TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

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

БАКАЛАВРСКАЯ РАБОТА

Тема работы
Сезонные особенности вариаций атмосферной альфа-радиоактивности

УДК 539.164.551.521.1

Студент

Группа	ФИО	Подпись	Дата
0А7А	Кажитаев Санжар Муралович		

Руководитель ВКР

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

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 ИЯТШ	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
Specialization: Nuclear Power Engineering / Nuclear medicine
Nuclear Fuel Cycle Division

BACHELORS WORK

Topic of research work
Seasonal features of variations in atmospheric alpha radioactivity

UDC 539.164.551.521.1

Student

Group	Full name	Signature	Date
0A7A	Kazhiaev Sanzhar Muralovich		

Scientific supervisor

Position	Full name	Academic degree, academic rank	Signature	Date
Professor of NFCF	Yakovleva Valentina Stanislavovna			

Consultant

Position	Full name	Academic degree, academic rank	Signature	Date
Senior lecturer of NFCF	Poberezhnikov Andrey Dmitrievich	-		

ADVISERS:

Section "Financial Management, Resource Efficiency and Resource Saving"

Position	Full name	Academic degree, academic rank	Signature	Date
Professor	Hasanov Maharram Ali oglu	PhD		

Section "Social Responsibility"

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Perederin Yuri Vladimirovich	PhD		

ADMITTED TO DEFENSE:

Programme Director	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Bychkov Petr Nikolaevich.	PhD		

Tomsk – 2021

TOMSK POLYTECHNIC UNIVERSITY | ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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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:

бакалаврской работы

Студенту:

Группа	ФИО
0А7А	Кажитаев Санжар Муралович

Тема работы:

Сезонные особенности вариаций атмосферной альфа-радиоактивности	
Утверждена приказом директора (дата, номер)	28.04.2021 г., №118-33/с

Срок сдачи студентом выполненной работы:	09.06.2021

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

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

Перечень подлежащих исследованию, проектированию и разработке вопросов	- обзор литературных источников; - источники атмосферной альфа-радиоактивности; - методы и приборы измерения альфа-активности в приземной атмосфере; - внутри суточные и сезонные особенности в динамике атмосферной альфа-радиоактивности; - корреляционный и регрессионный анализ радиационных и метеорологических величин; - анализ полученных результатов; - финансовый менеджмент, ресурсоэффективность и ресурсосбережение; - социальная ответственность; - заключение по работе.
Перечень графического материала *(с точным указанием обязательных чертежей)*	Презентация для защиты ВКР

Консультанты по разделам выпускной квалификационной работы

(с указанием разделов)

Раздел	Консультант
Социальная ответственность	Передерин Юрий Владимирович
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	Гасанов Магеррам Али оглы

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

Задание выдал руководитель / консультант (при наличии):

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А7А	Кажитаев Санжар Муралович		

TASK FOR SECTION

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

Student:

Group	**Full name**
0A7A	Kazhitaev Sanzhar Muralovich

School	**SNTE**	**Research and Education Centr**	**DNFC**
The level of education	bachelor	**Direction/ specialty**	14.03.02 Nuclear physics and technology / Nuclear Power Engineering/Nuclear medicine

Initial data for the section "Financial Management, Resource Efficiency and Resource Saving":	
1. The cost of scientific research resources (SR): material and technical, energy, financial, informational and human	The cost of material resources and special equipment is determined in accordance with the market prices of the city of Tomsk. Performers' tariff rates are determined by the staffing table of NI TPU.
2. Rates and rates of resource consumption	Electricity tariff 2.45 rubles. for 1 kW * h
3. The used system of taxation, rates of taxes, deductions, discounting and crediting	Contributions to extrabudgetary funds - 30%
List of questions to be researched, designed and developed:	
1. Assessment of the potential, prospects and alternatives to the NI position of resource efficiency and resource conservation	Calculation of competitiveness SWOT analysis
2. Formation of a plan and schedule for development and introducing NI	Work structure, determination of labor intensity, development of a research schedule
3. Drawing up the budget of the NI	Calculation of the budget for the implementation of research
4. Assessment of the resource, financial, budget efficiency of scientific research	Integral financial indicator. An integral indicator of resource efficiency. Integral efficiency indicator
List of graphic material (with exact indication of the required drawings)	
1. Assessment of the competitiveness of scientific research *2. SWOT Matrix* *3. Gantt chart* *4. NI budget* *5. The main indicators of the effectiveness of research*	

Date of issue of the task for the section on a line chart	15.02.2020

The assignment was given by the consultant:

Position	**ФИО**	**Academic degree, title**	**Signature**	**Data**
Full Professor	Hasanov Maharram Ali oglu	Doctor of Economic Sciences		

The student accepted the assignment:

Group	**Full name**	**Signature**	**Data**
0A7A	Kazhitaev Sanzhar Muralovich		

TASK FOR SECTION

"SOCIAL RESPONSIBILITY"

student:

Group	Full name
0A7A	Kazhitaev Sanzhar Muralovich

School	**SNTE**	**Research and Education Centr**	**DNFC**
The level of education	bachelor	**Direction/ specialty**	14.03.02 Nuclear physics and technology / Nuclear Power Engineering/Nuclear medicine

Subject FQW:

Seasonal features of variations in atmospheric alpha radioactivity	
Initial data for the section "Social responsibility":	
1. Characteristics of the research object (substance, material, device, algorithm, technique, working area) and its scope	- a model for the registration of γ-quanta by a system of NaI (Tl) detectors formed in the study of reactions of synthesis of light nuclei; experimental nuclear physics
List of questions to be researched, designed and developed:	
1. Legal and organizational security issues: - special (typical for the operation of the research object, the projected working area) legal norms of labor legislation; -organizational measures for the layout of the working area.	- Federal law of 09 Jan. 1996 No. 3-F3 "On radiation safety of the population" - SanPiN 2.2.2 / 2.4.2732-10 "Hygienic requirements for personal computers and work organization
2. Industrial safety: **2.1. Analysis of the identified harmful and dangerous factors** **2.2. Rationale for mitigation measures**	Harmful and dangerous factors: - deviation of microclimate indicators; - increased noise level; - insufficient illumination of the working area; - increased level of electromagnetic radiation; - psychophysiological factors; - increased level of ionizing radiation; - danger of electric shock.
3. Environmental safety:	- analysis of the impact of the object and the research process on the environment; - development of organizational and technical measures to protect the environment.
4. Safety in emergencies:	- selection and description of a typical emergency - fire; - justification of measures to prevent emergencies; - the order of actions in the event of an emergency.

Date of issue of the task for the section on a line chart	**05.05.2020**

The assignment was given by the consultant:

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

The student accepted the assignment:

Group	Full name	Signature	date
0A7A	Kazhitaev Sanzhar Muralovich		

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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«Национальный исследовательский Томский политехнический университет» (ТПУ)

Школа ___________________________инженерная школа ядерных технологий_____________
Направление подготовки _________14.03.02 Ядерные физика и технологии______________
Уровень образования ___________бакалавриат____
Отделение школы ______________отделение ядерно-топливного цикла_________________
Период выполнения _____________весенний семестр 2020 /2021 учебного года______________

Форма представления работы:

бакалаврская работа

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Срок сдачи студентом выполненной работы:	09.06.2021

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
10.05.2021	*Обзор литературных источников*	*20*
24.05.2021	*Методы и приборы измерения альфа-активности в приземной атмосфере*	*25*
25.05.2021	*Экспериментальные данные и их анализ*	*25*
04.06.2021	*финансовый менеджмент, ресурсоэффективность и ресурсосбережение;*	*10*
04.06.2021	*социальная ответственность*	*10*
08.06.2021	*Заключение по работе*	*10*

СОСТАВИЛ:
Руководитель ВКР

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

Консультант (при наличии)

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

СОГЛАСОВАНО:
Руководитель ООП

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

TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

Work submission form:

bachelor's work

CALENDAR RATING PLAN
completion of the final qualifying work

The deadline for the student's completed work:	09.06.2021

date control	Section (module) name / type of work (research)	Maximum section (module) score
10.05.2021	*Review of literary sources*	*20*
24.05.2021	*Methods and instruments for measuring alpha-activity in the surface atmosphere*	*25*
26.05.2021	*Experimental data and their analysis*	*25*
04.06.2021	*financial management, resource efficiency and resource conservation;*	*10*
04.06.2021	*Social responsibility*	*10*
08.06.2021	*Conclusion on work*	*10*

COMPOSED:
Head of the WRC

Position	Full name	Academic degree, title	Signature	date
Professor of NFCF	Yakovleva Valentina Stanislavovna	Doctor of Technology		

Consultant (if available)

Position	Full name	Academic degree, title	Signature	date
Senior lecturer of NFCF	Poberezhnikov Andrey Dmitrievich	-		

AGREED:
PLO leader

Position	Full name	Academic degree, title	Signature	date
Associate Professor	Bychkov Petr Nikolaevich.	PhD		

РЕЗУЛЬТАТЫ ОБУЧЕНИЯ (КОМПЕТЕНЦИИ ВЫПУСКНИКОВ)

Код компетенции	Наименование компетенции
	Универсальные компетенции
УК(У)-1	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.
УК(У)-2	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.
УК(У)-3	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.
УК(У)-4	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.
УК(У)-5	Владеть одним из иностранных языков на уровне не ниже разговорного.
УК(У)-6	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.
	Профессиональные компетенции
ПК(У)-1	Использовать основные законы естественнонаучных дисциплин в профессиональной деятельности, применять методы математического анализа и моделирования, теоретического и экспериментального исследования.
ПК(У)-2	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

Код компетенции	Наименование компетенции
	угрозы, возникающие в этом процессе, соблюдать основные требования информационной безопасности, в том числе защиты государственной тайны).
ПК(У)-3	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.
ПК(У)-4	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.
ПК(У)-5	Способность к организации метрологического обеспечения технологических процессов, к использованию типовых методов контроля качества выпускаемой продукции; и к оценке инновационного потенциала новой продукции.
ПК(У)-6	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.
ПК(У)-7	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;
ПК(У)-8	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.
ПК(У)-9	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.

LEARNING OUTCOMES (COMPETENCES OF GRADUATES)

The code competence	Competence name
	Universal competences
UC (U)-1	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.
UC (U)-2	Ability to logically correct, reasoned and clearly build oral and written speech; critically assess your strengths and weaknesses, outline ways and choose means of developing strengths and eliminating weaknesses.
UC (U)-3	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.
UC (U)-4	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; be aware of the social significance of their future profession, be highly motivated to perform professional activities.
UC (U)-5	Know one of the foreign languages at a level not lower than the spoken one.
UC (U)-6	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 for full-fledged social and professional activity.
	Professional competence
PC (U)-1	Use the basic laws of natural sciences in professional activities, apply the methods of mathematical analysis and modeling, theoretical and experimental research.
PC (U)-2	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).
PC (U)-3	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.
PC (U)-4	Readiness for the operation of modern physical equipment and devices, for the development of technological processes in the course of preparing the

The code competence	Competence name
	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.
PC (U)-5	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.
PC (U)-6	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 objects of research, 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 and carrying out on the basis of standard computer-aided design packages and research objects.
PC (U)-7	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;
PC (U)-8	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.
PC (U)-9	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.

Abstract

The final qualifying work consists of 89 pages, 22 figures, 22 tables, 33 sources.

Key words: radioactivity, ionizing radiation, alpha radiation, radon, variations, atmosphere.

The object of research is alpha radioactivity in the surface atmosphere, depending on the season of the year and meteorological conditions.

Objective of the work - Investigation of seasonal characteristics of variations in atmospheric alpha radioactivity.

The work investigated the features in the dynamics of atmospheric alpha-radioactivity on different time scales from intra-diurnal to synoptic scales, performed a regression and correlation analysis of experimental data on radiation and meteorological quantities.

As a result of the study, it was found that monitoring the alpha background can replace the measurement of integral values of volumetric activity and the equivalent equilibrium volumetric activity of radon in the surface atmosphere. No significant correlations revealed between instantaneous values of radon volumetric activity and alpha-radiation flux density in certain periods of the year lasting from several days to several weeks, in good weather conditions.

The degree of implementation: the results of the work were included in the report on the international conference "Prospects for the development of fundamental sciences".

Field of application: the results of the study can be used to replace radon monitoring by measuring the alpha background in the surface atmosphere for the purposes of radioecology and radiobiology, assessing the doses of population exposure to natural radionuclides.

Economic efficiency / significance of the work is to reduce the cost of outdoor radon monitoring using alpha detectors, including in winter conditions, which is not possible with existing radon radiometers.

List of Acronyms and Abbreviations

IR – Ionizing Radiation;

PDD – Percentage Depth Dose;

VA – Volumetric Activity

DSS – Distance from Source to Surface;

DDP – Daughter Decay Products.

