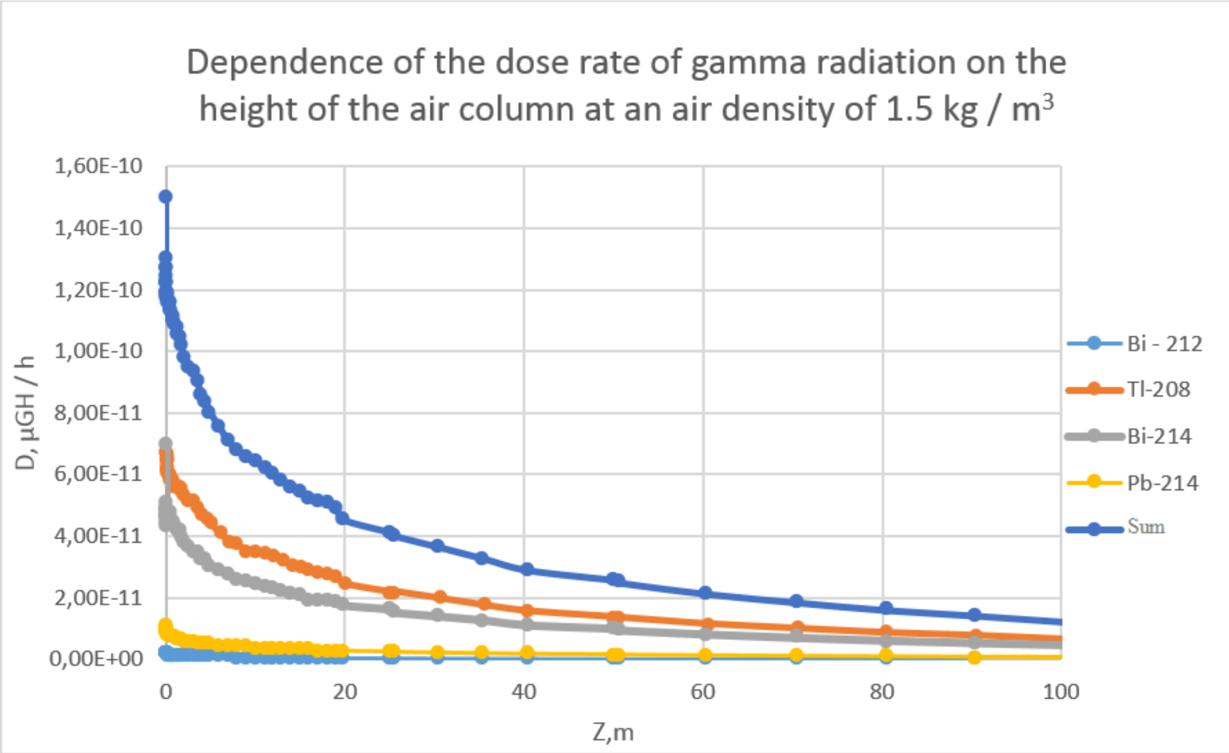

Figure 3.6 – Change with height Dγ at an air density of 1.5 kg / m^3

It was determined that the air density does not significantly affect the value of the total dose rate of γ-radiation, but we can say that at a lower air density, its value is still higher than at a higher air density, especially in the surface layer of the atmosphere, which can be seen from Figure 3.7.

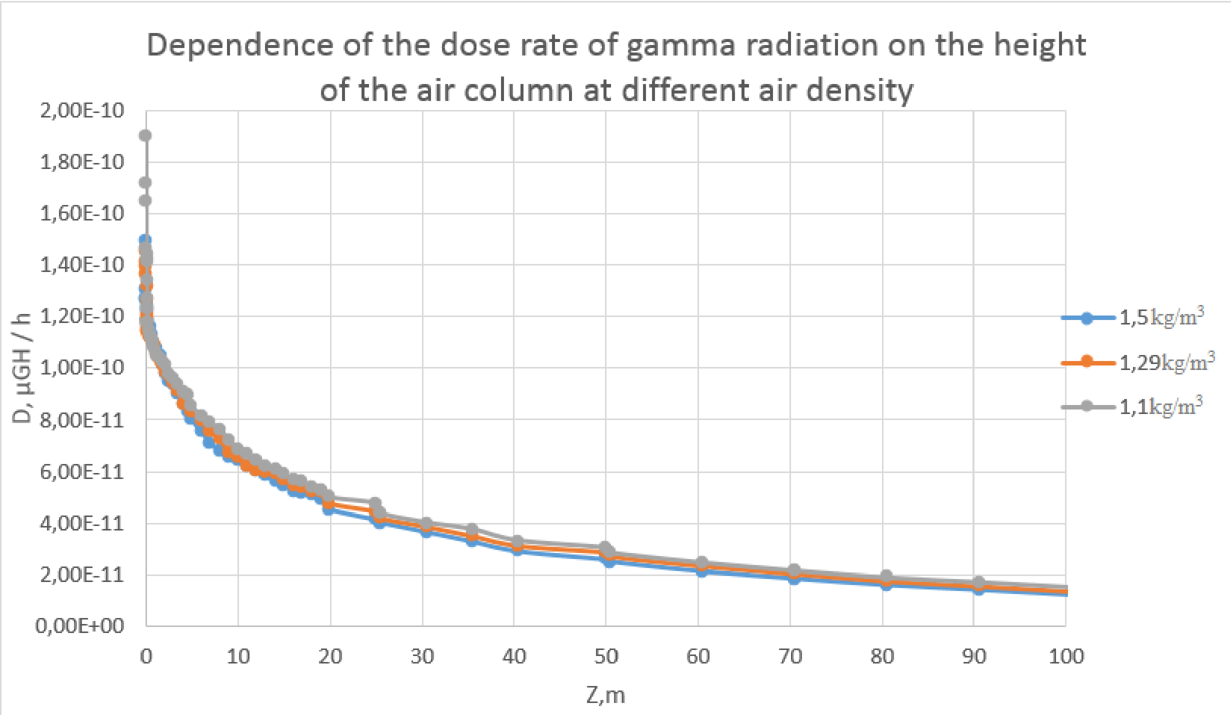

Figure 3.7 – Change with height Dγ at different air density air density

The percentage contribution of each radionuclide at five different altitudes is shown in Figure 3.8.

