TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

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

ВЫПУСКНАЯ КВАЛИФИКАЦИОННАЯ РАБОТА МАГИСТРАНТА

Тема работы
Исследование сезонных трендов в динамике плотности потока радона с поверхности земли

УДК 550.422:546.296:551.51"54"

Обучающийся

Группа	ФИО	Подпись	Дата
0АМ13	Толмачёв Никита Сергеевич		

Руководитель ВКР

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

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

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

По разделу «Социальная ответственность»

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

ДОПУСТИТЬ К ЗАЩИТЕ:

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

Томск – 2023г.

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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
MEP/MPEP Nuclear and radiation safety
Nuclear Fuel Cycle Division

GRADUATE QUALIFICATION WORK OF A MASTER STUDENT

Work theme
Research of seasonal trends in density dynamics radon flow from the soil's surface

UDC 550.422:546.296:551.51"54"

Student

Group	**Full name**	**Signature**	**Date**
0AM13	Tolmachev Nikita Sergeevich		

Scientific supervisor

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

ADVISERS:

Section "Financial Management, Resource Efficiency and Resource Saving"

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

По разделу «Социальная ответственность»

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

ADMITTED TO DEFENSE:

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

Tomsk – 2023.

TOMSK POLYTECHNIC UNIVERSITY
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Отделение школы (НОЦ) Отделение ядерного топливного цикла

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

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

Обучающийся:

Группа	ФИО
0АМ13	Толмачёв Никита Сергеевич

Тема работы:

Исследование сезонных трендов в динамике плотности потока радона с поверхности земли	
Утверждена приказом директора (дата, номер)	*33-46/с*

Срок сдачи обучающимся выполненной работы:	25.05.2023

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

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

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

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

Задание выдал руководитель / консультант (при наличии):

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

Задание принял к исполнению обучающийся:

Группа	ФИО	Подпись	Дата
0АМ13	Толмачёв Никита Сергеевич		

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
Nuclear Fuel Cycle Division

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

TASK
for graduation qualification work

Student:

Group	Full name
0AM13	Tolmachev Nikita Sergeevich

Тема работы:

Research of seasonal trends in density dynamics radon flow from the soil's surface	
Approved by the order of the director (date, number)	*33-46/c*

Deadline for students to submit completed work:	25.05.2023

TECHNICAL TASK:

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

Consultants for the sections of the final qualifying work *(indicating sections)*	
Chapter	**Consultant**
Social responsibility	Perederin Yuri Vladimirovich
Financial management, resource efficiency and resource saving	Spitsina Lyubov Yurievna

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

The task was issued by the manager

Position	Full name	Academic degree	Sign	Date
Professor NFCD	Yakovleva V.S.	Doctor of technical sciences		

The task was accepted by the student:

Group	Full name	Sign	Date
0AM13	Tolmachev Nikita Sergeevich		

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

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Обучающийся:

Группа	ФИО
0АМ13	Толмачёв Никита Сергеевич

Тема работы:

Исследование сезонных трендов в динамике плотности потока радона с поверхности земли

Срок сдачи обучающимся выполненной работы:	25.05.2023

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
10.04.2023	*Обзор литературных источников*	10
24.04.2023	*Методы измерения плотности потока радона*	15
25.04.2023	*Определения зависимости динамики плотности потока радона от климатических условий*	20
26.04.2023	*Создание модели плотности потока радона от текущей температуры атмосферы*	20
03.05.2023	*Анализ полученных результатов*	15
04.05.2023	*Финансовая ответственность*	10
05.05.2023	*Социальная ответственность*	10

СОСТАВИЛ:

Руководитель ВКР

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

СОГЛАСОВАНО:

Руководитель ООП/ОПОП

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

Обучающийся

Группа	ФИО	Подпись	Дата
0АМ13	Толмачёв Никита Сергеевич		

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

CALENDAR RATING PLAN
completion of the final qualifying work

Student:

Группа	ФИО
0AM13	Tolmachev Nikita Sergeevich

Work theme:

Research of seasonal trends in density dynamics radon flow from the soil's surface

The deadline for the student's completed work:	25.05.2023

Control date	Section name	Maximum score of a section (module)
10.04.2023	*Literature review*	10
24.04.2023	*Methods for measuring radon flux density*	15
25.04.2023	*Determining the dependence of the dynamics of the radon flux density on climatic conditions*	20
26.04.2023	*Creating a model of radon flux density from the current temperature of the atmosphere*	20
03.05.2023	*Analysis of the results*	15
04.05.2023	*Financial responsibility*	10
05.05.2023	*Social responsibility*	10