NFCD – Nuclear Fuel Cycle Division;

SNSE – School of Nuclear Science and Engineering;

TPU – Tomsk Polytechnic University;

Lowess – locally weighted scatterplot smoothing;

RW – Research Work;

FQP – Final Qualifying Work;

SWOT – Strengths, Weaknesses, Opportunities, Threats;

MPC – Maximum Permissible Concentration;

EMF – Electromagnetic Field;

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Introduction

Radioactive pollution of the atmosphere can be caused by various types of ionizing radiation, that is, electromagnetic and corpuscular radiation, which includes alpha, beta, gamma rays, X-rays, fluxes of protons and electrons, slow and fast neutrons. Exposure to such radiation can cause significant damage to living tissue, and therefore there is an increasing need for the use of appropriate detectors, which, in the event of a possible danger, would allow resorting to protective measures. This problem is so important, and the reliability of the readings of such detectors is so undeniable that often measuring instruments installed near the source of pollution are equipped with alarm mechanisms that are triggered in case of exceeding the level of radioactivity established for various types of radiation in the observation area. The problem is especially complicated by the uncertainty of the values of the units of measurement of radioactivity (both basic and derivative) and related basic concepts. The physical nature and intensity of radiation also create their own difficulties, as well as our insufficient knowledge about the results of the interaction of radiation with matter and about the effect of radiation on living cells and tissues.

When working with radioactive α-emitting isotopes, contamination of work items, clothing, hands, etc. can occur. Therefore, in rooms intended for working with radioactive substances, it is necessary to systematically carry out dosimetry control, the purpose of which is to check the degree of α-contamination with isotopes of various surfaces (tables, clothes, hands, etc.). The sanitary rules establish the maximum permissible levels of contamination with α-active isotopes of surfaces.

Chapter 1 Literature review

Radon gas is a significant source of natural radioactivity in the atmospheric boundary layer. It constantly arises in nature during the radioactive decay of mother nuclei, after which it enters groundwater, natural gases and air. That is why knowledge of the fluctuations of the natural radioactivity of the atmosphere, which is the main medium of human life, is so important. The temporal variability of radon in the air near the earth in relation to weather elements and the processes of vertical mixing in the atmosphere have been studied by various authors.

Currently, many articles have been published on the dynamics of the volumetric activity of radon in the atmosphere in many countries. These studies show that the concentration of radon varies throughout the day and seasons. It depends not only on the radium content and its distribution in the soil, but also on porosity, permeability, moisture content and other parameters. [4,5,6,10].

According to the results of analyzes of some studies, differences in radon concentration were confirmed, which strongly depended on the concentration of radium in the earth's crust, geographical conditions, distribution of land and sea. Scientists believed that the concentration of radon depends on the ratio of the components of the mixture of air and ocean. [6].

1.1 Features of the dynamics of active volumetric radon in the atmosphere

1.1.1 Daily variations of radon

It is known that the surface concentration of radon changes during the day, which is caused by daily changes in vertical turbulent mixing in the atmosphere, advection, and the value of the ^{222}Rn flux from the soil. These factors, in turn, are influenced by the meteorological parameters of the atmosphere: wind speed and direction, humidity, pressure, intensity of solar radiation.

In [11], the background radon concentration and the level of the ambient background atmospheric radon in Korea were detected throughout 2011 using a real-time monitoring system at Gosana station.

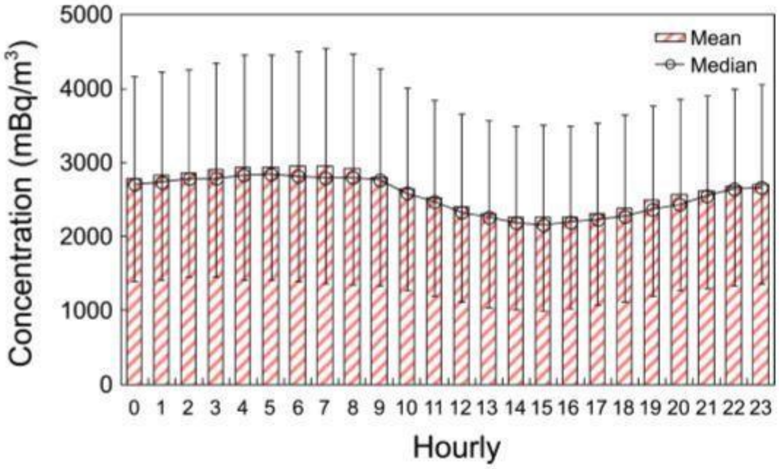


Figure 1 - Daily variations in hourly mean radon concentrations.

Figure 1 shows that the daily radon cycle was characterized by an early morning maximum (7 hours) and a minimum in the middle of the day (3 hours). The highest nighttime compound concentrations (2956 mBq/m^3) were observed around sunrise, when the mixing depth of the atmosphere was the smallest, and the lowest values (2259 mBq/m^3) were observed at the beginning of the day, when the mixing depth was greatest.

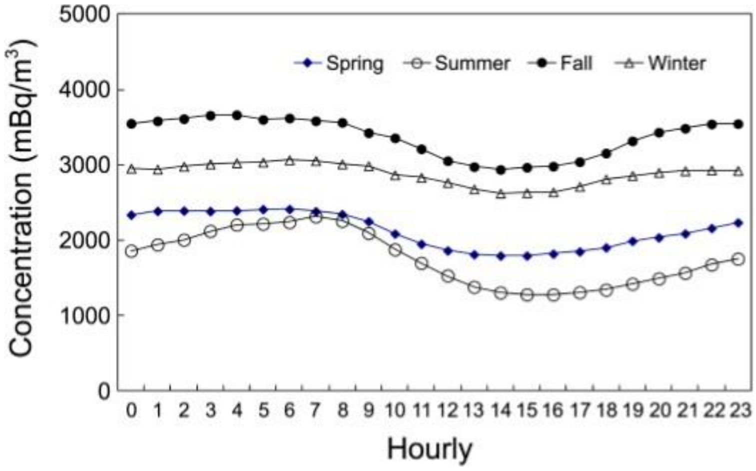


Figure 2 - Daily graph of hourly radon concentrations over four seasons.

In winter, air masses are delivered to the study area, mainly through the Yellow Sea. Due to the fact that large bodies of water have a large heat capacity, they show small daily changes in surface temperature. Consequently, large water bodies have a stabilizing effect on the depth of mixing of the atmosphere, which leads to a relatively small daily variability in the depth of mixing in winter. This is reflected in the small amplitude of the combined daily radon cycle in the area compared to the typical for the interior regions. On the contrary, in summer, most of the air masses in Goosan pass through Jeju Island, which leads to much more significant diurnal variations in the depth of atmospheric mixing due to the relatively large diurnal variation in surface temperature, which is more typical for continental regions.

Japanese scientists also investigated the daily minimum concentration of radon observed in Fukushima Prefecture from 2003 to March 2011 in [5]. Seasonal variation was calculated by applying a sinusoidal model to the daily minimum radon concentration during a normal period of operation. Within the daily variation in radon concentration, the daily minimum radon concentration is independent of topography. Therefore, the daily minimum radon concentration should be used to analyze the representative variation in radon concentrations around a specific area.

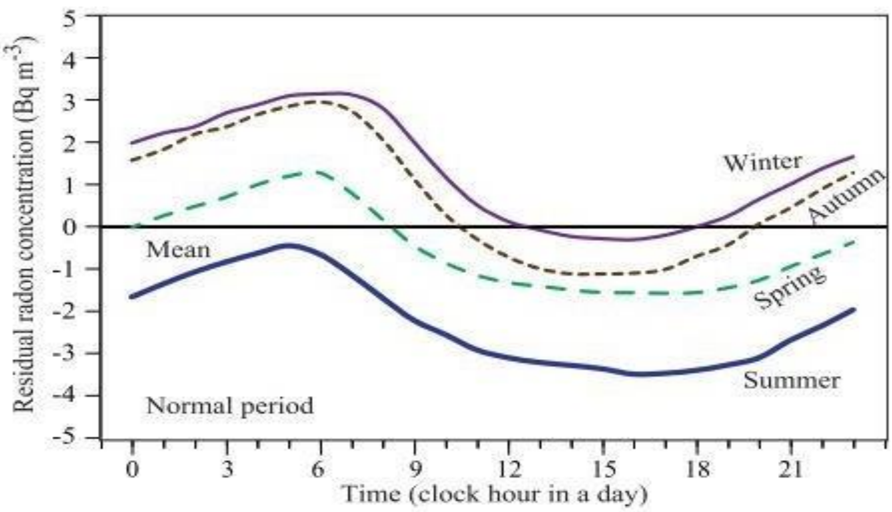


Figure 3 - Daily changes in residual radon concentrations over four seasons (subtraction of the linear trend and conversion of radon concentration from the ionization current) [7].

Figure 3 shows the diurnal variation of residual radon concentrations in each season. Seasonal fluctuations in the minimum radon concentration coincide with changes in the upper part of the mixing layer. In winter, higher values of the minimum radon concentration reflect a sinking of the upper part of the mixing layer; while in summer, lower values of the minimum radon concentration reflect an increase in the height of the upper part of the mixing layer. Changes over four seasons follow a general pattern: the decrease in radon concentrations after sunrise is due to the generation of high turbulence in the daytime mixing layer. It can be seen that the minimum concentration of radon is usually reached at the end of the day, when the mixing layer is fully developed. The concentration gradually increases from midday (15:00) until the next morning (06:00) and suddenly drops at sunrise, as the concentration of atmospheric radon is highly dependent on changes.

1.1.2. Seasonal features of radon

Seasonal variability of radon in the atmosphere is also primarily associated with meteorological factors: atmospheric stratification, atmospheric precipitation and atmospheric circulation [12].

If we consider temperature inversions as one of the main factors determining variations in surface radon, then it should be noted that both the power and the intensity of the inversion are characterized by significant seasonal variability. Over the continental and some coastal regions of the world, the maxima of the power and intensity of the inversion are observed in winter, and minima - in summer. It is also noted that low-power surface inversions are more often observed in the warm season, and more powerful ones - in the cold [12]. Atmospheric precipitation contributes to a change in the state of the soil: moistening, filling the pores of the soil with water and, consequently, reducing the exhalation of radon into the atmosphere. The presence of snow or ice on the soil surface leads to the accumulation of radon in the soil and its intense emission into the atmosphere in the first hours after the melting of the snow cover, as already noted.

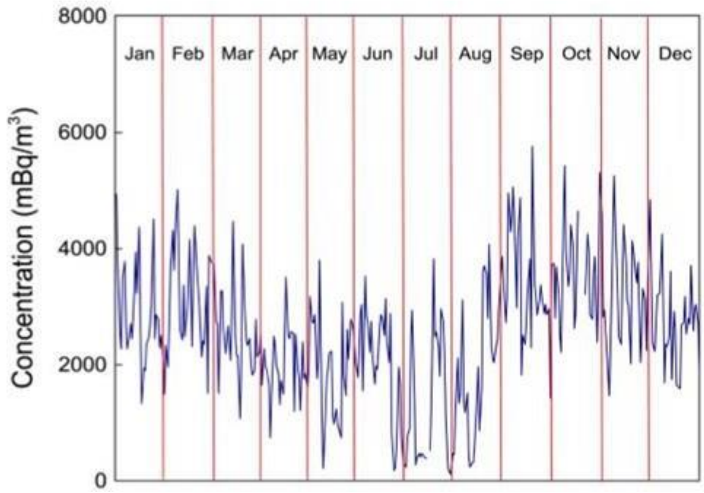


Figure 5 - Annual time series of daily radon VA [11]

According to the results of work [11], a bright pronounced seasonality is shown, characterized by high concentration in winter and low concentration in summer. In this study, high radon concentrations were observed from September to February (2666-3595 mBq/m^3). This is the period of the most stable earth inflow due to strong northerly winds, a northwest component and dry air masses during the height of the Asian winter monsoon. During the winter monsoon, the air flow in the lower atmosphere is directed from the Asian continent towards the Pacific Ocean; returns back in summer time. The lowest monthly mean radon concentrations (1243 mBq/m^3) were observed in July, which was a period of relatively dominant oceanic production due to the strong southerly component of the wind direction and humid air masses. The ocean is a minor source of radon. For the most part, average monthly wind speeds are high between December and March.

Table 1 - Monthly mean values and standard deviations of radon VA in two regions of Slovakia [9].

Month and year	FMPI CU [Bq·m⁻³]	SMI [Bq·m⁻³]
February 2019	5.6 ± 3.2	4.7 ± 3.6
March 2019	5.1 ± 3.6	4.8 ± 3.7
April 2019	4.0 ± 2.5	4.3 ± 3.8
May 2019	5.4 ± 3.2	6.7 ± 5.1
June 2019	6.3 ± 3.2	8.9 ± 5.5
July 2019	5.4 ± 3.2	6.8 ± 4.7
August 2019	4 ± 4.3	6.5 ± 6.0
September 2019	4.2 ± 3.4	4.8 ± 5.8
October 2019	5.6 ± 2.8	6.6 ± 5.0
November 2019	6.5 ± 3.4	7.3 ± 3.9

According to the results of work [9] during 11 months of radon monitoring in 2018, the mean annual values of radon VA of 5.4 and 6.1 Bq/m^3 were obtained for FMPI and SMI air, respectively. In the SMI area, the maximum radon VA values were observed during the summer, in contrast to the winter maximums observed in the FMPI area. A significant change in meteorological parameters, such as wind speed or temperature, caused a corresponding significant change in radon VA in two regions in Slovakia. However, the daily cycles of radon, as well as the average values of radon VA, were affected by the terrain orography of the radium and radon contained in the soil. The effect of orography was especially clearly visible in the SMI region, where, due to the special conditions of solar irradiation, an increase in radon VA during the summer months was observed already at 12 a.m., and the maximum of the daily cycle occurred as before at 11 p.m.