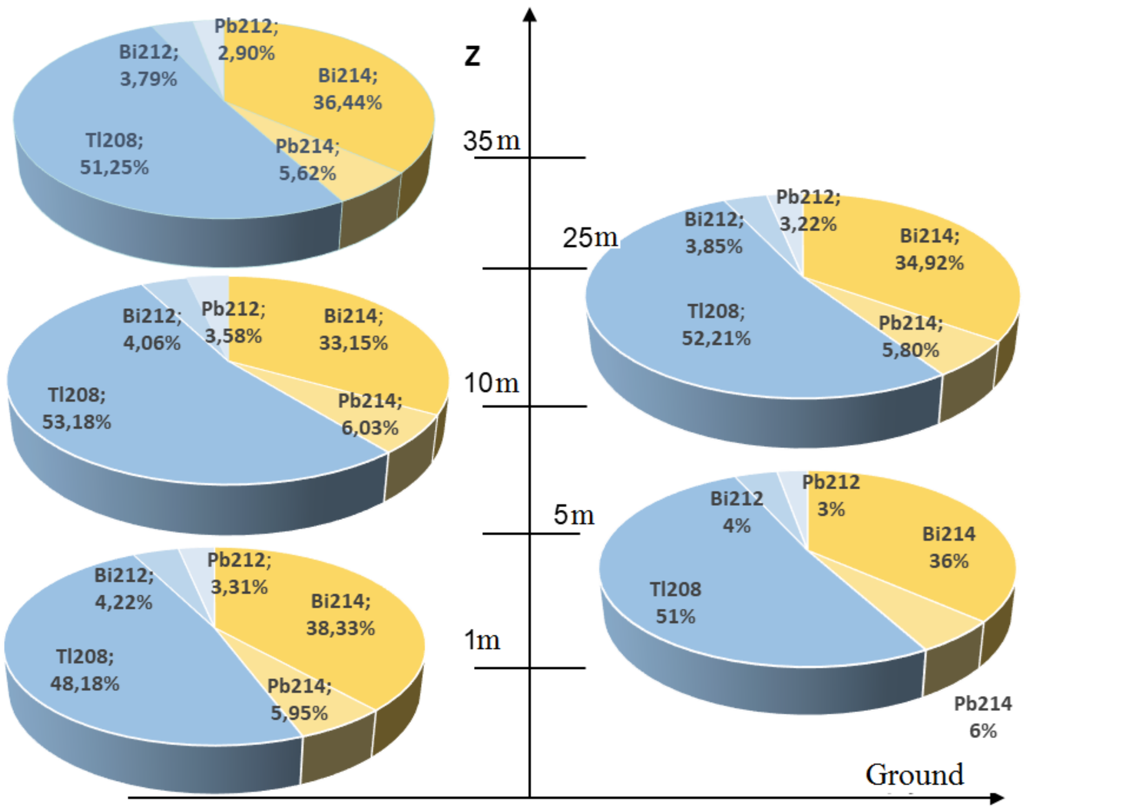

Figure 3.8 – Contribution to the power of γ-radiation of five radionuclides

3.3 Influence of the state of the atmosphere on the mean value of VA DPR

The average VA of each radionuclide was determined using a model, which is a system of equations that takes into account the processes of transport of radionuclides under the action of vertical wind, molecular diffusion, turbulence, etc.:

In the one-dimensional case, when the z axis is directed away from the surface, the equation is written as follows:

$$\begin{cases} (D_{M_i} + D_T)\dfrac{d^2A_i(z)}{dz} - v_w\dfrac{d}{dz}A_i(z) - \lambda_i A_i(z) = 0, \text{for } i = 1{,}6; \\ (D_{M_i} + D_T)\dfrac{d^2A_i(z)}{dz^2} - v_d\dfrac{d}{dz}A_i(z) + \lambda_i A_{i-1}(z) - \lambda_i A_i(z) = 0, \\ \qquad \text{for } i = 2-5, 7-11; \end{cases} \tag{3.1}$$

Boundary conditions:

$$\begin{cases} -\left(D_{M_i} + D_T\right)\dfrac{dA_i(z)}{dz}\Big|_{z=0} + v_w A_i(z)|_{z=0} = q, \text{for } i = 1{,}6; \\ \left(D_{M_i} + D_T\right)\dfrac{dA_i(z)}{dz}\Big|_{z=0} + v_d A_i(z)|_{z=0} = 0, \text{for } i = 2-5{,}7-11; \\ A_i(z) \to 0, z \to \infty. \end{cases} \tag{3.2}$$

Here: $A_i(z)$ – volumetric activity function of *i*-th radionuclide, Bq/m3; indices i = 1–5 correspond to radon ^{222}Rn and its decay products, respectively ^{218}Po (RaA), ^{214}Pb (RaB), ^{214}Bi (RaC) and ^{214}Po (RaC'); indices i = 6–11 correspond to the ^{220}Rn thoron and its decay products, respectively ^{216}Po (ThA), ^{212}Pb (ThB), ^{212}Bi (ThC), ^{212}Po (ThC') and ^{208}Tl (ThC"); q_i is the flux density of radon (i = 1) (q_1 = 10 mBq/m^{2}s) and thoron (i = 6) (q_2 = 1 Bq/m^{2}s) from the soil surface, Bq·m^{-2}·s^{-1}; D_M - molecular diffusion coefficient (0.01-1), m^2 / s; D_T — coefficient of atmospheric turbulence, m^2/s; $v_d = v_W + v_F + v_R$; v_W - vertical component of wind speed, m/s; *vF* — sedimentation rate under the action of gravity, m/s; *vR* is the rate of washing out of aerosol particles from the atmosphere by precipitation, m/s;

λ_i is the decay constant of the i-th radionuclide, z-height to the atmospheric cloud (300m) s – 1; j = 1 corresponds to the radon isotope, and j = 2,3, ... is the DPR [16].

When modeling the dependence of the average VA DPR on the state of the atmosphere, it was found that the height of the lower edge of clouds from 850m to 1500m does not affect its values with a turbulent diffusion coefficient ranging from 0.01 ... 0.1, which can be seen from the figures below.

Figures 3.9 - 3.13 show the dependence of VA for different radionuclides in different conditions of the atmosphere:

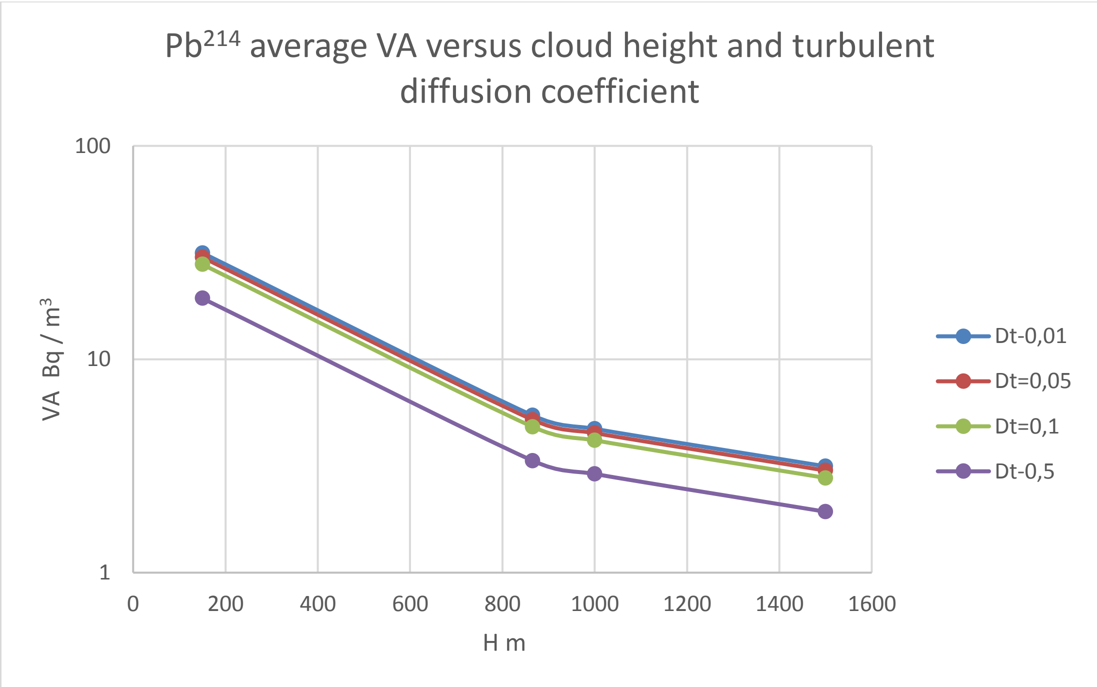

Figure 3.9 – Influence of the state of the atmosphere on VA ^{214}Pb

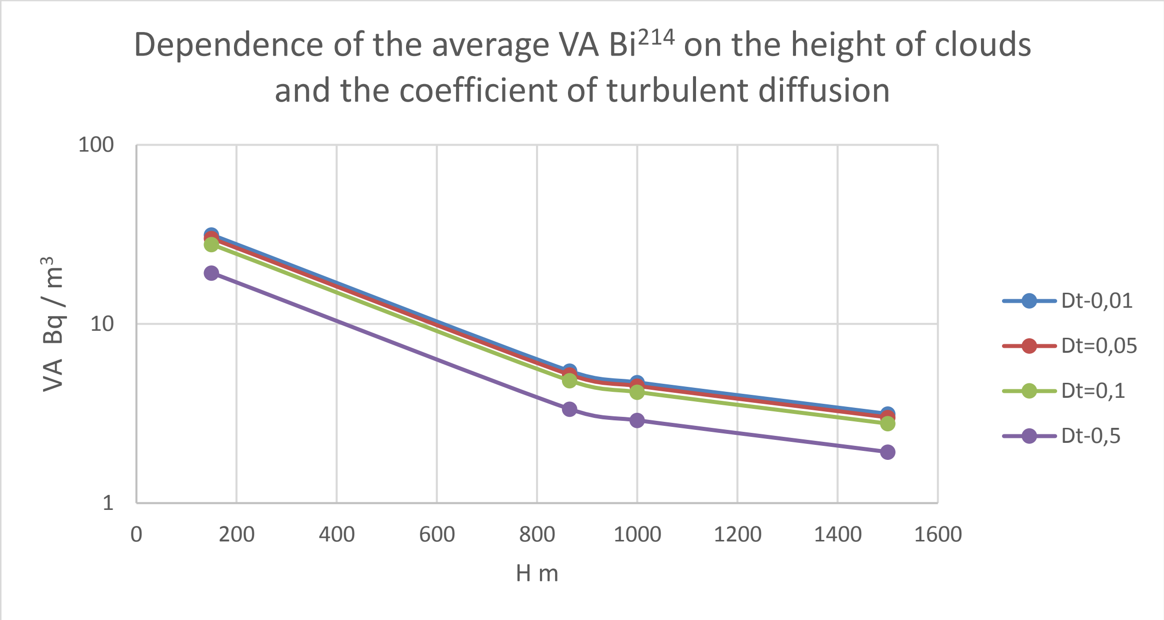

Figure 3.10 – Influence of the state of the atmosphere on VA ^{214}Bi

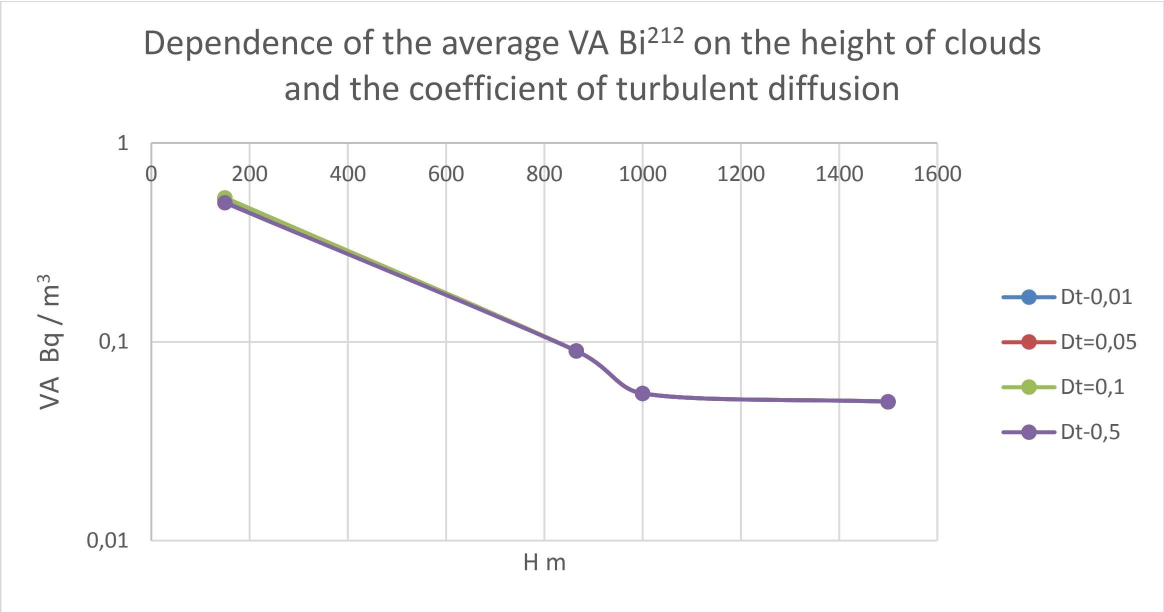

Figure 3.11 – Influence of the state of the atmosphere on VA ^{212}Bi

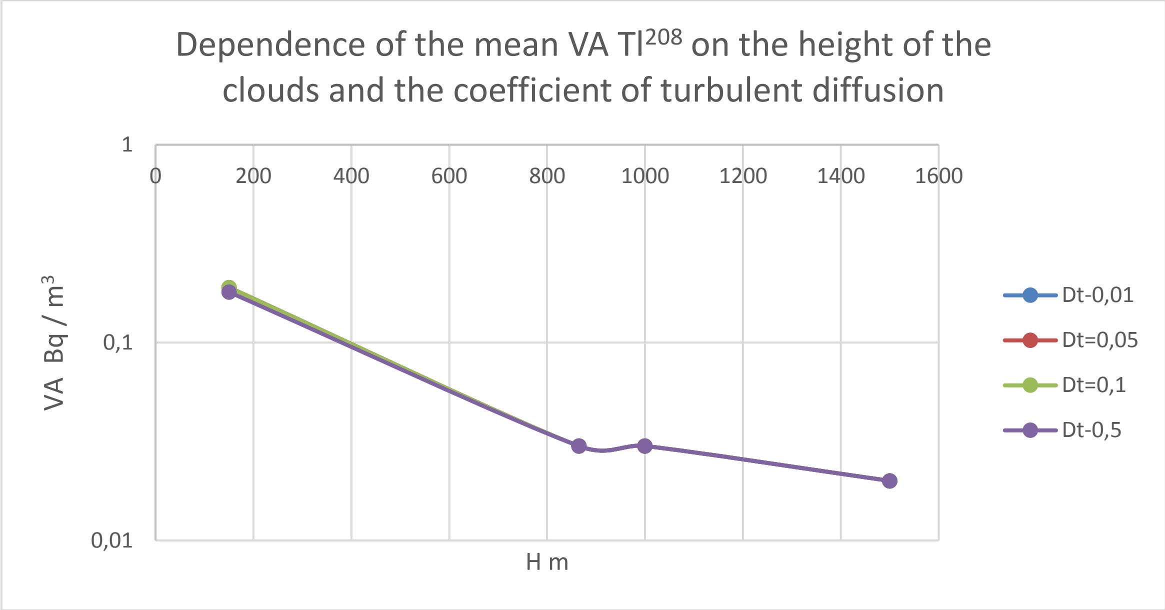

Figure 3.12 – Influence of the state of the atmosphere on VA ^{208}Tl

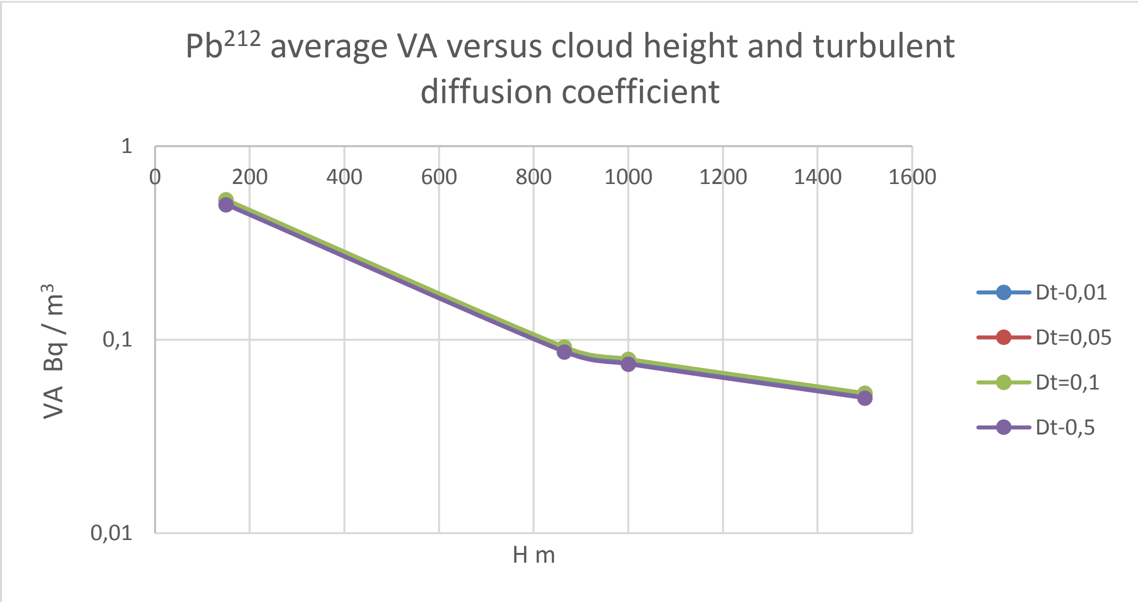

Figure 3.13 – Influence of the state of the atmosphere on VA ^{212}Pb

From modeling the effect of the state of the atmosphere on VA, it can be noted that VA for such radionuclides as Bi^{212}, Tl^{208}, and Pb^{212} is three orders of magnitude less than for Bi^{214} and Pb^{214}, therefore, the change in their VA is not large and remains almost constant regardless of the state of the atmosphere..

Hence, it follows that the contribution to the real dose rate of γ-radiation will differ from the contribution to the dose rate per decay in such a way that the main contribution will be made only by two radionuclides, namely Bi^{214} and Pb^{214}, therefore, in the further study, only these DPRs will be considered.

3.4 Influence of heavy rainfall on the dynamics of the gamma background and the activity of precipitated on the earth's surface ^{214}Pb and ^{214}Bi

To calculate the VA of radionuclides ^{214}Pb and ^{214}Bi, a code was written in the Wolfram Mathematica program and a model of radon transport in the atmosphere was used:

$$\frac{dA}{dz} = (Dm + Dt) * A'' - \lambda * \mathrm{A} = 0 \tag{3.3}$$