COMPOSED:
HEAD OF FQW

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

AGREED:
Head of BEP

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

Student

Группа	ФИО	Подпись	Дата
0AM13	Tolmachev Nikita Sergeevich		

PLANNED RESULTS OF DEVELOPMENT OF MEP/MPEP

Code competencies	Name of competence
Universal competencies	
UK(U)-1	Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy
UK(U)-2	Able to manage a project at all stages of its life cycle
UK(U)-3	Able to organize and manage the work of the team, developing a team strategy to achieve the goal
UK(U)-4	Able to apply modern communication technologies, including in foreign language(s), for academic and professional interaction
UK(U)-5	Able to analyze and take into account the diversity of cultures in the process of intercultural interaction
UK(U)-6	Able to determine and implement the priorities of their own activities and ways to improve it based on self-assessment
General professional competencies	
OPK(U)-1	Able to formulate goals and objectives of the study, choose evaluation criteria, identify priorities for solving problems
OPK(U)-2	Able to apply modern research methods, evaluate and present the results of the work performed
OPK(U)-3	Able to draw up the results of research activities in the form of articles, reports, scientific reports and presentations using computer layout systems and office software packages
Professional competencies	
PK(U)-1	Ability to create theoretical and mathematical models in the field of nuclear physics and technology
PK(U)-2	Willingness to apply methods of research and calculation of processes occurring in modern physical installations and devices in the field of nuclear physics and technology
PC(U)-3.	Willingness to develop practical recommendations for the use of research results
PC(U)-4.	Ability to assess risk and determine safety measures for new installations and technologies, compose and analyze scenarios of potential accidents, develop methods to reduce the risk of their occurrence
PC(U)-5.	Ability to analyze technical and computational-theoretical developments, to take into account their compliance with the requirements of the laws of the Russian Federation in the field of nuclear and radiation safety, atomic energy
PC(U)-6.	The ability to objectively evaluate the proposed solution or project in relation to the modern world level, prepare an expert opinion
PC(U)-7.	The ability to formulate terms of reference, use information technology and application packages in the design and calculation of physical installations, use knowledge of methods for analyzing environmental and economic efficiency in design
PK(U)-8	Willingness to apply methods of optimization, analysis of options, search for solutions to multi-criteria problems, accounting for uncertainties in design
PC(U)-9.	Ability to solve problems in the field of development of science, engineering and technology, taking into account legal regulation in the field of intellectual property

PC(U)-10.	Readiness for teaching activities in the main educational programs of higher education and additional professional education (APE)
PK(U)-11.	Ability to design and economic justification of an innovative project, content, structure and procedure for its development

ABSTRACT

The final qualifying work consists of 97 pages, 12 figures, 29 tables, 24 sources, 2 adj.

Key words: specific activity, volumetric activity of radon in soil air, advection rate, porosity, radon flux density.

The object of research is the dynamics of the radon flux density in the surface atmosphere.

The purpose of the work is to study the features of the dynamics of the density of the radon flux from the soil into the surface atmosphere, the search for patterns and influencing factors.

In the course of the study, the analysis of the radon flux density in the surface atmosphere was carried out, the experimental data were obtained by measurements using a storage chamber.

In the Wolfram Mathematica software environment, the radon flux density in the surface atmosphere was simulated based on the diffusion-advective equation of radon transfer in a porous medium.

As a result of the study, the values of the pore activity of radon in the soil air were obtained for different geological structures of the territory and the physical and geological characteristics of soils, and the values of the radon flux density in the surface atmosphere were calculated. To describe the dynamics of the radon flux density, a sinusoidal function of the current atmospheric temperature was selected.

Economic efficiency of work: high.

Scope: dosimetric control.

Significance: high.

CONTENTS

INTRODUCTION

The release of soil gases into the atmosphere, especially radioactive gases, still remains an important problem in the study of relationships between soil and atmosphere. Information about the release of radon from the soil into the surface atmosphere has been of interest for more than half a century in solving problems of geophysics and meteorology. And since the end of the 90s of the last century, it was the value of the radon flux density that began to attract the attention of researchers. This is mainly due to the use of the radon flux density value to assess the potential radon hazard of the territory.

Today, radon flux density values are studied in many fields such as radio ecology - measuring the potential hazards of areas and buildings and then determining the fire risk of the public, electricity, seismology - predicting earthquakes, atmospheric physics and climatology - examining the effect. radon air The influence of objects near the surface.

By now, it is known that the radon flux density experiences seasonal variations associated with the influence of the seasons of the year and weather conditions.

In this regard, a reliable determination of the radon hazard of the territory under construction is possible only with long-term measurements of the radon flux density or previously known patterns in seasonal dynamics for a given region.

1 LITERATURE REVIEW

1.1 History of the discovery of radon

Radon is a radioactive gas, colorless, odorless, the heaviest element of the zero group of the periodic system, the only noble gas that does not have stable and long-lived isotopes. For the ability to luminesce in a condensed state, radon was supposed to be called niton (from Latin nitens - shining).