Atmospheric radon concentrations were monitored from autumn 2018 to winter 2018 in an abandoned coal mining area in Poland [7]. Strong spatial and seasonal fluctuations of radon VA in the atmosphere were observed (Figure 6). Spatial variations correlated with changes in uranium content in the basement. Seasonal changes were positively correlated with temperature and negatively correlated with humidity, resulting in maximum atmospheric radon activity in summer. The strong influence of the local uranium content in the basement indicates its importance in the planning of monitoring campaigns.

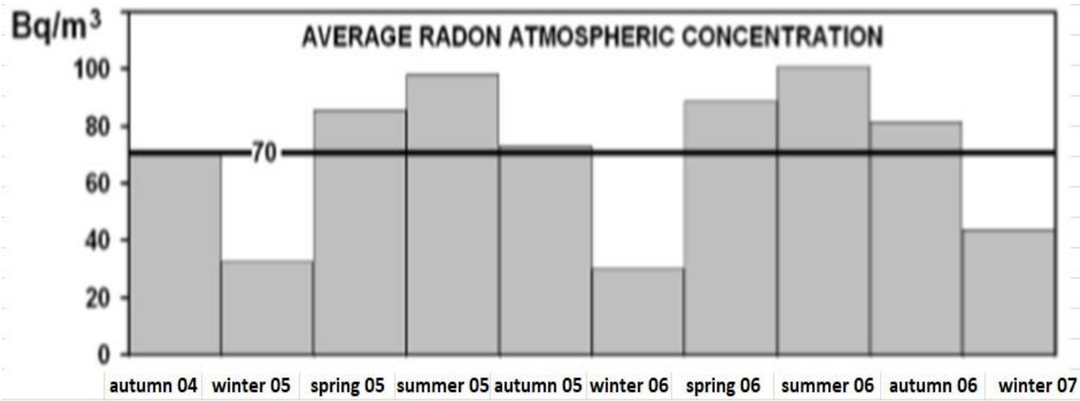


Figure 6 - Seasonal variation of atmospheric radon in Poland

It was found that the existence of porous tailing dumps of coarse-grained rock fragments in Poland is the main reason for the increase in the average concentration of atmospheric radon on average, resulting in an average value of 70 Bq/m^3 for 77 monitoring sites. The tailings dump had the highest concentration of atmospheric radon, reaching a maximum of 131 Bq/m^3 in the summer of 2018. Due to the usually high concentrations of atmospheric radon, seasonal fluctuations (the highest values were noted during the summer, the lowest during the winter and intermediate during the spring and autumn) were mainly controlled by changes in local conditions of expiration due to fluctuations in air temperature and humidity. The influence of long-range transport from continental or oceanic air masses seems to be less significant, since a strong local spatial differentiation was observed over the entire year. It was found that in mountain valleys with poor ventilation, where the basement has differentiated uranium content and porosity, the local factor has a strong effect on the concentration of atmospheric radon.

Differences in the concentration of radon in different places strongly depended on the concentration of radium in the earth's crust and geographic conditions, i.e. distribution of land and sea. Scientists believed that the concentration depends on the ratio of the components of the mixture of air and ocean. Therefore, the influence of radon transported from the distant Eurasian continent and radon arising from the measurement area depends on changes in vertical convection [9]. The temporary change in the residual concentration of radon is influenced by atmospheric turbulence, which is strongly associated with a change in surface temperature.

In [9], radon VA in the surface atmosphere was monitored in two regions of Slovakia. The orography of settlements is different, ranging from plains to hilly terrain. Regions are located at a distance of up to 130 km from each other. The first site was the campus of the Faculty of Mathematics, Physics and Computer Science - Comenius University (FMRI CU). The second sampling site was located in the area of the Slovak Metrology Institute (SMI) in Bratislava and is located about 3 km west of the FMRI CU campus.

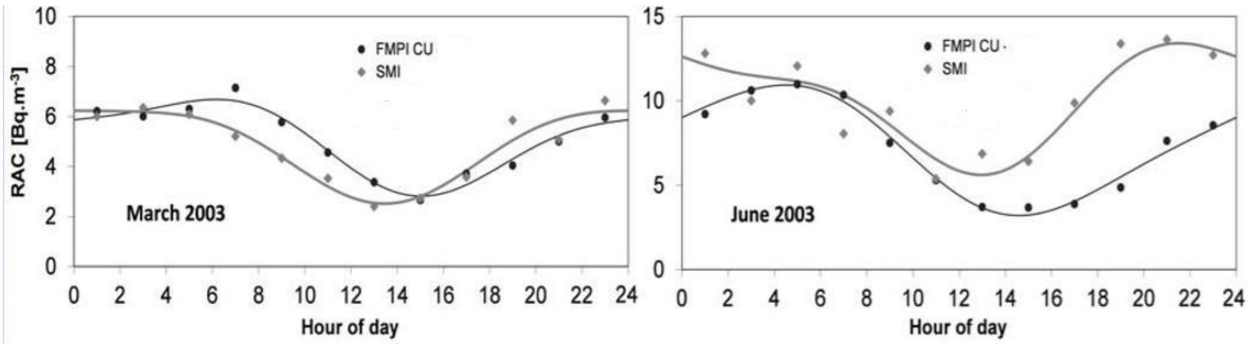


Figure 7 - Daily variations of radon VA on FMRI PU and SMI for two months of 2003 [9].

The amplitudes of the daily variation of the series are similar in both settlements, 3.5 Bq/m^3 in June and 2 Bq/m^3 in March. Similar diurnal patterns of radon VA were found between two regions. However, there was a noticeable time shift (up to 5 hours) in the daytime minimum and maximum radon VA between the FMRI and SMI terrain. This effect was due to the fact that the measurement area based on the SMI was exposed to solar radiation only until 3 am in the summer and 12 am in the winter due to screening from the west to the nearby hills. This led to an earlier decrease in the intensity of vertical exchange processes in the SMI air, which led to an earlier increase in radon VA, always a couple of hours earlier than the similar increase observed at the FMPI campus. This effect is especially noticeable in the summer months, when the influence of solar radiation on the time series of radon VA is more significant than in winter. Measurements show that monthly average radon VA values in the SMI area are usually higher (by 21-40%). In the SMI area, the maximum radon VA values were observed during the summer, in contrast to the winter maximums observed in the FMPI area. In the SMI region in summer, the maximum was a consequence of the relatively high VA radon during the day, as well as at night (higher than in the FMPI region).

The daily variation in Japan at work [5] is the same and does not depend on the seasonal year, and in work [11] made in Korea and in work [9] in two regions of Slovakia, they have different diurnal variations in radon VA for different seasons due to the fact that that different features of the movement of air masses in Korea and a significant change in meteorological parameters, such as wind speed or temperature, caused a corresponding significant change in radon VA in settlements in Slovakia.

As a result, we can say that the minimum concentration of radon is observed during the day, when vertical mixing of air is most active, and radon released from the soil rises to the overlying layers of the atmosphere, and is also transferred in space due to air advection. In the evening, when the earth's surface cools down and vertical air movements weaken, temperature inversion is established. Temperature inversion prevents the vertical and horizontal transport of radon in the surface layer of the atmosphere, which contributes to the accumulation of radon released from the soil in the surface layer and an increase in its surface concentration by several times compared with daytime values. As the sun rises, the temperature inversion collapses, turbulent mixing intensifies, and the radon concentration in the surface layer decreases sharply.

1.1.3 Sources of atmospheric alpha radioactivity

From the very beginning of its formation, the earth's crust contains natural radioactive elements (NRE), which create a natural background radiation. Rocks, soil, atmosphere, waters, plants and tissues of living organisms contain radioactive isotopes of potassium-40, rubidium-87 and members of three radioactive families originating from uranium-238, uranium-235 and thorium-232. These parent nuclides are as old as the Earth itself - about 4.5 billion years. They still exist only because the half-lives of the founders of radioactive families are very long and are $4.5 \cdot 10^9$ years for uranium-238, $0.7 \cdot 10^9$ years for uranium-235, and $14 \cdot 10^9$ years for thorium.

Members of radioactive families are tightly bound together. Each link of the radioactive series is formed at a rate determined by the half-life of the previous nuclide, and decays in accordance with its own half-life. Thus, after a while, equilibrium is established in the decay chains, that is, how many daughter elements decay, the same amount is born in accordance with the half-lives of the parent nuclides. After a long chain of transformations, stable lead isotopes are finally formed (Fig. 2) [3].

The only gaseous product that is born in the process of decay of the three families of NRE is radon. The greatest contribution to the gas component of the NRE is made by the radioactive families of uranium-238 and thorium-232, during the decay of which radioactive radon-222 and radon-220 are formed (the latter is often called thoron by the name of the original parent nuclide).

Radon is an inert gas, colorless and odorless, almost 10 times heavier than air, boiling point – 65°C, dissolves in water. Radon, like its "parents", is an alpha emitter. In the process of decay, they produce a family of other alpha emitters, which are generally referred to as daughter decay products (DDP). Moreover, unlike radon and thoron, DDP are not gases, but solids - unstable isotopes of lead, bismuth, polonium and thallium, which themselves are powerful sources of alpha radiation. For example, when the uranium-238 family decays, eight alpha particles are released, of which four are radon and its DDP. Moreover, the first four alpha particles are emitted with a half-period of about 1 billion years (uranium-radium decay), and the next three with a half-period of 3.825 days, that is, the intensity of the alpha radiation of radon and DDP is many times higher than the intensity of the alpha radiation of uranium and radium, together taken.

Radon and thoron are present, like its parent nuclides, in all building materials and rocks. The inert gas formed during the disintegration process immediately, microcracks of rocks, is captured by flows.

Historically, the harmful effect of radon on the human body was noticed back in the 16th century, when the mysterious mountain sickness of miners attracted the attention of doctors for a long time: mortality from lung cancer among miners was 50 times higher than among the rest of the population. Much later, an analysis of the causes of death of mine workers at uranium mines in Europe in southern Germany and Czechoslovakia showed that from 30 to 50% of miners working in uranium mines die of lung cancer. Therefore, work on the study of the radiation effect of radon began to develop intensively.

The concentration of radon in the air is determined by the number of decays of radioactive nuclei per second in a cubic meter of air. For radon, this is practically equal to the number of alpha particles generated in the decay process. For the unit of the number of decays, 1 Becquerel is currently accepted, which is equal to one act of decay per second. Sometimes the off-system unit of 1 Curie is still used, equal to the number of decays of 1 g of radium-226, or $3.7 \cdot 10^{10}$ decays per second, or 1 Curie = $3.7 \cdot 10^{10}$ Becquerel. The average radon content in the air of the surface atmosphere is approximately 3.7 Bq/m^3, or 10^{-10} Ci/m^3.

The concept of “latent energy” is often used to describe the integral volumetric activity of daughter products of radon decay in air. Latent energy is the total energy of alpha radiation, which is released per unit volume of air during the decay of all short-lived DDP (for radon-222 up to lead-210, which has a half-life of 22 years, see Fig. 1). If the air contains 3700 Bq/m^3 (100 pCi/l) of radon-222 in complete equilibrium with the daughter decay products, then the value of the latent energy will be equal to $1.2835 \cdot 10^5$ MeV/L. This value, rounded up to $1.3 \cdot 10^5$ MeV/l, is called the "working level" (WL) and is widely used abroad to determine the volumetric activity of DDP in air, although it is an off-system unit. The use of the concept of "latent energy" is due to the fact that the amount of latent energy is proportional to the equivalent dose rate created by the daughter products of radon decay in the lung tissue. In one of its reports, the United States Environmental Protection Agency provides information on a study of the risk of diseases and deaths caused by exposure to radon and compares this degree of risk with data on external exposure due to fluoroscopic examinations and smoking (Table 1) [2]. Recent studies by the US Environmental Protection Agency have shown that radon-related lung cancer among smokers is three times higher than in non-smokers, that is, despite the fact that the risk of smoking is significantly lower than the radon risk (see Table . 1) Smoking increases the risk of exposure to radon.