where λ – decay constant of radon, 1/s;

Dm – molecular diffusion coefficient, m^2/s;

Dt – turbulent diffusion coefficient, m^2/s.

Border conditions:

$$A'(0) = -\frac{q}{Dm + Dt}, A(H) = 0 \tag{3.4}$$

where q – flux density, $Bq/(m^2*s)$.

Activity of radon decay products depending on altitude:

$$(Dm + Dt) * A''_0 - vf * A'_0 + \lambda_0 * A_1 = 0 \tag{3.5}$$

where A_1 – volumetric activity of the previous element, Bq/m^3;

vf – settling speed, m/s.

Further, a correction was introduced for the washout capacity of various types of precipitation. For this, a washout constant was introduced, which can be represented as:

$$L = k_r k_0 I \tag{3.6}$$

where I – precipitation intensity, mm/h;

k_r – the value of the absolute leaching capacity of rain (for all nuclides, with the exception of inert gases, is equal to 10-5 h/(mm×s);

k_0 – relative washout capacity of other types of sediments, the values of which are given in Table 3.4:

Table 3.4 – Relative leaching capacity of sediments

Precipitation type	k_0
Rain	1,0
Downpour	2,8
Drizzle	4,5

Figures from 3.14 - 3.17 show the dependence of VA for radionuclides ^{214}Pb and ^{214}Bi at different duration of precipitation and different intensity:

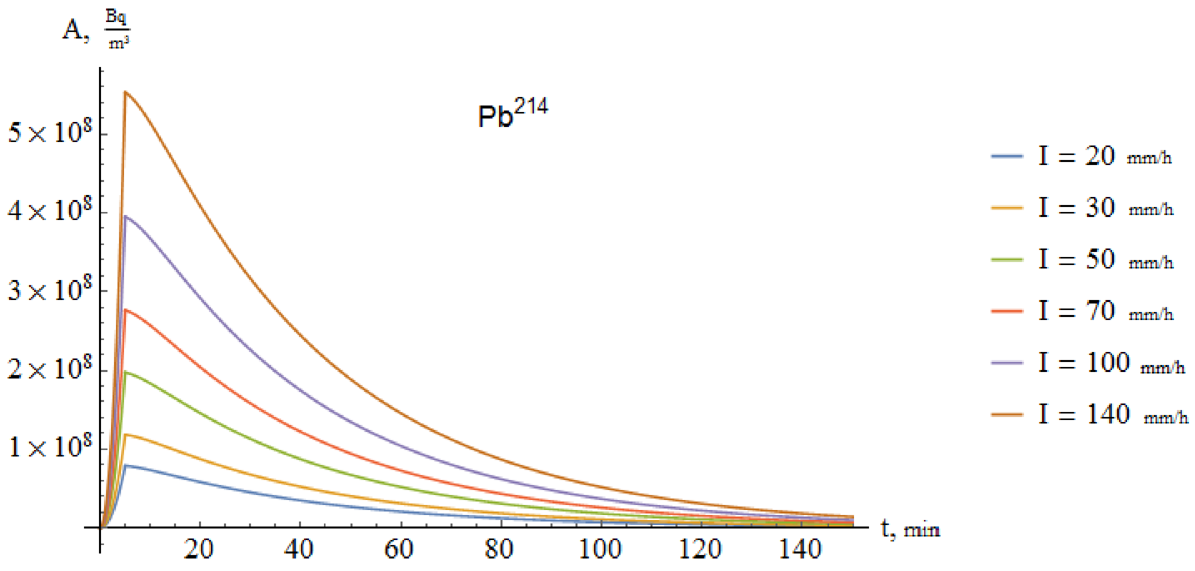

Figure 3.14 – Influence of precipitation of different intensity and duration of five minutes on the VA of the radionuclide ^{214}Pb

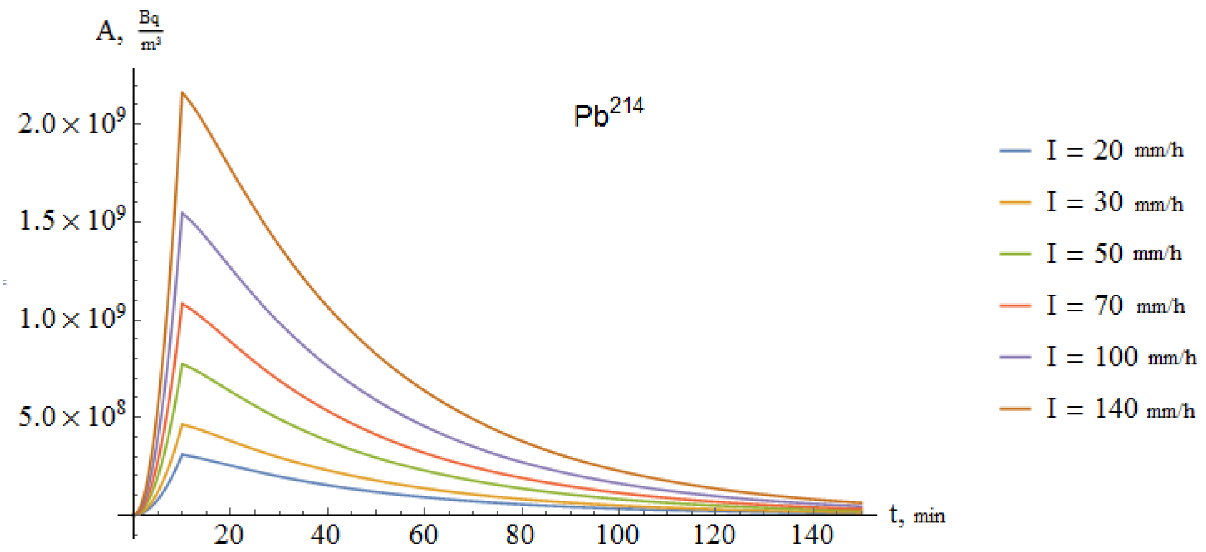

Figure 3.15 – Influence of precipitation of different intensity and duration of 10 minutes on the VA of the radionuclide ^{214}Pb