In 1900, F. Dorn showed that this phenomenon is caused by biological products released from radium (electrolyte). Research on Ra-226 radiation has shown that it behaves similarly to xenon and other natural gases. The average atomic mass of radiation is 222. All these determined the place of the new element called radon in the season [1, 2].

Radon has been discovered many times, and unlike other similar stories, each new discovery doesn't affect the previous one, it just adds something new.

1.2 Origin of radon isotopes

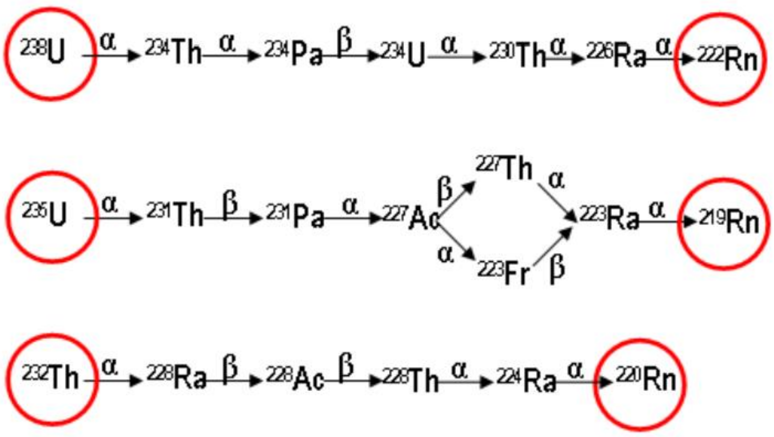
Thoron - 220

The emanation of thorium (thoron), discovered in 1900 by E. Rutherford and R. Owens [1, 2], is a member of another natural radioactive family, the thorium family. This is an isotope with a mass number of 220 and a half-life $\boldsymbol{T_{1/2}}$=54.5 seconds. Pure thoron is a gas with a density of 9.816 kg/m3 (under normal conditions).

Actinion-219

Discovered in 1903 by Andre-Louis Debierne (French physicist and chemist) and F. Gisel [1, 2], is a decay product of Ra-226. This is the third natural isotope of radon, and of the natural is the shortest-lived, with a half-life $T_{1/2}$= 3.92 seconds and a mass number of 219. In its pure form under normal conditions, it is a gas with a density of 9.771 kg / m³.

Radon is the longest-lived radioactive element with 19 known isotopic forms, atomic number 86, and mass number 204 to 224 [1]. They also collect the radiation of the entire galaxy under the name "Radon" because they are both positive and come from isotopes of radium. The name "radon" refers to the position of the isotope group below the xenon at the specified time. Radon does not have any stable isotopes. The most stable of all of them is Rn-222 ($T_{1/2}$= 3.8235 days), which is part of the natural radioactive family of uranium 238U ($T_{1/2}$= 4.51109 years) and is a direct decay product of radium Ra-226 . Most of the times the name "radon" refers to this particular isotope.



Pic.1.2.1 Series of natural radioactive families before the formation of radon

The thorium family Th-232 $T_{1/2}$ = 1.41 1010 years includes Rn-220 ($T_{1/2}$= 55.6 s), which is called thoron (Tn). The family of uranium U-235 ($T_{1/2}$=7.13108 years) includes Rn-219 ($T_{1/2}$= 3.96 s), it is called actinon (An). The final decay product for all three families is one of the stable isotopes of lead with atomic number 82, for the uranium family - Pb-206, for the thorium family - Pb-208, and for the actinium family - Pb-207.

Like helium, almost all radon gas diffuses deep into the earth and water. A r ough estimate contains 115 tonnes of radon up to 1.6 km deep in the upper reaches, with about 4 kg less radon in the centre. Radon is found in the heart of the earth, in the soil, in the seas and oceans, in the air, in natural gas, in gasoline, in the human body and in animals. Radon is only found in the air and ice of Antarctica.

1.3 Physical properties of radon isotopes

Radon is a colorless monatomic gas that can be easily liquefied into a colorless phosphorous liquid with a density of about 5 g/cm^3. Radon is 55 times heavier than helium and 7.6 times heavier than air.

One liter of this gas weights almost 10 grams of mass. Radon is two times heavier than xenon and four times heavier than krypton and is readily soluble in water.

When showing gas in a container filled with equal amounts of water and air, at room temperature it can be seen that one-third of the radon is in water and three-quarters in air; At 0 ° C - half of the radon is dissolved. in the water. Even at 100°C, water contains about 10% radon. The solubility of gases decreases in the presence of electrolytes. This is one of the reasons why the radon content in seawater is lower than in rivers [2].