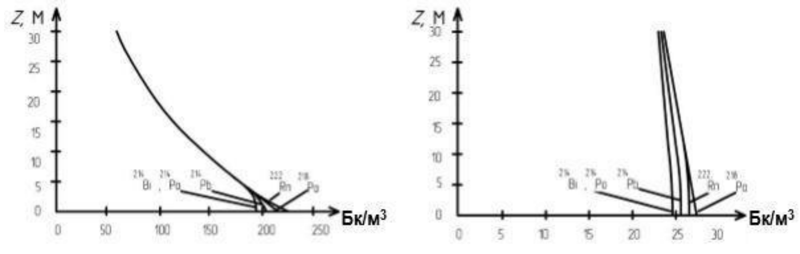
When assessing the radon risk, it should always be remembered that the contribution of radon itself to exposure is relatively small. With a radioactive equilibrium between radon and its DDP, this contribution does not exceed 2%. Therefore, the dose of radiation to the lungs from DPR of radon is determined by a value equivalent to the equilibrium volumetric activity (EEVA) of radon [1, 2]:

$$C_{Rn\ eq} = n_{Rn}F_{Rn} = 0,1046n_{RaA} + 0,5161n_{RaB} + 0,3793n_{RaC} ,$$

where n_{Rn}, n_{RaA}, n_{RaB}, n_{RaC} – volumetric activity of radon and its DDP (RaA, RaB, RaC, how often Po-218, Pb-214, Po-214 nuclides are denoted) Bq/m^3 , respectively; F_{Rn} – equilibrium coefficient, which is defined as the ratio of the equivalent equilibrium volumetric activity of radon in air to the real volumetric activity of radon. In practice, always $F_{Rn} < 1$ (0,4–0,5). To go to units of WL, it is necessary to multiply the EEVA value by a factor equal to 34.6 MeV/(l·Bq)

1.1.4 Vertical profile of active volumetric radon in the atmosphere

In [1], the influence of various factors on the vertical distribution of the volumetric activity of radon isotopes and daughter decay products in the surface atmosphere was found. Modeling of vertical profiles of volumetric activity in the range of variation of the turbulent diffusion coefficient from 10^{-3} to 0.1 m^2/s is presented in the following figures.



а б

Figure 8 - Dependence of the volumetric activity of radon and daughter decay products on the height at: a) $D_T = 10^{-3}$ m^2/s; б) $D_T = 0,1$ m^2/s.

It can be seen that a change in the coefficient of atmospheric turbulence strongly changes the vertical profile of the volumetric activity of radon, thoron and their decay products, especially near the earth's surface. With an increase in the coefficient of turbulent diffusion from $D_T = 10^{-3}$ to 0,1 m^2/s there is a transition from an exponential dependence of the volumetric activity of radon and daughter decay products from altitude to a linear one, the values of the volumetric activity at the earth's surface decrease by an order of magnitude. Decrease in D_T to values less than 10^{-3} m^2/s will lead to an increase in the volumetric activity of radon and thoron near the earth's surface to values of more than 200 Bq/m^3.

The influence of changes in the vertical speed and direction of the wind on the vertical profiles of the volumetric activity of radon isotopes and daughter decay products are shown in Figure 7. The direction of the wind speed with a positive value coincides with the direction of the z axis, negative values show that the wind is directed towards the earth's surface.

With an increase in the wind directed upward from the earth's surface, there is a strong decrease in the volumetric activity of radon isotopes and daughter decay products at the earth's surface and the leveling of radionuclide concentrations along the height.

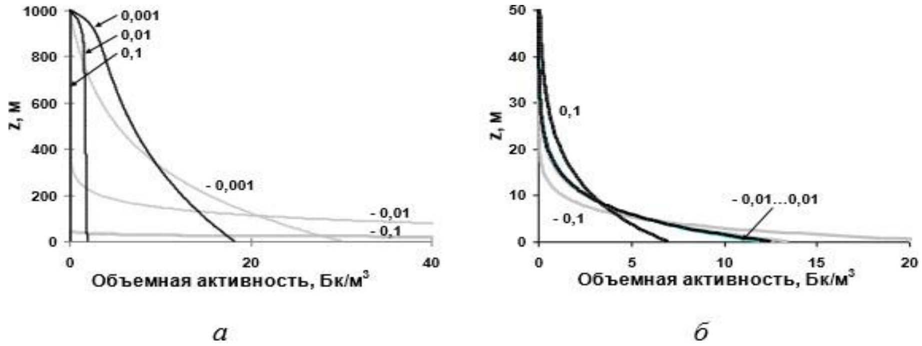


Figure 9 - Change in height at different wind speed and direction of volumetric activity a) radon; b) thoron [1]

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

The effect of the speed and direction of the vertebral wind on the equilibrium coefficient of radon and thoron are shown in Fig. 9, from article [18] it was obtained that the violation of radioactive equilibrium occurs mainly with the wind directed from the earth's surface, and increases with its strengthening.

The wind blowing from top to bottom, on the contrary, restores the radioactive balance between radionuclides. For the coefficient of radioactive equilibrium between thoron and DDP, a completely different dependence is observed.

The activity of thoron near the earth's surface can exceed the activity of its decay products by several orders of magnitude. At a certain altitude in a very small air layer, their activities are compared, and then the thoron completely disintegrates. Thus, thoron and its decay products are almost never in radioactive equilibrium in the atmosphere.

The wind directed to the earth's surface reduces the activity of radon and DDP isotopes at high altitudes and, conversely, greatly increases and compares their VA at the earth's surface. With an increase in the wind directed upward from the earth's surface, there is a significant decrease in the VA of radon isotopes and DDP at the earth's surface and the leveling of the concentration of radionuclides along the height.

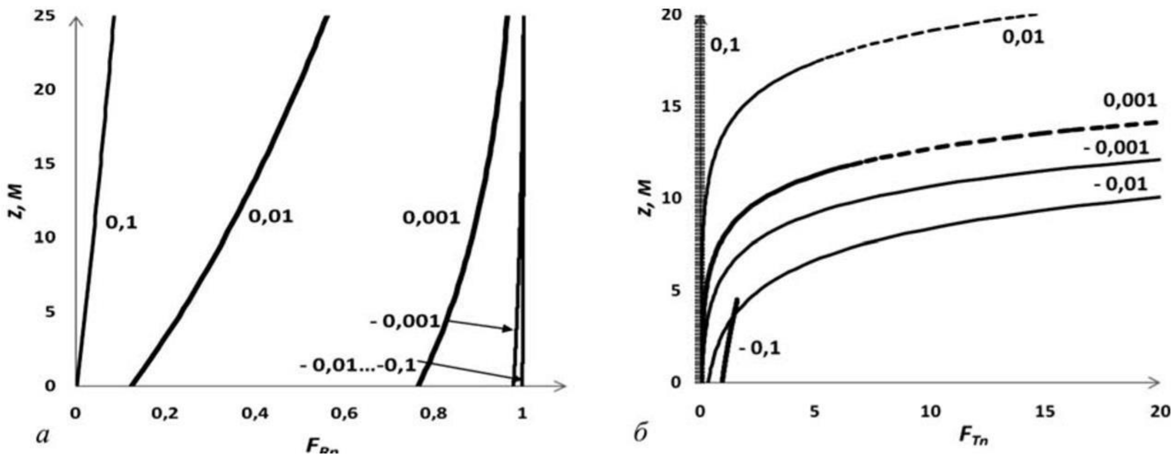


Figure 10 - Change with height of the coefficient of radioactive equilibrium depending on the speed of the vertical wind a) between radon and DDP; b) between thoron and DDP. [18]

1.1.5 Conclusion on the first chapter

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

The ground-level radon concentration can vary greatly (by a factor of 2 or more) during the day, which is caused by daily changes in vertical turbulent mixing in the atmosphere, advection, and the magnitude of the radon flux from the soil.

As a result of an analysis of the literature, it was revealed that there is a daily maximum concentration, which is observed when the atmosphere is the least mobile, and a minimum, which is observed during the day, when vertical mixing of air due to turbulent diffusion have maximum value.

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

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

Violation of radioactive equilibrium occurs mainly with the wind directed from the earth's surface, and increases with its strengthening.

Chapter 2 Methods and instruments for measuring alpha-activity in the surface atmosphere

2.1 Methods for measuring alpha radiation flux density

As you know, the natural radioactive gas radon is a decay product of radium, which, in turn, appeared as a result of the decay of uranium-238 [5].

Firstly, radon, as a radiogenic gas, is continuously generated in rocks during radioactive decay, that is, it is always present in any mountain range, and its concentration decreases both due to decay (the half-life of radon is 3.825 days) and due to migration from the massif into the air is constantly compensated by the new generation of this gas. Поэтому среднее содержание радона в массиве всегда постоянно и определяется концентрацией урана (радия) в этом массиве.

Secondly, the migration of radon in the mountain range and its release from the soil surface are determined by the macroscopic diffusion coefficient, which depends on many factors. The most important of these are porosity, permeability and fracturing. In the presence of fracturing (permeability) of the upper part of the massif and ascending gas flows, convection transport of radon with gas jets can be carried out from depths of up to 200 m [3].

Thirdly, despite the fact that the content of radon in these streams is negligible, there are no problems with its registration due to its radioactivity. For example, radon is reliably detected when there are approximately 30-50 decays per second in one cubic meter, that is, the radon activity is 30-50 Bq/m^3. This means that one cubic meter contains (0.2-0.3)$\cdot 10^7$ radon atoms, or its concentration in the gas mixture is about 10-16%.

The permeability of the rock mass, the presence of interconnected pores and cracks in it, significantly depends on the stress-strain state of the rock mass. Obviously, when the mass is compressed, its permeability decreases, and when unloading, it increases. The apparent diffusion coefficient changes accordingly. Consequently, dynamic changes in the concentration of radon in the near-surface layer of the soil will reflect dynamic changes in the stress-strain state of the rock mass in a significant amount. These factors served as the basis for studying the field of variations in radon exhalation as a short-term precursor of seismic events.

The specificity of measurements of alpha activity is due to the fact that the range of emitted alpha particles in the detector substance, as in the substance of a solid sample, is very limited, usually no more than 70 μm. This limits the maximum effective layer thickness of the sample to be measured. An increase in the sample thickness does not lead to an increase in the minimum measurable activity by this detector.

Known methods for measuring the total alpha activity in air, water and soil include several stages: sampling, preparation of counting samples, measuring the counting rate of samples on a radiometric installation, determining the initial activity of OOS based on the results of measuring the test sample, or by comparing the counting rates counting sample and comparison sample. In radiometric installations, as a rule, scintillation and semiconductor detectors are used..

When preparing samples, the initial material of samples with the total specific alpha activity of radionuclides and mass goes through, depending on the specifics of the sample, several processes: evaporation, concentration of radionuclides, chemical co-precipitation, ashing, etc. As a result, its mass, in the general case, decreases to M_{con}, $\leq M_{probe}$. All or part of this mass is used to make a counting sample (CS).

The complexity of sample preparation is mainly due to two circumstances: the low range of alpha particles and the need to increase the mass content of radionuclides in the samples to the minimum measurable activities when using one method or another in the allotted period of a single measurement (usually 3 - 10 hours). This determines the high labor intensity and relatively low productivity when conducting analyzes.

In the practice of measurements, methods of absolute and relative radiometry are used.

Absolute radiometry - direct direct determination of the activity of an ionizing radiation source without using any standard sample. Disadvantage - any direct method of radiometry requires a priori information about the source: its composition, list of contained radionuclides, energy spectrum of radiation, density, etc. Based on this, a number of corrections to the measurement results are introduced.

Relative radiometry is realized on the basis of comparing the measurement results of the investigated source and the reference (standard, exemplary, with known activity) source with a certified activity value. In this case, the structures of the reference and investigated sources must be the same, the measurement conditions must also be completely identical. This means that in the radiometry of the source and the standard, the geometry and measurement modes must be fully reproduced using the same radiometric equipment. Relative radiometry methods are convenient for mass measurements of homogeneous sources, for example, for solving environmental and medico-hygienic problems.

Measurements can be carried out using dielectric track detectors or a radiometric installation.

The properties of track detectors make it possible to use them to measure total alpha activity in almost all cases when other alpha radiometric methods are used. However, there are a number of situations when the use of the tracking method is preferable because of its higher sensitivity or for other reasons, for example, in the case of measuring the background alpha activity in the presence of powerful fluxes of β- and γ-radiation. In addition, track detectors can repeat the shape of the surface under study and can be made to any required size.

Thus, a comparison of methods for measuring the levels of alpha activity using semiconductor, scintillation and track detectors shows that when carrying out large-scale monitoring measurements, where the duration of measurements within one to two months is not a limiting factor, it is advisable to use track detectors. An important advantage of TDs is their high sensitivity, due to the possibility of a multiple increase in the exposure time of the sample on the detector. At the same time, the measurement process can run in parallel on tens and even hundreds of samples. Simultaneous processing of all detectors significantly reduces the complexity and duration of analysis per one counting sample. The high sensitivity of track detectors makes it possible to significantly simplify the sample preparation process, since the requirements for the degree of concentration of the studied radionuclide are significantly reduced.