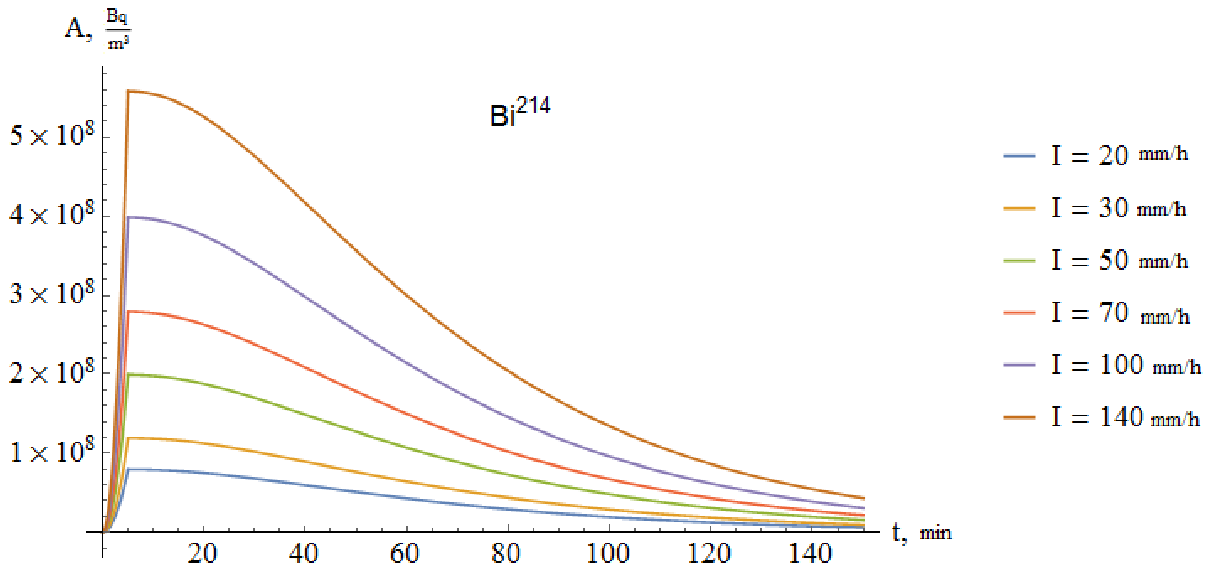

Figure 3.16 – Influence of precipitation of different intensity and duration of five minutes on the VA of the radionuclide ^{214}Bi

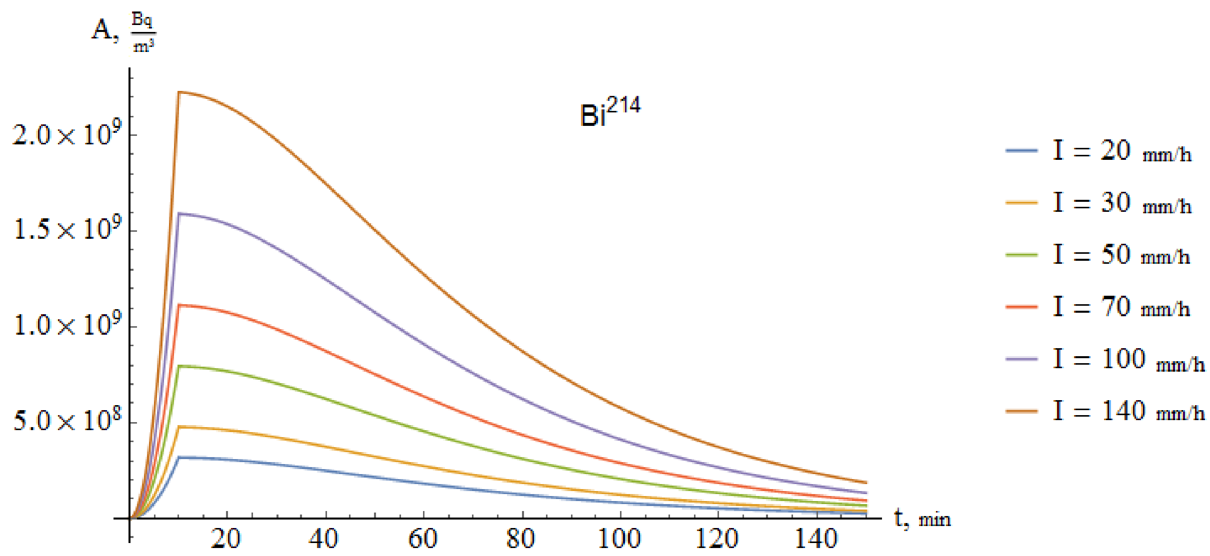

Figure 3.17 – Influence of precipitation of different intensity and duration of 10 minutes on the VA of the radionuclide ^{214}Bi

Figures 3.18 - 3.21 show the change in VA for radionuclides ^{214}Pb and ^{214}Bi with different duration of precipitation and different intensity:

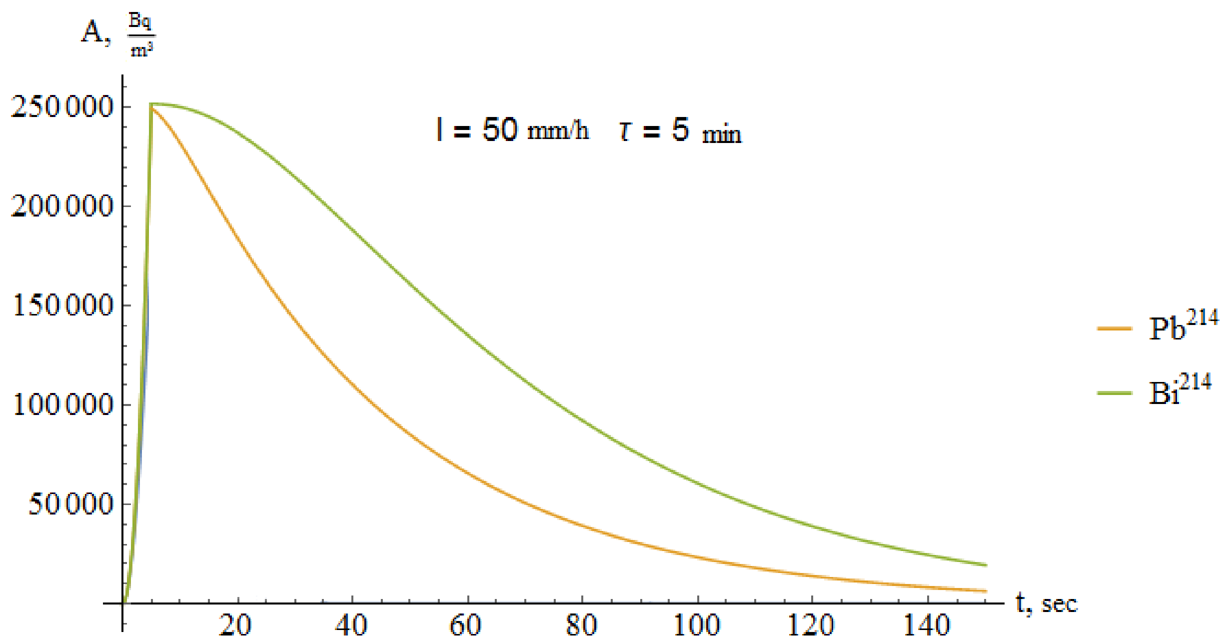

Figure 3.18 – Influence of precipitation with an intensity of 50 mm/h and a duration of five minutes on a change in VA ^{214}Pb and ^{214}Bi