Table 1.3.1 Physical properties of radon

Boiling temperature	- 62 °C
Melting temperature	- 71 °C
The density of radon in the gaseous state under normal conditions	9,727 kg/m^3
Atom radius	214 pm
Ionization energy	10,74 eV

1.4 Release of radon into the surface atmosphere

Radon is released (exhaled) from the soil by two mechanisms: through circulation and diffusion [1-4]. First, radon, as carbon monoxide, is formed in rocks during radioactive decay, it is all the time present in mountains, and its concentration decreases due to decay and migration of air. and is constantly replaced with new generations of these oils. Therefore, the average radon level in the array is always constant and is determined by the uranium (radium) concentration in the array. Second, the migration of radon in the mountains 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 fracture. In the presence of cracks (permeability) and upward airflow in the upper part of the plot, convective radon will reach a depth of 200 m. For example, radon should be recorded at a decay rate of 30-50 per cubic meter per second. Radon activity is 30-50 Bq/m^3.

This can tell that each cubic meter contains (0.2-0.3)·10^7 radon atoms, or about 10-16% of it, in the gas. [1-4].

1.5 Radon registration methods

Until now, there were many different physical and physiological methods to collect radon activity. Like other radioactive substances, radon can be detected by dosimetry equipment due to the decay of isotopes and subsequent materials. In terms of area, they often refer to the so-called volumetric activity (VA) - the ratio of the activity of the material to the volume of the material, measured in becquerels per cubic meter (Bq/m^3)[].

There are many ways to collect radon directly or from its decay products. One method for direct recording is the electrostatic deposition of radon and its decay products (DCP) on the surface of a semiconductor alpha decay detector following the energy difference between particles. Modern radon monitors are based on the working principle of general radon monitoring "AlphaGuard" developed by Genitron Instruments GmbH from Germany, radon monitor from SARAD GmbH (Germany), PPA-01M-01 from Russia, PAA-20P2 "Poisk" and others . Air measurement can be done using an active breast pump or where the chamber inlet is usually sealed with a membrane containing only radon to make the product optional. The second method is better because it achieves the final result faster than using passive devices or carbon adsorbers that can be used for recording. [1-4].

1.5.1 Registration of radon in water.

It is worth mentioning the method of detecting radon in water. Direct measurements are often difficult due to the environment, so other methods are required. Selected water samples are placed in a gas-filled container in a sealed box containing a radon meter. The air in the circuit replaces the oil dissolved in the water and after a while the radon concentration in the air reaches equilibrium with the water in the system. Then, by measuring the radon concentration in the body and knowing the volume of water and air, it is not easy to calculate the initial radon concentration in a water sample.

1.5.2 Geological emanation survey

Emanation survey is a field radiometric method based on the study of the spatial distribution of concentrations of free emanation of radioactive free emanation of radioactive gases of radon Rn^{222} and thoron Tn^{220} in the subsurface soil layer.

Emanation survey is carried out in order to trace the zones of tectonic disturbances hidden under sediments, predict the development of landslide processes, identify areas of development of deformations of the earth's surface during the formation of a displacement trough above the worked-out mine workings.

The prerequisite for the use of electrical surveys in engineering processes and geophysical surveys in engineering and disaster surveys is the presence of stress areas in the State stone due to mining activities.

The local stress and depression state causes physical phenomena such as sound, magnetism and electricity to occur in the block, resulting in an increase in the earth's surface electric power and the earth's electric power potential. big stone.

The radioactive gas anomalies near the Earth's surface are believed to result from dispersal of the rock mass through cracks created by tectonic activity and anthropogenic impact. However, the amount of radon and especially toron in a parcel is not important; It is measured in meters for radon and in centimeters for thoron.

However, in the theoretical and practical studies, especially when combined with other geological and geophysical researches, the wide possibilities of this method emerge.

Along with other geophysical methods in nature, radiography can be used to identify cavities and freezes in geological sections associated with natural and anthropogenic effects (karst, old mine shafts), and standard layers are used to study the nature and formation of mountains.

1.6 Chapter Conclusions

As a result of the work in this section, different scientific articles and also different studies on the subject of the work were investigated. The history of the discovery of radon and its isotopes was studied, as well as the gradual discovery of ways to use this gas.

The characteristics of radon were studied, as well as its origin in nature.

Various methods of registering radon both in air and in water were studied, in particular, the method of geological emanation survey was studied.

2. METHOD FOR MEASURING RADON FLUX DENSITY

2.1. Storage chamber method

There are many methods and tools used to measure the flux density of radon on the earth's surface. In this article, we discuss a method that uses a storage chamber, which is a "cover" installed on the ground surface in this study, from radon accumulating in a unit of measurement, and the way radon accumulates in activated carbon. Short-term products that then measure the effectiveness of radon through Gamma or beta radiation. The meaning of the method is that the flow of radon in the soil increases the radon concentration in the dam subject to the study area. Based on the geometric size of the accumulator, the exposure time and the concentration of radon, the radon flow rate of the soil can be estimated. The specific use of the deposition and recalculation method of radon flux density varies from author to author.