According to the method of recording radioactive radiation, radiometric methods are divided into ionization (measurement of the general ionization effect of radiation) and pulsed (counting the number of particles of α or β radiation or quanta of γ radiation). The distribution of activity over the surface of the studied volume is usually determined by the method of photoemulsion autoradiography [4].

Radiometric methods are also distinguished by the method of source preparation, by the geometry of measurements, by the physical phenomena used.

The first group includes methods: "infinitely thin" and "infinitely thick" layers, "transferring the label to gas", "complete evaporation of samples".

The second group includes methods of a certain solid angle and "4π-counting".

The third group of methods includes calorimetric, gravimetric, liquid scintillation counting, methods of internal filling counters, ionization chambers, mass spectrometric, emission spectral, coincidence method, etc.

Modern radiometric devices make it possible to automatically measure hundreds of radioactive preparations according to a given program with processing the measurement results using a computer.

Radiometry is widely used in solving a wide variety of problems - from research using tagged atoms to determining the age of rocks and in archeology.

2.1.1 Direct measurements

In order to make direct measurements of alpha, beta and photons of background activity, tools and methods provide the required detection sensitivity. Instrument type and direct measurement method are selected by identifying the type of potential contamination, the sensitivity measurement requirements, and the objectives of the radiological survey. Direct measurements are taken by placing the instrument at an appropriate distance above the surface, at least a reasonable height of 50 m, away from obstructions such as buildings, trees, etc. At this altitude, measurements are taken over a predetermined time interval (eg 10 sec, 60 sec, etc.). The minified integrated counting method is a practical field survey procedure for most equipment and provides detection sensitivity. Alternatively, direct measurements can be carried out on-site systematic surveys and scan reviews.

2.1.2 Measuring instruments and sensors

A portable germanium detector or gamma spectrometer can be used to estimate the concentration of gamma-emitting radionuclides in the field. As in the laboratory, based on a germanium detector with a multichannel analyzer, gamma spectrometry can be distinguished among various radionuclides gamma and X-ray energy to provide specific measurement of nuclides.

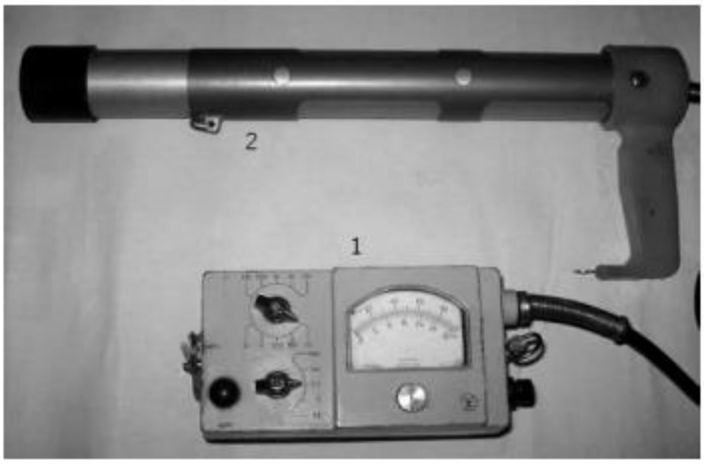


Figure 11 – СРП-68-01 radiometer: 1 – measuring board, 2 – detection head

A calibrated detector measures the flux density of primary photons at specific energies specific to a specific radionuclide (NRC 1995b). This measure of energy density can then be converted to concentration units. Under certain conditions, the energy density indicator can be dosed directly. The indicator of energy density should be considered the main parameter for assessing the level of radiation in a certain place, since it is a directly measurable physical quantity.

One of the most common in the exploration industry is СРП-68-01. The number "01" means that the device is intended for pedestrian gamma shooting. There is also СРП-68-02, used for gamma ray wells, СРП-68-03 used for blasthole gamma shooting. СРП-68 are highly reliable and easy to use. Also used devices СРП-88, lighter, smaller and equipped with a digital display from which the measured values are taken. СРП-88 has a larger measuring range.

2.2 Alpha radiation detection unit БДПА-01

BDPA-01 is a highly sensitive scintillation detector designed to measure the flux density of alpha particles from contaminated surfaces in the range from 0.1 part min-1 cm-2.

Features:

- High sensitivity and wide range
- Fast adaptation to changing radiation field
- Search for sources of alpha radiation
- Is an intelligent detection unit (RS232 interface)
- Built-in LED stabilization system
- Ability to operate over a wide temperature range in the field (IP64)
- Storage in the nonvolatile memory of the device and transfer to the PC up to 500 measured sectors

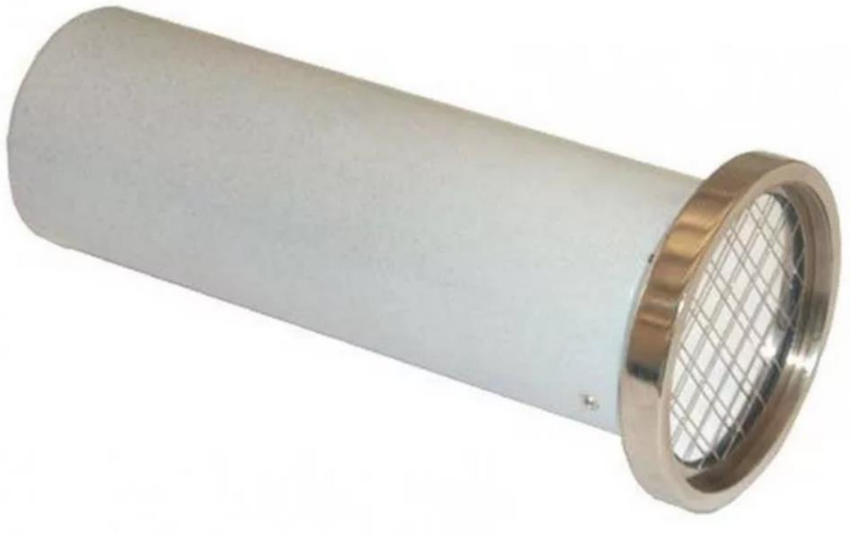


Figure 12 - БДПА-01 alpha detection unit

2.2.1 Conclusion on the second chapter

The main radiometers for measuring the VA of radon, thoron and detectors of the flux density of alpha and beta radiation were considered.

The analysis of the above radiometers manufactured in the Russian Federation and abroad allowed us to conclude that all of them are not intended for automated year-round monitoring, and in cold periods of time (from -15ºC and below) require special protection

Chapter 3 Experimental data and their analysis.

3.1 peculiarities in the dynamics of atmospheric alpha radioactivity

One of the factors causing disturbances in the change in the concentration of alpha activity in the atmosphere can be a change in the stress state of rock massifs, which can lead to a tectonic earthquake or explosion-like destruction of an extremely stressed part of the rock in a mine working in deep mines. The scales of these phenomena are different in spatial and energy coordinates, but the physics of the phenomena is practically the same: with an increase in the stress state of rocks above a certain limit, irreversible changes in the structure of the rock mass begin. Dynamic changes in the structure of rocks associated with a change in their stress state, respectively, cause changes in time in the magnitude of radon exhalation [4].

Experiments carried out at the Severouralsky bauxite mine (SUBM) in mines at depths of 300 to 600 m showed that dynamic changes in the stress state of the rock mass cause changes in time in the magnitude of radon exhalation. Moreover, depending on the distance from the observation point to the epicenter of the future seismic event, these changes have a different character.

In the immediate vicinity of the epicenter of the future rock burst, the emission of radon from the rock mass decreases. A noticeable decrease in the radon content preceding a rock burst can begin 15-20 hours before the moment of a rock burst and is observed within a radius of up to 100 m from the coordinates of the future epicenter; therefore, the zone of dynamic reduction of radon emission will be conventionally called the compression zone or the "near" zone.

At a distance of more than 500 m from the future epicenter of the rock burst, the change in the radon concentration in the observation well is different. The rock burst is preceded not by a decrease, but by a sharp increase (by 8-10 times) in the radon content in the observation borehole, and the rock burst follows after the passage of the maximum radon concentration in time. This observation area has been called the stretch zone or "far" zone. Accordingly, there is also a certain intermediate zone (approximately from 100 to 500 m), in which there are practically no changes in the radon concentration in the observation well.

Thus, the phenomenon of spatial zoning of radon emission was discovered depending on the distance to the future epicenter of the seismic event. At the same time, spatial changes in the dynamics of radon emission are clearly nonlinear.

In 1976-1985, the US Geological Survey conducted a unique experiment in Central California to register the release of radon from a rock mass. Registration was carried out at 60 observation points located along the earth's crustal faults known for their seismicity: San Andreas, Hayward, Calaveras (Fig. 1). The availability of a large amount of data on the study area along the San Andreas fault made it possible to build maps of the retrospective (studied after the event) dynamic changes in radon concentration before a seismic event.

When constructing these maps, the following principle was used. For each observation station, the dynamics of changes in radon concentration before a seismic event was determined: a decrease, an increase, or an indefinite change; observation stations with one feature were combined into one zone, and between stations with different features, the border of zones was drawn at distances equal to half the distance between these stations. Then, stations were marked on the map, within which this seismic event was recorded, and only then the epicenter of this earthquake was plotted on the map.

As an example, let us consider the maps of dynamic changes in radon concentration (Fig. 2), which were constructed for the main seismic events of these years. As can be seen from the graphs in Fig. 2, at stations 42, 44, 45, 46, 47, 49, there is a tendency towards a decrease in radon emission from the massif. The indicated trend is distorted at certain time intervals by a sharp increase in concentration, which is associated with local earthquakes with a magnitude less than 3. Due to their low energy, such seismic events, as a rule, are not included in the catalogs, but they are of significant importance in the analysis of the earthquake preparation process. The considered behavior of radon indicates (by analogy with the results obtained in deep mines) the presence of compression in the zone of the location of the indicated observation points. The radius of this zone is approximately 28-30 km.

The behavior of the radon concentration curve outside the specified zone is significantly different. In some zones, there is a tendency to an increase in the concentration of radon, which is associated (by analogy with the results obtained in deep mines) with the presence of tensile forces, in others it is impossible to note any characteristic changes. Interestingly, only one compression zone is observed, located near the epicenter of the future earthquake, and several extension zones far from the epicenter. This is probably due to the alternation of loading and unloading zones at the top of the array.

It is interesting to consider changes in radon concentration along profiles associated with major tectonic faults. For this purpose, the entire study area, more than 350 km long, was conditionally divided by 40 pickets into equal parts and the spatial-temporal behavior of radon along each of the selected fault profiles was analyzed: San Andreas, Hayward, Calaveras. The results of this analysis are shown in Fig. 3.

From the graphs in Fig. 3 it follows that in the direction southeast of the city of Santa Rose (see Fig. 1) at a distance of 60-100 km along all three profiles there is a zone of anomalous decrease in radon concentration. Based on these results, it is possible to draw a conclusion about a possible earthquake with an epicenter located in this area, which is based on two known facts: 1) a decrease in radon exhalation is associated with an increase in the stress state of the massif (compression of the massif), 2) tectonic earthquakes are observed mainly in zones compression.

Three consecutive earthquakes (01.VIII, 05.VIII and 10.VIII 1979) with magnitudes of 4.0, 5.8 and 4.2, respectively, whose epicenters are located in close proximity to each other, cause a dynamic decrease in radon concentration before the seismic event on a large area (Fig. 4). The insignificant time difference between these events does not affect the radon concentration due to the relatively long exposure time of the track detector recording it. The maximum magnitude of the shock on August 5, 1979 is 5.8, so the area of preparation for the earthquake ("near" zone) is quite large - at least 100 km in length. To the north and south of the designated compression zone, as before, there are zones of alternating unloading [1].

Within the compression zone (region 4 in Fig. 4), a characteristic decrease in radon concentration is observed. Moreover, at points where the energy of local earthquakes is low, the concentration of radon decreases by 5-8 times (stations 39, 10, 12, 15). Outside the compression zone (stations 34 and 21), the behavior of radon is significantly different. If at station 34 there is an increase in the concentration of radon, which is typical for the extension zone, then at station 21 the behavior of radon has no characteristic features (intermediate zone).

Two seismic events (20 and 25 January 1980) occurred almost simultaneously with the epicenters located at almost the same point (Fig. 5). The magnitudes of these events are 5.8 and 5.3, respectively. The dynamic decrease in radon concentration preceding these earthquakes is similar to the previous case and is noted over a large area with a length of at least 100 km and a width of more than 60 km.

In the "far" zone from the epicenter (southeastern part of the San Andreas fault), there is an alternation of zones similar to that described earlier, with changes characteristic of the "far" and intermediate zones of earthquake preparation, which can also be explained by the alternation of zones of loading and unloading of the upper part of the rocks.