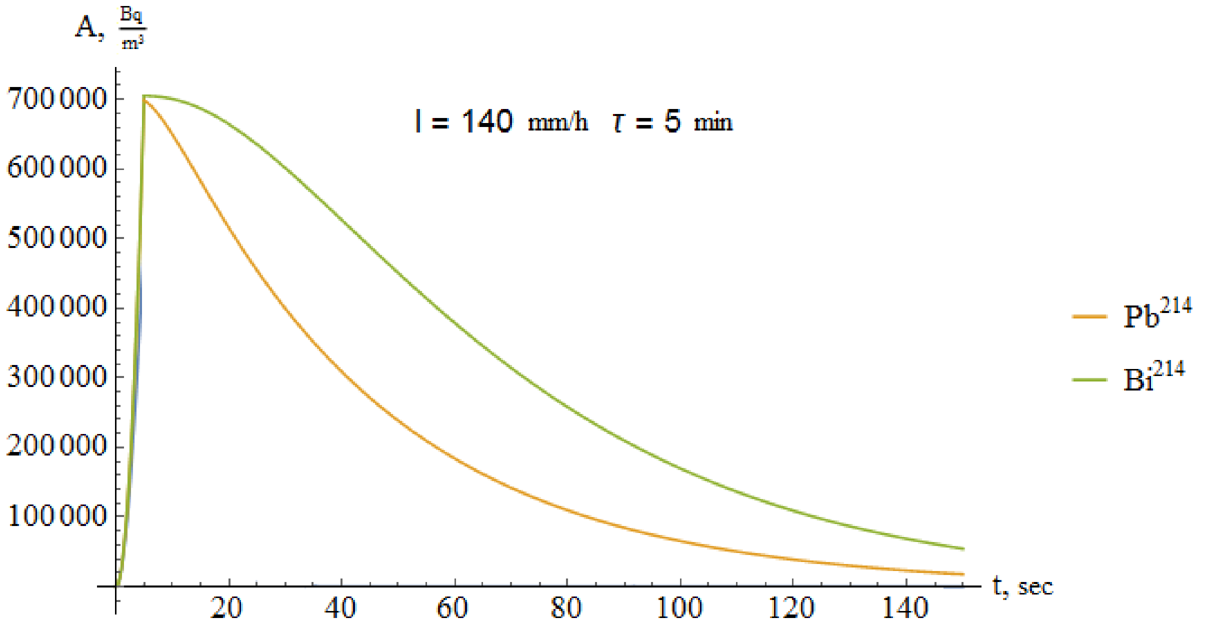

Figure 3.19 – Influence of precipitation with an intensity of 140 mm/h and a duration of five minutes on a change in VA ^{214}Pb and ^{214}Bi

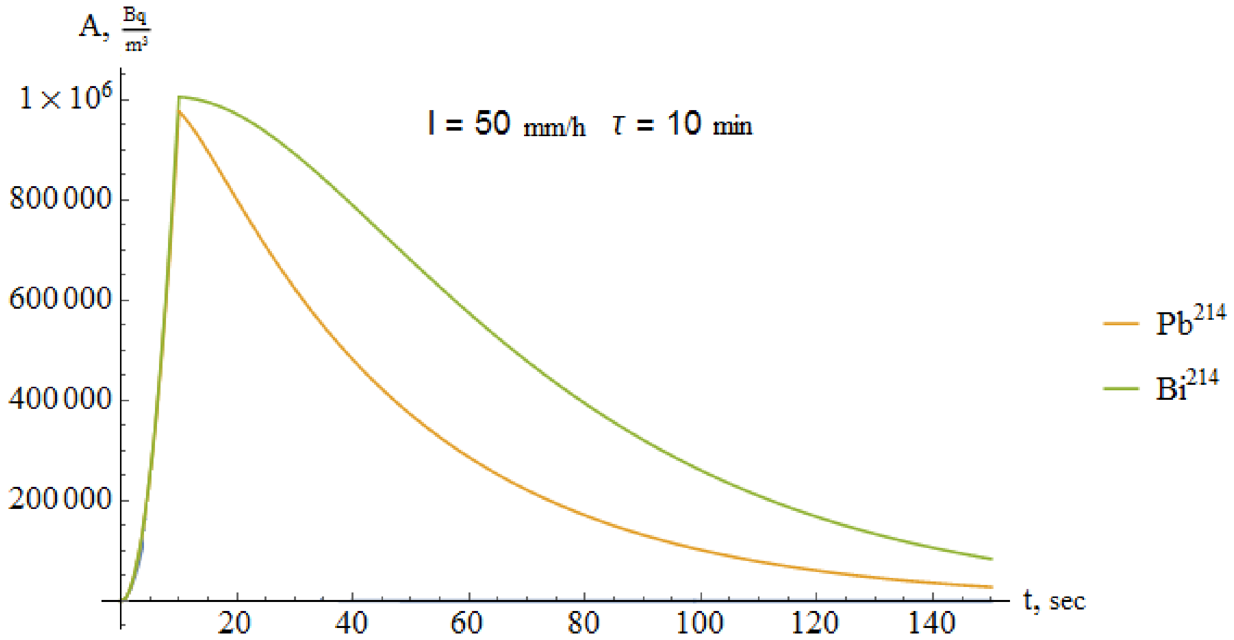

Figure 3.20 – Influence of precipitation with an intensity of 50 mm/h and a duration of 10 minutes on a change in VA ^{214}Pb and ^{214}Bi

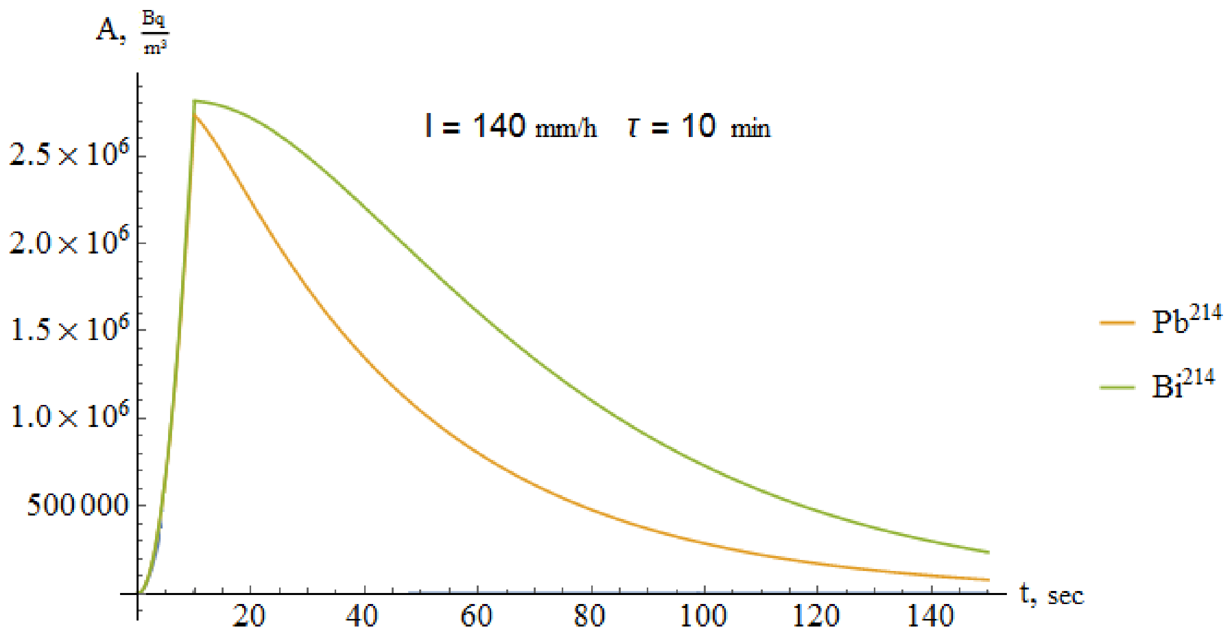

Figure 3.21 – Influence of precipitation with an intensity of 140 mm/h and a duration of 10 minutes on a change in VA ^{214}Pb and ^{214}Bi

3.5 Conclusion on chapter 3

From the results presented in the graphs above, the dependence of the volumetric activity on the intensity and duration of rainfall follows, that is, the greater the intensity of rainfall, the greater the surge in volumetric activity and, consequently, the dose rate, which means that there is a directly proportional dependence of VA on the intensity of precipitation. As you can see on the graphs, an increase in intensity by an order of magnitude corresponds to an increase in the same value and VA.