Experimental studies have shown that the concentration in the storage chamber changes linearly as the equilibrium value is reached. This problem is a result of the volume of the airtight chamber of radon egress from the soil surface. Ignoring the nonlinearity of the radon flow into the storage room will lead to an underestimation of the radon flux density. To measure radon flux density as a measure of indoor radon concentration, techniques for measuring and estimating the kinetics of radon accumulation are used in practice at home and abroad.

Portable radon radiometer RRA-01M-03 is designed for measuring volumetric activity of ^{222}Rn and the number of decays of ^{216}Po (ThA) in air. The radiometer simultaneously measures temperature, ambient relative humidity and atmospheric pressure.

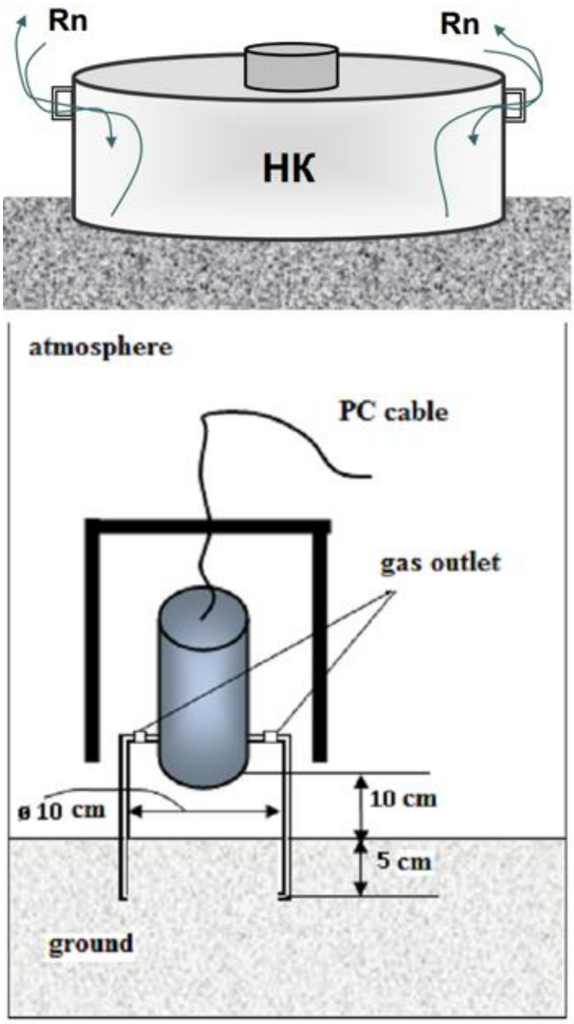
Together with the sampling device (set) POU-04, the radiometer can measure the volumetric activity of radon in water, subsoil air, as well as the radon's flux density from the soil surface.

The principle of operation is that the analyzed air with the help of a microblower at a speed of 0.8 l/min enters the measurement chamber with a volume of 1.6 l, which is a plastic hollow cylinder, hermetically sealed with flanges on both sides, through an aerosol filter through an aerosol filter. An aerosol filter is placed on the front (inlet) flange, and a semiconductor detector is installed in the center of the rear (outlet) flange. The aerosol filter is designed to clean the controlled air from the dispersed phase of aerosols, including the daughter products of the decay of thoron-220 and radon-222. When sampling air in conditions of high humidity, at the inlet of the measuring chamber, under the decorative cover, a filter-drier is provided, which selectively absorbs water vapor from the analyzed air.

The measurement of radon 222 and thoron 220 volume is based on the electrostatic precipitation of positive ions Po-218 (RaA) and Po-216 (ThA) from selected air samples to the surface of electronic equipment using good energy utilization for electrical equipment. electrodes of the potential chamber. Radon 222 activity was determined separately from the number of alpha particles recorded from RaA decay by alpha spectroscopy. The electrical pulse produced when an alpha particle strikes the detector is amplified by a value-sensitive preamplifier and fed to the input of an amplitude-to-digital converter for further processing by a microprocessor. After selecting the amplitude, pulses corresponding to alpha particles from RaA are recorded by the microprocessor counter and then displayed on the liquid crystal matrix according to relative (number of recorded data out of alpha) and true (radon 222 volume activity). Due to the short half-life of RaA, the results of RaA at the measurement site will not affect the results of subsequent measurements.