3.2 correlation and regression analysis of radiation and meteorological values

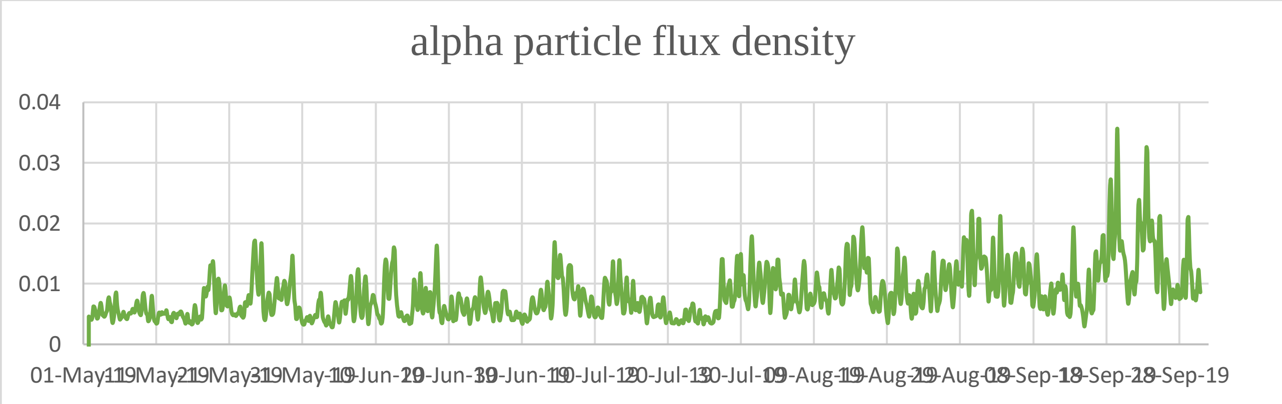


Figure 13 - Dynamics of alpha background during May-October period

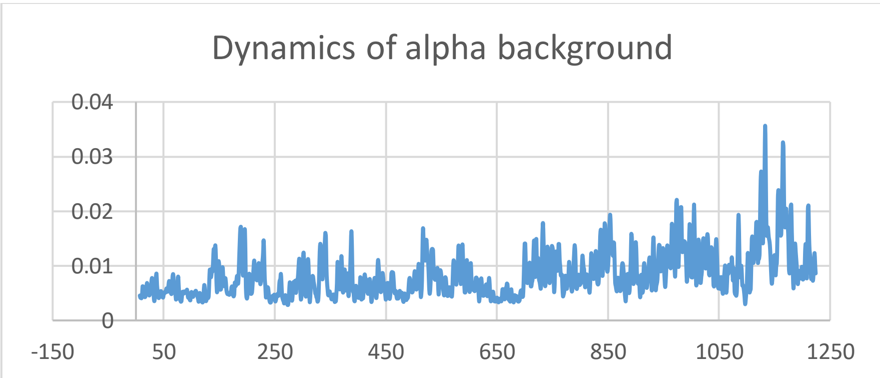


Figure 14 - Dynamics of the alpha background

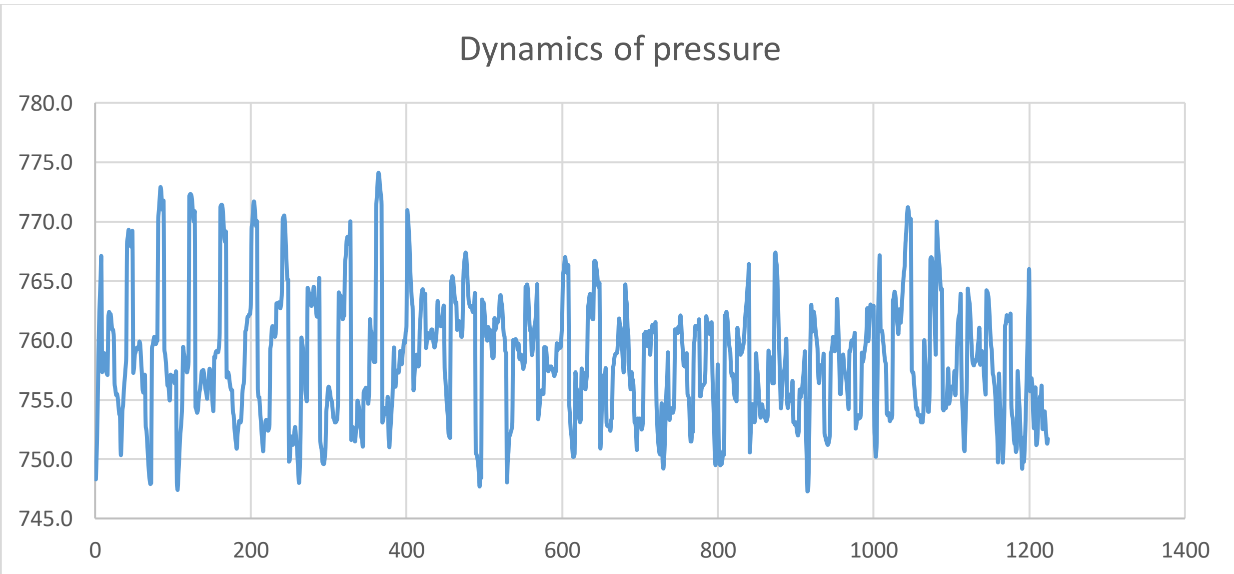


Figure 15 - Dynamics of the pressure

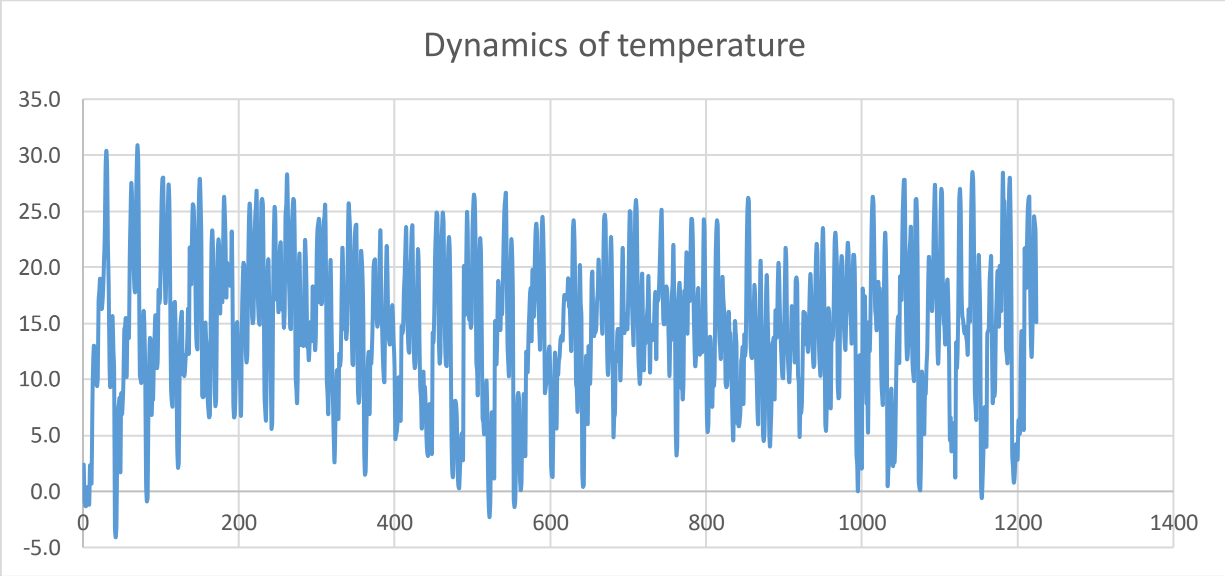


Figure 16 - Dynamics of the temperature

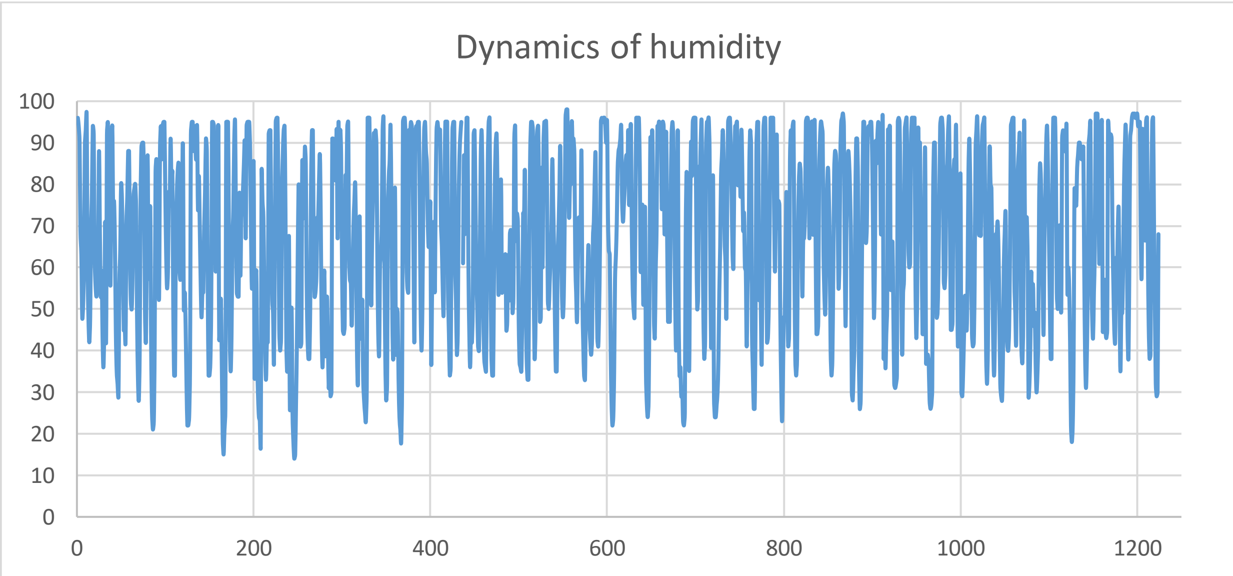


Figure 17 - Dynamics of the humidity

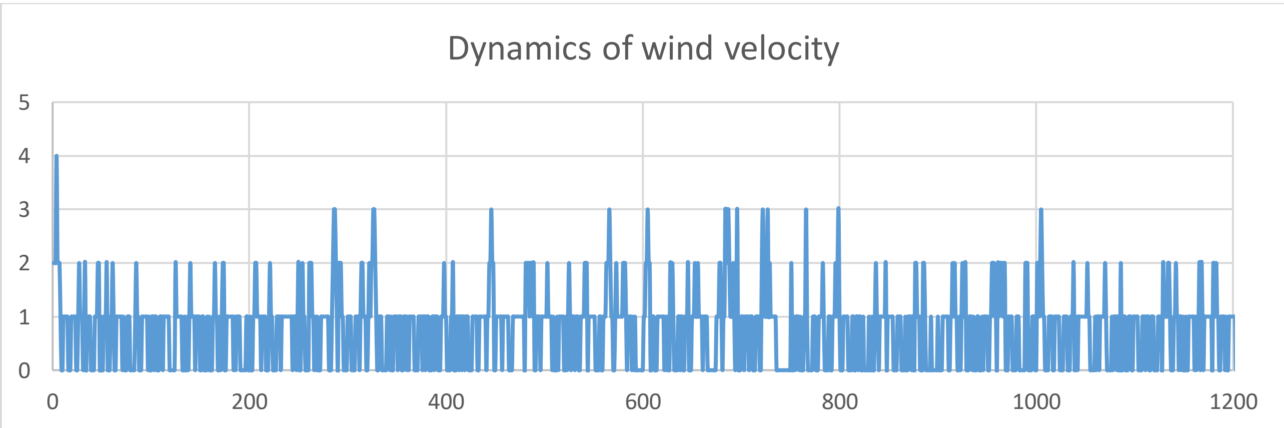


Figure 18 - Dynamics of the wind velocity

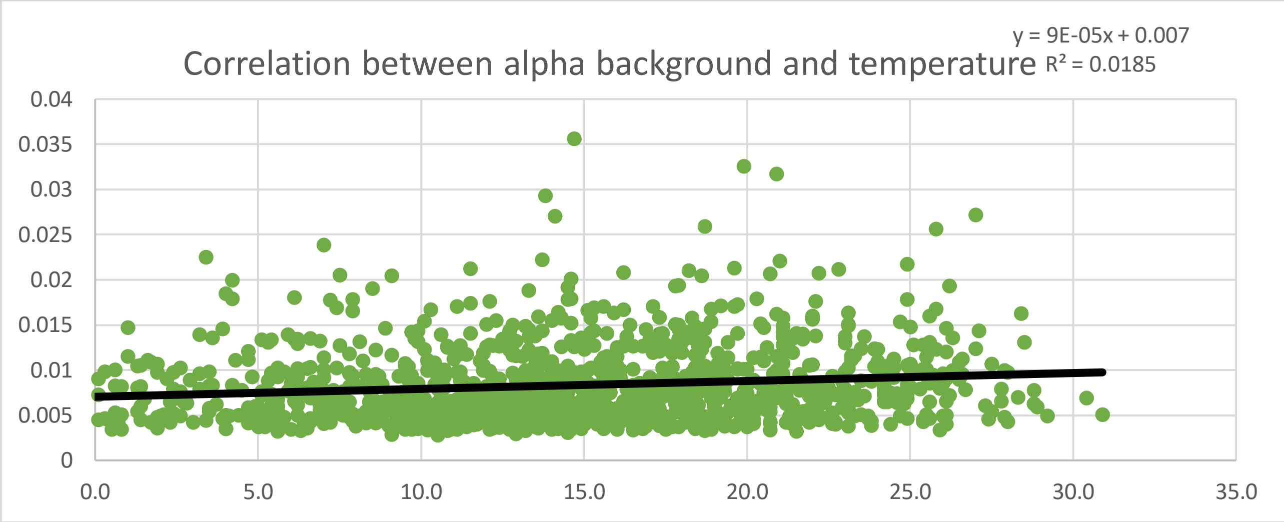


Figure 19 - Correlation between alpha background and temperature

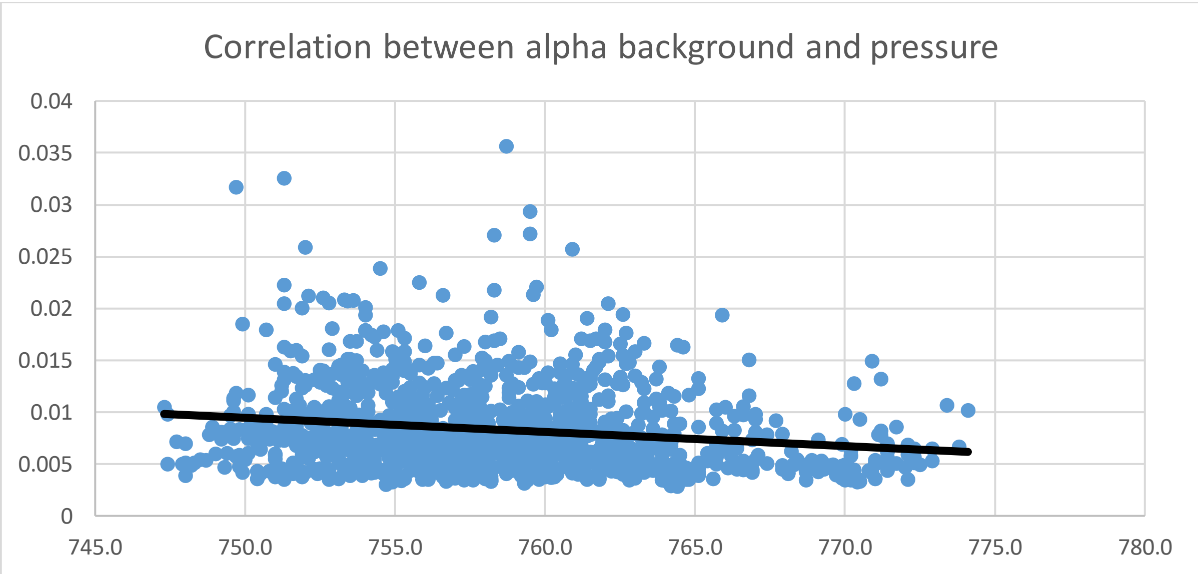


Figure 20 - Correlation between alpha background and pressure

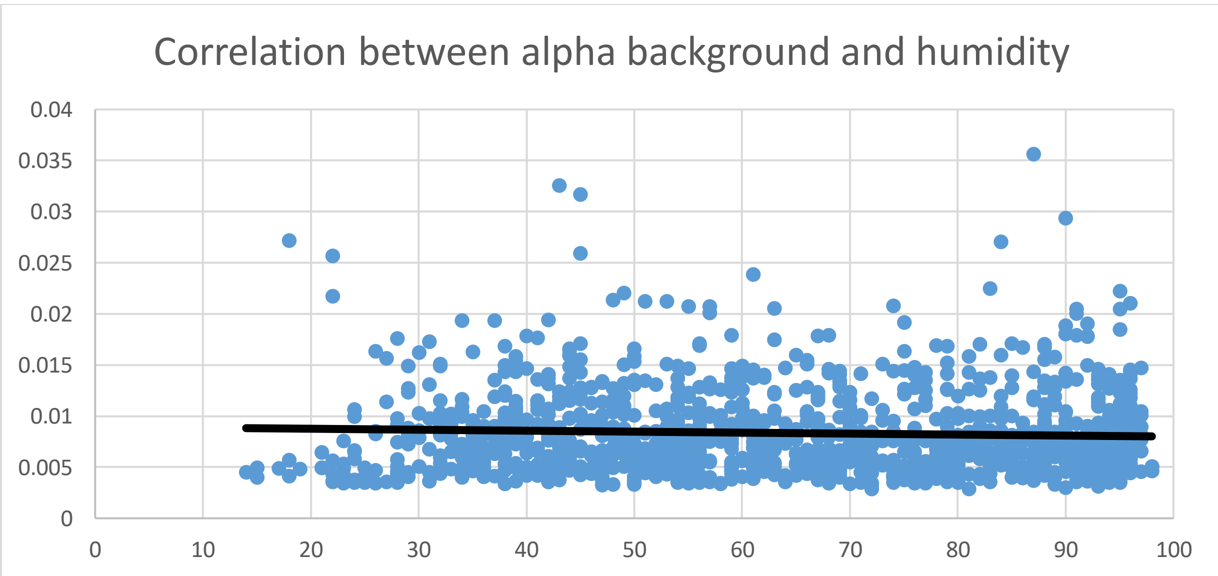


Figure 21 - Correlation between alpha background and humidity

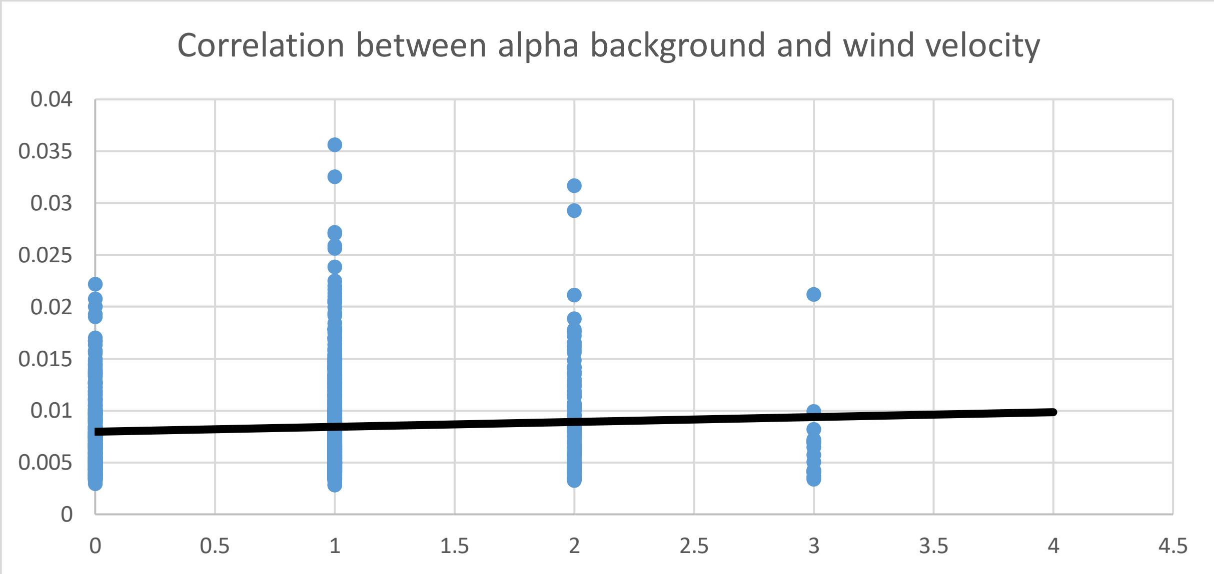


Figure 22 - Correlation between alpha background and wind velocity

3.3 conclusion on chapter 3

The correlation coefficients between the alpha background, temperature, relative humidity, wind speed, taking into account precipitation, turned out to be insignificant (0.14, -0.17 and -0.05, 0.08, respectively).

To sum up, it is difficult to draw conclusions about the relationship between the alpha background and meteorological values.

Chapter 4 Financial management, resource efficiency and resource saving

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

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

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

Planning and preparation of research work.

Budget calculation for research work.

Development of evaluation of commercial potential.

4.1 Competitiveness analysis of technical solutions

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

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

The use of climatic chamber to depict the environmental conditions for different temperature range.

The use of an inorganic scintillation detector and laptop to measure dose rate and count rate at low background gamma radiation.

The use of excel software to analysis the results.

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

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

Gamma background radiation – P_f.

Low radioactive source – P_i.

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

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

$$C = \sum W_i \cdot P_i,$$

(4.1)

C - the competitiveness of research or a competitor;

Wi– criterion weight;

Pi – point of i-th criteria.

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

noise immunity;

set of terminals relay protection;

reliability of relay protection;

smart interface quality;

energy efficiency;

ease of operation;

ability to connect to PC;

estimated lifetime;

safety;

etc.

Table 4.1 Evaluation map

Evaluation criteria *Example*	Criterion weight	Points		Competitiveness Taking into account weight coefficients	
		P_{f1}	P_i	C_f	C_i
1	2	3	4	7	8

Technical criteria for evaluating resource efficiency					
1. Energy efficiency	0.1	4	3	0.4	0.3
2. Reliability	0.2	5	4	1	0.8
3. Safety	0.2	5	4	1	0.8
4. Functional capacity	0.1	5	5	0.5	0.5
Economic criteria for performance evaluation					
1. Development cost	0.1	5	4	0.5	0.4
2. Market penetration rate	0.1	3	4	0.3	0.4
3. Expected lifecycle	0.2	5	4	1	0.8
Total	1	32	28	4.7	4.0

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