It is also noticeable that for Pb^{214} and Bi^{214}, because of their large $T_{1/2}$ (26,8 and 19,9 minutes respectively), the curves on the graph before the end of precipitation correspond to exponential growth, and after the end of precipitation - to a slow decline in VA.

Chapter 4 Financial Management, Resource Efficiency and Resource Conservation

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

4.1.1 Potential consumers of research results

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

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

4.1.2 Analysis of competitive technical solutions

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

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

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

$$К = \sum B_i \cdot Б_i \qquad (7)$$

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

$К_ф$ – competitiveness of scientific research,

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

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

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

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

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

Evaluation criteria	**Criterion weight**	**Points**		**Competitiveness**	
		$Б_ф$	$Б_{к1}$	$К_ф$	$К_{к1}$
Technical criteria for assessing resource efficiency					
1. Reliability of the received data	0,35	5	3	1,75	1,05
2.Immunity of detecting devices	0,2	4	2	0,8	0,4
3. Reliability of the received data	0,12	4	3	0,48	0,36
4.Easy to operate	0,15	5	4	0,75	0,6
5. Convenience in operation	0,1	5	3	0,5	0,3
6. Energy efficiency	0,08	4	5	0,32	0,4
Total:	**1**	**-**	**-**	**4,6**	**3,11**

4.1.3 SWOT- analysis

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

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

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

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

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

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

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

Table 4.2 – SWOT analysis

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

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

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

Table 4.3 – Interactive matrix

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

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

4.2.1 The structure of work in the framework of scientific research

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

– leader;
– student.

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

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

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

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

4.2.2 Determination of the complexity of work

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

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

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

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

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

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

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

$$T_{\text{р}_i} = \frac{t_{\text{ожі}}}{Ч_i} \qquad (4.2)$$

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

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

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

4.2.3 Development of a scientific research schedule

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

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

$$T_{ki} = T_{pi} \cdot k \tag{4.3}$$

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

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

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

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

$$k = \frac{T_{кг}}{T_{кг} - T_{вд} - T_{пд}}, \tag{4.4}$$

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

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

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

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

The value of the calculated calendar coefficient:

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

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

Table 4.5 – Time indicators of scientific research

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

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

Table 4.6 – Schedule of research work on the topic

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

12	C	3,4												

- student; - supervisor; - supervisor + student.

4.2.4 Scientific and technical research budget (STI)

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

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

4.2.4.1 Basic salary of theme performers

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

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

$$З_{зп} = З_{осн} + З_{доп}, \quad (4.6)$$

where $З_{осн}$ – basic salary;

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

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

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

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

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

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

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

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

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

Average daily wages are calculated using the formula:

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

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

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

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

Table 4.7– Balance of working hours

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

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

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

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

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

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

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

Table 4.8 – Calculation of basic wages

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

4.2.4.2 Contributions to extrabudgetary funds

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

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

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

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

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

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

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

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

$$k_{\text{внеб}} = 0{,}271.$$

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

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

Table 4.9 – Contributions to off-budget funds

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

4.2.4.3 Overheads

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

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

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

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

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

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

then the cost of consumed electricity is:

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

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

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

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

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

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

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

Table 4.10 – Research project budget

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

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

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

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

The integral financial development indicator is defined as:

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

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

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

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

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

Since the development has one execution, then:

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

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

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

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

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

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

n – number of comparison parameters.

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

Table 4.11 – Assessment of the characteristics of project execution

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

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

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

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

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

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

Table 4.12 – Development efficiency

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

4.4 Conclusion on chapter 4

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

Chapter 5 Social Responsibility

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

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

5.1 Assessment of harmful and dangerous factors

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

Table 5.1 – Possible harmful and dangerous factors

Factors (GOST 12.0.003-2015 [18])	Regulatory documentation
1. Microclimate	GOST 30494-96. Residential and public buildings. Indoor microclimate parameters [19]
2. Noise	GOST 12.1.003-83. Occupational safety standards system (SSBT). Noise. General safety requirements (with Amendment No. 1) [20]
3. Illumination of the working area	SNiP 23-05-95 *. Natural and artificial lighting (with Amendment N 1) [21]
4. Fire and explosion hazard	SP 12.13130.2009. Determination of categories of premises, buildings and outdoor installations for explosion and fire hazard (as amended by amendment No. 1, approved by order of the Ministry of Emergency Situations of Russia dated 09.12.2010 No. 643) [22]

	GOST 12.1.004-91 Occupational safety standards system. Fire safety. General requirements [23]
5. Electrical safety	GOST 12.1.009-76 Occupational Safety Standards System (SSBT) [24] GOST R12.1.019-2017 SSBT Electrical Safety [25] GOST R IEC 61140-2000 Protection against electric shock. General provisions on safety provided by electrical equipment and electrical installations in their relationship [26]
6. Radiation safety	SanPiN 2.6.1.2523-09 Radiation safety standards NRB-99/2009 [27]

5.1.1 Microclimate

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

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

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

When standardizing meteorological conditions in industrial premises, the time of the year, the physical severity of the work performed, as well as the amount of excess heat in the room are taken into account. Optimal and permissible meteorological conditions of temperature and humidity are established according to [28] and are shown in Table 5.2.

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

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

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

To maintain these sanitary standards, it is enough to have a natural unorganized ventilation of the room and a local air conditioner of a complete air conditioning unit, which ensures the constancy of temperature, relative humidity, movement speed and air purity. A central heating system is required to provide a predetermined temperature level in winter according to [29]. In winter, a water heating system is used in the auditorium to maintain the required temperature. This system is reliable in operation and provides the ability to control temperature over a wide range. When installing a ventilation and air conditioning system in the auditorium, certain fire safety requirements must be observed. In winter, a heating system must be provided in the room. It must provide sufficient, constant and uniform heating of the air. In rooms with increased requirements for air purity, water heating should be used.

To protect the researcher from the harmful factor of deviation of microclimate indicators, microclimatic conditions are created by heating, exchange ventilation and air conditioning according to [28, 29].

5.1.2 Noise

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

To assess the noise environment, it is allowed to use a numerical characteristic called the sound level (measured in dB). In accordance with [30], the permissible noise level during work requiring concentration, work with increased requirements for monitoring processes and remote control of production cycles at workplaces in laboratory premises with noisy equipment is 75 dB. Areas with a sound level of 80 dB should be marked with safety signs according to [31].

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

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

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

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

Protection against increased noise levels is carried out by methods of its reduction in the source of formation and along the path of propagation, the device of screens and sound-absorbing facings, personal protective equipment according to [30, 31].

5.1.3 Lighting

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

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

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

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

The combined lighting system consists of general and local lighting. General lighting is designed to illuminate passages and areas where work is not being performed, as well as to equalize the brightness in the field of view of workers. Local lighting is provided by lamps located directly at the workplace. It should be preferred if different visual tasks are to be solved in several working areas of the room and therefore require different levels of illumination. It is also necessary when workplaces are geographically distant from each other. It should be borne in mind that the device only local lighting is unacceptable, since it creates a large difference in the illumination of the working surfaces and the surrounding space, which adversely affects vision [21].