When performing measurements, the following measuring instruments and auxiliary devices were used:

1. Alpha radiation detection unit BDPA-01;
2. sampling device POU (blower), air pumping speed 1,0±0,3 l/min;
3. accumulative chamber, free volume 0.5 l, sampling area 0,0110 $м^2$;
4. air sampler, volume 0,83 л;
5. connecting tubes PM 42 according to TU 64-2-286-79, tube channeldiameter 4 mm.



Pic. 2.1. Scheme for measuring the radon flux density.

Table 2.1. Characteristics of the detection unit.

Detector	ZnS(Ag), ø60 мм.
Alpha particle flux density measurement range, part./(min•cm^2)	0,1 - 10^5
Measurement range of fluence of alpha particles ^{239}Pu, см$^{-2}$	1 - 3•10^6
Surface activity measurement range ^{239}Pu, Bq•cm^{-2}	3,4•10^{-3} - 3•10^3
Energy range of detected alpha particles, MeV	3 - 7
Basic measurement error, %	
- in range 0,1 - 1 part./(min•cm^2)	±50
- in range 1 – 10^5 part./(min•cm^2)	±20
Sensitivity of ^{239}Pu, imp•c^{-1}/(part/(min•cm^2))	0,15
Operating temperature range, ^{o}C	-30 - +50
Relative humidity at temperature 35^{o}C, %	not higher than 98

2.2. Calibration and processing of measurement results

The following formula was used to determine the radon flux density:

$$RFD = (Q - Q_{\Phi})\frac{V_2+V_3}{T \cdot S_2}$$

where:

Q – average volumetric activity of radon, $Bq \cdot m^{-3}$;

$Q_{Ф}$ – average background volume activity of radon, $Bq \cdot m^{-3}$;

V_1 – sample volume in the sampler, l;

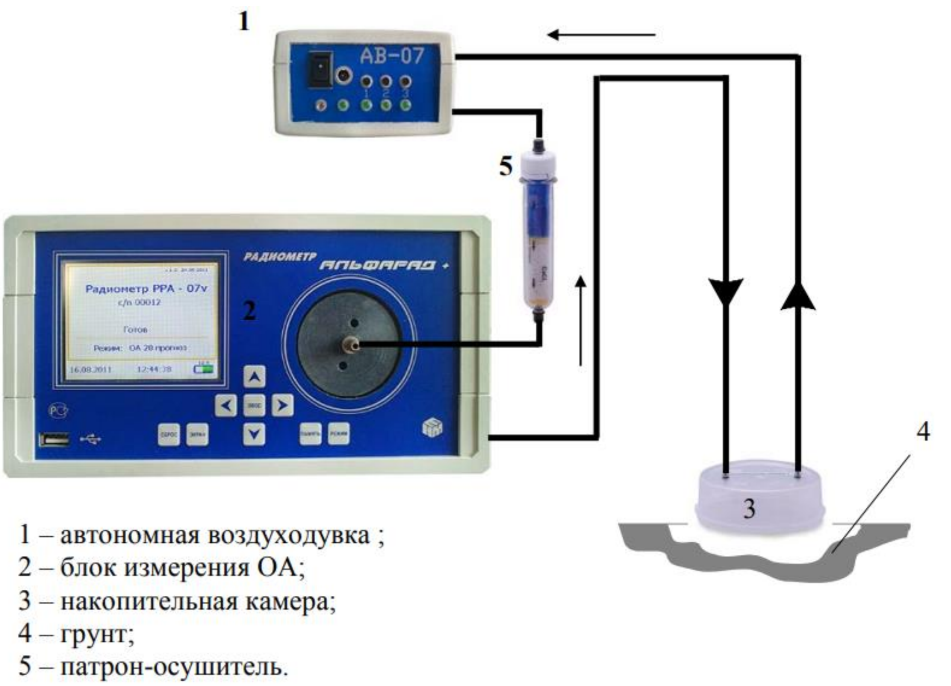
V_2 – measuring chamber volume , л;

V_3 – free volume of storage chamber and connecting tubes, $V_3 = 0.36$ l,

T – blower running time , T=300 c;

S_1 – radon collection area, S_1=0.014 $м^2$.

For calibration and conversion of values from pulses/s to mBq/m^3 c Alfarad radiometer was used:



Pic. 2.2.1. Scheme of measurement using the alpharad radiometer. To find the conversion factor k_α the following formula was used

$$ППР = N_{a(i)} k_\alpha$$

where $N_{a(i)}$- the number of pulses per second.

3. SIMULATION RESULTS AND EXPERIMENTAL DATA

3.1 Diffusion transport model

The impact of radon issues continues in many researches and applications. The analysis and explanation of the transport processes and processes of radon in various environments and the factors determining the spatio-temporal dynamics of the radon field have not been fully studied.