4.2 SWOT analysis

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

Table 4.2 SWOT analysis

	Strengths: S1. Low cost. S2. Simplicity of method. S3. Reliability of results obtained. S4.Small relative error for both the dose rate and the count rate. S4. Very safe. S5. Very important factor for all radiation detectors.	**Weaknesses:** W1. Taking measurement and analyzing takes lots of time. W2. Difficulty in regulating the climatic chamber to get the actual temperature. W3. Need to know how to operate the detector and climatic chamber technically. W4. Software sometimes take long to open.
Opportunities: O1.Data can be used to calculate dose rate for low background radiation in BDKG -03 scintillation detector. O2. Research institute could use the method to find the influence of ambient temperature on gamma background	**Strategy which based on strengths and opportunities:** 1. Obtained a method, which can be used to calibrate dose rate in radiation detectors.	**Strategy which based on weaknesses and opportunities:** Regulating of climatic chamber to attain the actual temperature for measurement.

radiation of any radiation detector used outdoor. O3. Researchers can use the method can be used to estimate the algorithm for calculating dose rate under the influence of different temperature range.		
Threats: T1. Lack of financial support in purchasing of equipment. T2. Lack of demand since it is needed only after development of a radiation detector. T3. Need of a climatic chamber to depict the environmental weather conditions.	**Strategy which based on strengths and threats:** Finding another equipment that can replace the climatic chamber to depict the environmental condition accurately.	**Strategy which based on weaknesses and threats:** Not being able to complete project due to lack of financial support and lack of climatic chamber.

4.3 Project Initiation

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

4.3.1 Objectives and Outcomes of Project

Table 4.4 Purpose and results of the project

Purpose of project:	To investigate the effect of ambient temperature on the readings of low gamma background radiation and to obtain a temperature correction factor that can be used to calculate the results of dose rate for low gamma background radiation obtained from scintillation detector (BDKG-03).
Expected results of the project:	The factory's temperature correction coefficient inside the detector (BDKG – 03) to be incorrect for low gamma background radiation. The factory's algorithm for calculating of dose rate for low background radiation to be incorrect.
Criteria for acceptance of the project result:	Validation of results by using the obtained algorithm for calculating of dose rate to recalculate measurement obtained in Tomsk for different temperatures and getting the same values independent of the temperature range.
Requirements for the project result:	Agreement between the results of project and the results of other authors on similar works.
	Industrial application. The results would help address the stabilization of temperature correction factor in scintillation detectors.
	Technical specification: To be able to measure the correct gamma dose rate at an area, effective stabilization of detectors at any environmental condition especially change in temperature is needed so as not to cause fluctuations in results. This is obtained by following laid down procedures and standard already established for evaluation and performance of radiation detection portal monitors.