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

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

Luminous flux for fluorescent lamps, 56 W:

$$F = Ra \cdot P, \qquad (5.1)$$

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

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

The required number of lamps to illuminate the laboratory classroom:

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

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

K – conversion factor, 4,5;

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

k – safety factor, 4,5;

S – illuminated area, 121 $м^2$;

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

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

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

To protect against insufficient illumination of the working area, natural lighting in its spectrum is the most acceptable, but it is not always sufficient. This is largely due to the mode of operation. General and combined lighting is generally recommended. Workplace illumination standards correspond to [21].

5.1.4 Electromagnetic fields

The main harmful factor when using a computer is electromagnetic radiation from the components of the computer. The norms of harmful permissible levels (VLU) of electromagnetic radiation of computers are established in the document [32], which are shown in table 5.3.

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

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

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

The screen and computer system units also emit electromagnetic radiation. Most of it comes from the system unit and video cable. The strength of the electromagnetic field at a distance of 50 cm around the screen in terms of the electrical component should correspond to [33].

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

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

In this laboratory, the radiation meets the standards [32, 33].

5.1.5 Fire and explosion safety

Depending on the characteristics of substances and materials in the room, according to the explosion and fire hazard, the premises are divided into categories A, B, C, D and E in accordance with [22]. The room in question belongs to category B, since it contains solid combustible substances in a cold state. Possible causes of fire:

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

In order to reduce the risk of fire and minimize possible damage, preventive measures are taken, which are subdivided into organizational, technical, operational and regime. Organizational and technical measures consist in conducting regular briefings of employees responsible for fire safety, training employees in the proper operation of equipment and the necessary actions in the event of a fire, certification of substances, materials and products in terms of ensuring fire safety, production and use of visual agitation tools to ensure fire safety [23]. Operational measures include preventive inspections of equipment. Regime measures include the establishment of rules for the organization of work and the observance of fire safety measures. To prevent a fire, the following fire safety rules must be observed:

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

In a room with electrical equipment, in order to avoid electric shock, it is advisable to use carbon dioxide or dry powder fire extinguishers. These fire extinguishers are designed to extinguish fires of various substances and materials, electrical installations under voltages up to 1000 V, flammable liquids. Chemical and foam extinguishers are not permitted. Fire extinguishers should be located at the protected object in accordance with the requirements so that they are protected from direct sunlight, heat flows, mechanical influences and other adverse factors (vibration, aggressive environment, high humidity, etc.). They must be clearly visible and easily accessible in the event of a fire. It is preferable to place fire extinguishers near the places where fire is most likely to occur, along the paths of the passage, as well as near the exit from the premises. Fire extinguishers should not interfere with the evacuation of people during a fire. According to fire safety requirements [22,23], there are 2 Powder fire extinguisher 3 fire extinguishers on the floor (portable powder fire extinguishers), staircases are equipped with hydrants, there is a fire alarm button.

5.1.6 Electrical safety

Electrical safety is a system of organizational and technical measures and means to protect people from harmful and dangerous effects of electric current, electric arc, electromagnetic field and static electricity in accordance with [24]. Electric current passing through the human body produces thermal, chemical and biological effects, thereby disrupting normal life activity. Employees hired to perform work in electrical installations must have professional training appropriate to the nature of the work.

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

As part of the current work, no contacts were made with open sources of electric current. The current flowing in the computer peripherals (computer mouse, keyboard) does not pose a significant danger to human health. According to the classification, this laboratory is suitable for class 1 premises in which operating voltages do not exceed 1,000 V [24, 25].

5.1.7 Radiation safety

Increased level of ionizing studies in the work area. Dangerous and harmful production factors associated with an increased level of ionizing radiation include the following types of radiation [28]:

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

b) particle flows:

- beta particles (electrons and positrons);
- alpha particles (nuclei of an atom of helium-4);
- neutrons;
- protons, other ions, muons, etc.;
- fission fragments (heavy ions arising from nuclear fission);

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

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

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

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

In the course of scientific research, involving theoretical calculations using a computer and no more, work with sources of ionizing radiation was not carried out [28].

5.2 Emergency situations

Emergency situation (ES) - a situation in a certain territory resulting from an accident, a dangerous natural phenomenon, catastrophe, natural or other disaster, which may or did entail human casualties, damage to human health or the environment, significant material losses and disruption living conditions of people [34]. There are two types of emergencies:

- technogenic;
- natural.

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

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

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

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

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

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

№	Emergency situation	Emergency prevention measures	Measures to eliminate the consequences of an emergency
1	Falling from height	1. Maintenance of the premises in proper order. 2. Limitation of working space. 3. Timely briefing.	1. Examine or interview the victim; 2.if necessary - call an ambulance; 3. stop bleeding, if any; 4. if there is a suspicion that the victim has a broken spine (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.
2	corresponding growth	1. Covering stair steps with anti-slip coating. 2. Timely briefing.	1. Call an ambulance; 2. stop bleeding, if any; 3. if there is a suspicion that the victim has a broken spine (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.

3	Falling down the stairs	1. Grounding of all electrical installations. 2. Limitation of working space. 3. Ensuring the inaccessibility of live parts of the equipment. 4. Timely briefing.	1. Quickly release the victim from the action of the electric current [26]; 2. call an ambulance; 3. if the victim has lost consciousness, but breathing is preserved, he should be laid down comfortably, unbuttoned tight clothing, create an influx of fresh air and ensure complete rest; 4. the victim should be allowed to smell ammonia, sprinkle water on his face, rub and warm the body; 5. In the absence of breathing, artificial respiration and heart massage should be done immediately.
4	Electric shock	1. Timely briefing. 2. Establishment of means of automatic fire extinguishing in premises. 3. Installation of smoke and fire detectors. 4. Providing evacuation routes and maintaining them in proper condition. 4. Control of the work of electrical appliances.	1. De-energize the room, cut off the air supply; 2. immediately report the fire to the duty officer or to the guard post; 3. If possible, take measures to evacuate people, extinguish a fire and save material assets.

This section discusses potential emergencies that may arise when working in laboratory classroom No. 118 of educational building No. 10. Measures to prevent and eliminate the consequences of these situations are considered, according to [26, 34].

5.3 Chapter Conclusions

The chapter discusses harmful and dangerous factors:

- microclimate [28, 29];
- noise [20, 30];
- illumination [21];

– fire hazard [22, 23];
– electrical safety [24, 25];
– electromagnetic radiation [32, 33];
– radiation safety [27].

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

The audience in question is assigned to class B for fire hazard [22] and 1 for electrical safety [24,25].

Conclusion

Based on the results of modeling the dynamics of the dose rate of γ-radiation formed in the surface atmosphere during rainfall, as well as analysis of the dependence of the dose rate of γ-radiation on the height of rain clouds, density and turbulence of the atmosphere, the following conclusions can be drawn:

- of the 5 short-lived decay products of radon and thoron (Tl-208, Pb-212, Bi-212, Bi-214, and Pb-214), washed out from the atmosphere by rainfall, only Bi-214 and Pb-214 make the main contribution to the total γ-radiation dose rate equal, on average, 86% and 14%, respectively;
- atmospheric density is a weak factor affecting the γ-background;
- the height of rain clouds in the range from 850 m to 1.5 km and above practically does not affect the average values of the VA of precipitated DPR of radon in a wide range of variation of the atmospheric turbulence coefficient from 0.01 m^2/s to 0.5 m^2/s, therefore, does not affect the magnitude of the surge in the dose rate of γ-radiation during rains;
- when the distance from the earth's surface to the lower edge of the clouds is less than 850 m, the mean values of the VA DPR of radon and thoron in the atmospheric column increase significantly (on average by 1.5-2 times), which can lead to overestimates of the γ-background during rains;
- there is a directly proportional dependence of VA on precipitation intensity, an increase in intensity by an order of magnitude corresponds to an increase in VA by the same value.

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