Diffusion-advection (diffusion-convection) model with simple solutions for many parameters and assumptions (stationary data, homogeneous media, etc.) is widely used in some special cases to simulate radon transport.

The term "advection" is often used abroad to denote the transitions of radon due to the influence of external forces, especially pressure gradients, but at the same time, convection, leakage and other processes occur during movement, only molecular diffusion. In Russia, the authors of these studies introduced the term "convection" to denote the movement of radon under the influence of the same external influence; this laid the groundwork for scientists who have been working on radon for some time, both in Russia and abroad. additionally. still valid now. However, to avoid confusion with the radon transfer process referred to by the word "convection", the term "advection" is used in this article. [4-8].

Modeling radon in the geological environment as close as possible to the real situation is a difficult task, because the geological environment is heterogeneous with different physical and geological properties. Solutions are not possible when considering non-uniform media, especially when product balance is not normal.

Usually, there is only one radon exchange during modeling - diffusion. Our analysis within the framework of the

Diffusion-convection model (see Diffusion-Convection Model) shows that only the diffusion process can be determined in calculating the radon change at a convection rate of cm/s. However, it is necessary to compensate for displacement at higher convective levels; otherwise this can lead to large errors in estimating, for example, the radon flux density at the Earth's surface.

3.2 Diffusion-convective model of radon transport

In this study, the Radon diffusion-convective transport equation in the semi-uniform approach has been shown to be useful. It can be obtained from the standard method by the equation for a radon particle ΔV in a small object for a short time Δt. This equation takes into account the generation, entry and exit of radon during the decay of radium in ΔV (226Ra), entry and exit by diffusion and convection, and loss of radon by radioactive decay. Since ΔV and Δt are zero, the equation takes the next form:

$$\frac{\partial N}{\partial t} = -div\vec{j} - \lambda N + S\ ,$$

where N is the number of radon particles per unit volume of the porous medium; $\vec{j}$ - radon particle current determined by diffusion and convection; S is the radon source function; λ - radon decay constant. The radon current in a porous medium due to diffusion is described by Fick's law with an effective diffusion coefficient $D_e = D \cdot \eta$, where D - diffusion coefficient in pore space, or true diffusion coefficient cm^2/s; η – soil porosity, rel. units Taking convection into account, the equation for $\vec{j}$ looks like:

$$\vec{j} = -D_e gradN + \vec{\upsilon}N\ .$$

In this context, convection should be understood as the vertical movement of radon due to geothermal and pressure gradients in the earth's crust, gas carried in the porous medium when the pores are filled with water, and turbulent effects in the pores when outside. Climate Change - Atmospheric pressure, temperature, wind and the interaction of heat exchange and water circulation in the "atmosphere-terrestrial" system. Assuming that the radon concentration changes only in the z-direction (the z-axis is from the Earth's surface), the equation turns into the following form:

$$\frac{1}{D_e}\frac{\partial N}{\partial t}=\frac{\partial^2 N}{\partial z^2}+\frac{\upsilon}{D_e}\frac{\partial N}{\partial z}-\frac{\lambda}{D_e}N+\frac{S}{D_e}.$$

The radon source function S determines the number of radon particles produced by the radioactive decay of a unit volume of radium in a porous medium called electric power:

$S = K_{em} A_{Ra} \rho_d$, (part/(cm^3/s))

where K_{em} - emanation coefficient;

A_{Ra} – specific activity of ^{226}Ra on the soil (Bq/g); ρ_d - dry soil density (g/sm^3).

In the experiment, the pore activity of radon is usually measured per unit volume of soil air:

$A = N\lambda / \eta$, (Bq/sm^3)

Multiplying equation by , we obtain the equation for the distribution of pore activity in a layered medium:

$$\frac{1}{D_e}\frac{\partial A}{\partial t}=\frac{\partial^2 A}{\partial z^2}+\frac{\upsilon}{D_e}\frac{\partial A}{\partial z}-\frac{\lambda}{D_e}A+\frac{S\lambda}{\eta D_e}$$

The main difficulty that arises in solving this equation is the choice of effective coefficients D_e, υ, K_{em}, This mostly depends on management and not directly on time. For example, the electrical energy of rocks depends on their physical condition (especially temperature and humidity over time), as well as materials and minerals at depth, as well as a usability value between 0.02 and 0.7. The diffusion coefficient of radon depends on the structure of the pores, the composition of the liquid in the pores, the adsorption capacity of the rock, humidity and temperature.

The value of the diffusion coefficient in porous materials can be obtained as: 10^{-1} см^2/c (pores are full volume filled with air) ~10^{-6} см^2/c.

A particularly serious problem arises when determining the rate of convection. This is mainly because most authors do not state that physical processes are related to diffusion and convection processes, and there is no reason to use approximations and model measurements. For example, there is a well-known method that takes into account not only molecular diffusion, but also the strength of radon due to vision, the diffusion coefficient in convective conditions.