4.3.2 Project Participants

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

- Scientific supervisor
- Engineer

Table 4.5 Structure of the project

№	Participant	Role in the project	Functions	Labor time, hours (working days (from table 7) × 6 hours)
1	Scientific Supervisor – A professor and a lecture of the Nuclear Science and Technology department at TPU.	Head of project	Formulating of research topic and giving directions of how to achieve the main aim. Ensuring that all task pertaining to the main objectives are done on time. Verification of results obtained.	48×6 = 288
2	Engineer – A student of the Nuclear Science and Technology department at TPU.	Executor	Performing of task and researching of literature review. Collecting of data and analysing of results.	82×6 = 492

4.3.3 Project limitations and Assumptions

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

Table 4.6 Project limitations

Factors	Limitations / Assumptions
3.1. Project's budget	326530.74
3.1.1. Source of financing	TPU
3.2. Project timeline:	25/05/2020 to 25/05/2021
3.2.1. Date of approval of plan of project	25/05/2021
3.2.2. Completion date	25/05/2021

6.3.4 Project Schedule

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

Table 4.7. Project Schedule

Job title	Duration, working days	Start date	Date of completion	Participants
Development of the technical task	6	1/02/2021	7/02/2021	Scientific Supervisor
Drafting and approval of terms of reference	11	7/02/2021	21/02/2021	Scientific Supervisor
Choosing of a research direction	2	21/02/2021	24/02/2021	Scientific Supervisor, Engineer
Collection and study of literature	24	24/02/2021	24/03/2021	Engineer
Choosing of experimental method	2	24/03/2021	25/03/2021	Scientific Supervisor, Engineer
Choosing of a	2	25/03/2021	26/03/2021	Scientific

place to conduct research				supervisor
Conducting of experiment to collect data of count rate and dose rate of gamma radiation using the BDKG-03 and climatic chamber	3	26/08/2021	29/03/2021	Engineer
Analysis of results obtained	16	29/03/2021	16/04/2021	Engineer, Scientific supervisor
Summary of results	4	16/04/2021	20/04/2021	Scientific Supervisor, Engineer
Checking and assessment of results	4	20/04/2021	23/04/2021	Scientific supervisor, Engineer
Compilation of results for report	7	23/04/2021	2/04/2021	Engineer
Preparation of report	4	2/05/2021	6/05/2021	Engineer
Defence preparation	16	6/05/2021	25/05/2021	Engineer

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

Table 4.8 A Gantt chart

№	Activities	Participants	T_c, days	Duration of the project											
				February			March			April			May		
				1	2	3	1	2	3	1	2	3	1	2	3
1	Development	Scientific	6												

	of the technical task	Supervisor													
2	Drafting and approval of terms of reference	Scientific Supervisor	11												
3	Choosing of a research direction	Scientific Supervisor, Engineer	2												
4	Collection and study of literature	Engineer	24												
5	Choosing of experimental method	Scientific Supervisor, Engineer	2												
6	Choosing of a place to conduct research	Scientific supervisor	2												
7	Conducting of experiment to collect data of count rate and dose rate of gamma radiation using the BDKG-03 and climatic chamber	Engineer	3												
8	Analysis of results obtained	Engineer, Scientific supervisor	16												
9	Summary of results	Scientific Supervisor, Engineer	4												
10	Checking and assessment of results	Scientific supervisor, Engineer	4												
11	Compilation of results for	Engineer	7												

	report														
12	Preparation of report	Engineer	4												
13	Defence preparation	Engineer	16												

Scientific Supervisor Engineer

4.4 Scientific and technical research budget

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

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

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

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

4.4.1 Calculation of material costs

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

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

(4.2)

where

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

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

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

k_T – coefficient taking into account transportation costs.

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

Table 4.9 Material costs

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

4.4.2 Calculation of the depreciation.

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

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

$$A = \frac{С_{перв} * Н_а}{100}$$

(4.3)

A - annual amount of depreciation;

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

$Н_а = \frac{100}{Т_{сл}}$ - rate of depreciation;

$T_{сл}$ - life expectancy.

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

Gamma detector:

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

(4.4)

$$D = \frac{118000}{5\times365} = 64.66\,\frac{\text{rubles}}{\text{day}}$$

(4.5)

Since the equipment was used for 3 days

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

(4.6)

Climatic chamber:

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

(4.7)

$$D = \frac{400000}{10\times365} = 109.589\,\frac{\text{rubles}}{\text{day}}$$

(4.8)

Since the equipment was used for 3 days

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

(4.9)

Table 4.10 Depreciation of special equipment (+software)

№	equipment identification	Quantity of equipment	Total cost of equipment, rub.	Life expectancy, year	Depreciation for the duration of the project, rub.

1.	Scintillation gamma radiation detector (BDKG-03)	1	118000	10	193.97
2.	Climatic chamber	1	400000	10	328.77
3	Laptop	1	30000	-	30000
Total					30522.74

4.4.3 Basic salary

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

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

$$S_b = S_a \cdot T_w ,$$

4.10)

where S_b – basic salary per participant;

T_w – the duration of the work performed by the scientific and technical worker, working days;

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

The average daily salary is calculated by the formula:

$$S_d = \frac{S_m \cdot M}{F_v} ,$$

(4.11)

where,

S_m – monthly salary of a participant, rubles;

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

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

F_v – valid annual fund of working time of scientific and technical personnel (251 days).

Table 4.11 The valid annual fund of working time

Working time indicators	
Calendar number of days	365
The number of non-working days - weekend - holidays	 52 14
Loss of working time - vacation - isolation period - sick absence	48
The valid annual fund of working time	251

Monthly salary is calculated by formula:

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

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

$k_{premium}$ – premium rate;

k_{bonus} – bonus rate;

k_{reg} – regional rate.

Table 4.12 Calculation of the base salaries

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

4.4.4 Additional salary

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

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

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

where,

W_{add} – additional salary, rubles;

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

W_{base} – base salary, rubles.

Table 13. Additional Salary

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

4.4.5 Labor tax

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

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

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

where,

k_b – coefficient of deductions for labor tax.

In accordance with the Federal law of July 24, 2009 No. 212-FL, the amount of insurance contributions is set at 30%. Institutions conducting educational and scientific activities have rate - 27.1%.

Table 4.14 Labor tax

	Project leader	Engineer
Coefficient of deductions	27.1%	
Salary (basic and additional), rubles	94240.60	79974.03
Labor tax, rubles	25444.96	21672.96
Total		47117.92

4.4.6 Overhead costs

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

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

Overhead is calculated according to the formula:

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

where,

kov – overhead rate.

Table 4.15 Overhead

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

4.4.7 Other direct costs

Energy costs for equipment are calculated by the formula:

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

where,

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

P – power of equipment, kW;

F_{eq} – equipment usage time, hours.

Table 4.16 Other direct costs

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

4.4.8 Formation of budget costs

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

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

Table 4.17 Items expenses grouping

Name	Cost, rubles
Material costs	2600.00
Equipment costs	30522.74
Basic salary	158376.94
Additional salary	15837.69
Labor tax	47117.92
Overhead	69685.85
Other direct costs	1566.00
Total planned costs	325707.14

4.5 Evaluation of the comparative effectiveness of the project

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

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

The integral financial measure of development is defined as:

$$I_f^d = \frac{C_i}{C_{max}} \qquad 4.17)$$

where,

I_f^d – integral financial measure of development;

C_i – the cost of the i-th version;

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

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

The integral financial measure of development can be calculated as:

$$I^d{}_f = \frac{C_i}{C_{max}}$$

(4.18)

where,

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

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

$$I^{d}{}_{f} = \frac{325707.14}{400000.00}$$

(4.19)

$$I^{d}{}_{f} = 0.814$$

(4.20)

and

$$I^{a}{}_{f} = \frac{C_i}{C_{max}}$$

(4.21)

$$I^{a}{}_{f} = \frac{400000.00}{400000.00}$$

(4.22)

$$I^{a}{}_{f} = 1$$

(4.23)

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

Since the development has one performance, then I_f^d = 1.

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

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

(4.24)

where,

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

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

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

n – number of comparison parameters.

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

Table 4.18 – Evaluation of the performance of the project

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

$$I^a{}_m = \sum_{i=1}^{n} a_i b_i^a$$

(4.25)

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

(4.26)

$$I^a{}_m = 4.5$$

(4.27)

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

(4.28)

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

(4.29)

$I^p{}_m = 4.2$

(4.30)

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

$$I_e^P = \frac{I_m^P}{I_f^{d,}}, \qquad I_e^a = \frac{I_m^a}{I_f^{a,}} \qquad I_{\text{исп.2}} = \frac{I_{\text{р−исп2}}}{I_{\text{финр}}^{\text{исп.2}}} \quad (4.31)$$

etc

(4.32)

$$I^p{}_e = \frac{I^p{}_m}{I^d{}_f} = \frac{4.5}{0.877} = 5.13 \quad (4.33)$$

$$I^a{}_e = \frac{I^a{}_m}{I^a{}_f} = \frac{4.2}{1} = 4.2 \quad (4.34)$$

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

$$E_c = \frac{I^p_e}{I^a_e} \quad (4.35)$$

.

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

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

Table 4.19 Efficiency of development

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

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

4.6 Conclusion

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

These stages include:

development of a common economic project idea, formation of a project concept;

organization of work on a research project;

identification of possible research alternatives;

research planning;

assessing the commercial potential and prospects of scientific research from the standpoint of resource efficiency and resource saving;

determination of resource (resource saving), financial, budget, social and economic efficiency of the project.

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 123 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

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.

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. To calculate the air exchange rate of a fan in a laboratory with a volume of V = 70 m3 (S = 20 m2, h = 3.5 m), which will circulate air masses in the room, we use the formula

[27]: $$W = V * k, \quad (5.1)$$

where k is the normalized air exchange rate (for laboratories k = 3).

Substituting the data into formula (5.1), we obtain the characteristic of the fan air exchange rate:

$$W = 70 * 3 = 210 \frac{м^3}{ч}$$

Thus, a VARP Alpha 210 × 270 fan with a capacity of 210 m3 / h must be supplied to the classroom.

Also, a central heating system is needed to provide the set temperature level in winter according to [28]. 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 [26-28].

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 room 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 given preference 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 complete illumination of the classroom with a working computer with fluorescent ceiling lamps.

Luminous flux for fluorescent lamps, 56 W:

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

where Ra = 80Lm / W is the minimum color rendering index for a fluorescent lamp.

$$F = 80 \cdot 56 = 4480 \ Lm.$$

The required number of lamps to illuminate the laboratory classroom:

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

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

K - is the conversion factor, 4.5;

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

k - safety factor, 4.5;

S - area of the illuminated room, 121 m2;

z is a correction factor that takes into account uneven illumination, 0.9.

$$N = \frac{300 \cdot 121 \cdot 0{,}9 \cdot 4{,}5}{4{,}5 \cdot 4480 \cdot 0{,}45} = 16{,}2 \text{ pcs.} \qquad (5.3)$$

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 constituent parts of the computer. The norms of harmful permissible levels (VLU) of electromagnetic radiation of computers are established in [32], which are shown in table 21

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 research by scientists, therefore, as far as possible, its effect on the human body should be limited.

Table 21 - 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 Гц - 2 кГц	25 V/m
	In the frequency range 2 kHz - 400 kHz	2,5 V/m
Magnetic flux density	In the frequency range 5 kHz - 2 kHz	250 nT
	In the frequency range 2 kHz - 400 kHz	25 nT

Electrostatic potential of the video monitor screen	500 V

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 subdivided into categories A, B, C, D and D 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 organizing work and compliance with fire safety measures. To prevent a fire, the following fire safety rules must be observed:

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

In a room with electrical equipment, in order to avoid electric shock, it is advisable to use carbon dioxide or dry powder fire extinguishers. These fire extinguishers are designed to extinguish fires of various substances and materials, electrical installations under voltages up to 1000 V, flammable liquids. Chemical and foam extinguishers are not permitted. 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 OP¬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 magnitude of the absorbed radiation dose and on the individual characteristics of the organism. The changes caused can be reversible or irreversible. Any kind 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 normal territory resulting from an accident, natural phenomenon, catastrophe, natural or other disaster that may increase or entail human casualties, damage to human health or the environment, significant material losses and violation of conditions life of people [34]. There are two types of emergencies:

- technogenic;

- natural.

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

A dangerous event includes a sudden and uncontrollable source of energy: a moving object, uncontrollable movement or energy.

Let's consider possible emergencies in the classroom laboratory No. 123 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 for the prevention and elimination of the above emergencies in table 22

Table 22 - 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.	1. Quickly release the victim from the action of the electric current [26];

		2. Limitation of working space. 3. Ensuring the inaccessibility of live parts of the equipment. 4. Timely briefing.	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

Revealed synchronism in the dynamics of the integral values of OA and EEVA of atmospheric radon and PP of alpha radiation on an annual scale.

To sum up, it is difficult to draw conclusions about the relationship between the alpha background and meteorological values. The following research is necessary to determine the dependence between the precipitation and alpha background, and the correlation must be found between the values above in case of low and high precipitation.

- significant correlations between instantaneous values of radon VA and alpha radiation PP only in certain periods of the year lasting from several days to several weeks;

- a significant correlation between the integral (monthly average) values of radon VA (K = 0.57) and radon EEVA (K = 0.71) and PP of alpha radiation.

The correlation coefficients between the alpha background, temperature, relative humidity, wind speed, taking into account precipitation, turned out to be insignificant (0.136, -0.169 and -0.051, 0.076, respectively).

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