The above problems that arise in the mathematical calculation of radon can be bypassed, remember that the main role of modeling is to determine the main distribution type of radon in media invasion. Then when solving the next equation:

$$\frac{1}{D_e}\frac{\partial A}{\partial t} = \frac{\partial^2 A}{\partial z^2} + \frac{\upsilon}{D_e}\frac{\partial A}{\partial z} - \frac{\lambda}{D_e}A + \frac{S\lambda}{\eta D_e}$$

Some basic amenities are recommended. Let us first consider examples that are not time-independent. This assumption is very good because, as noted, measurement of pore activity is usually done over a period of time (several days) and at a depth of 70 cm, where daily temperature and humidity changes are not significant. Then, under radioactivity equilibrium conditions, the radon exchange agent will be stable:

$$\frac{\partial^2 A}{\partial z^2} + \frac{\upsilon}{D_e}\frac{\partial A}{\partial z} - \frac{\lambda}{D_e}A = -\frac{K_{em}A_{Ra}\rho_d\lambda}{\eta D_e} \quad . (1.7)$$

Secondly, in the same system for a soil type, all coefficients can also be evaluated independently of the management. In this case, equation we got before has an analysis.:

$$A(z) = C_1 \exp^{(n-m)z} + C_2 \exp^{-(n+m)z} + A_\infty, \quad (1.8)$$

where $m = \frac{\upsilon}{2D_e}$; $n = \sqrt{\left(\frac{\upsilon}{2D_e}\right)^2 + \frac{\lambda}{D_e}}$; A_∞ - pore activity of radon, which comes in equilibrium with ^{226}Ra, equal to $A_\infty = \frac{K_{em}A_{Ra}\rho_s(1-\eta)}{\eta}$; C_1 and C_2 – constants of integration, which are determined later from the boundary conditions.

In equation (1.8), the density of dry soil □d is expressed in terms of the density of solid particles of soil ρ_s and porosity η as $\rho_d = \rho_s(1-\eta)$. For a semi-infinite emanating layer (the z-axis is directed downward from the daylight surface), the boundary conditions have the form:

$$A(0) = 0; \quad (1.9)$$

$$A(\infty) = \frac{K_{em} A_{Ra} \rho_s (1-\eta)}{\eta} = A_\infty \quad . \qquad (1.10)$$

Condition (1.9) reflects the free release of emanation into the atmosphere, where the concentration of radon is lower than in the soil air by about three orders of magnitude. Condition (1.10) means that at an infinitely great depth, the pore activity of radon reaches its equilibrium value A_∞, when ^{222}Rn is in radioactive equilibrium with ^{226}Ra. Taking into account the boundary conditions (1.9) and (1.10) formula (1.8) for pore activity takes the form:

$$A(z) = A_\infty \left(1 - \exp^{-Yz}\right), \qquad (1.11)$$

where $Y = \sqrt{\left(\frac{\upsilon}{2D_e}\right)^2 + \frac{\lambda}{D_e}} + \frac{\upsilon}{2D_e}$.

The radon flux density at depth z is determined by the equation:

$$q(z) = D_e \frac{\partial(\eta A(z))}{\partial z} + \upsilon\eta A(z) = \upsilon\eta A_\infty + (D_e A_\infty Y - \upsilon A_\infty)\eta \exp^{-Yz} \quad , \qquad (1.12)$$

and the density of the radon flux from the earth's surface is:

$$q(z)\big|_{z=0} = \eta D_e A_\infty Y \quad . \qquad (1.13)$$

To elucidate the role of the convective mechanism of radon transport in soil, the pore activity values involving only molecular diffusion were compared with the values measured in soil exposed to a depth of 70 cm in the city of Tomsk.

As mentioned above, the convective transport system takes into account all the physical processes (except molecular diffusion) responsible for the vertical movement of radon. The complexity, variety, and randomness of this process do not allow us to construct a model that adequately captures the physics of convective convection. Convection rate cannot be measured with respect to natural conditions. However, if the convection value is used as the phenomenological parameter of the model, it can be found by comparing the numbers and experiments.

3.3 Radon transfer processes in inhomogeneous porous media

The models discussed so far in the literature consider only one emission soil layer. This is because the surface layer of the inhabitants is mostly 5-10 meters thick clay, loam, sandy loam, sand, etc.

This simplification is based on the assumption that the specific activity of Ra-226 in uranium-containing rocks is many times higher than that of sedimentary rocks that usually form at the upper margins.

However, there are many problems in electrical ecology and geophysics that need to be resolved when taking into account the existence of two emitting soil layers with different properties.

3.4 Obtained experimental and calculated data

In this part of work the results of measurements of the radon flux density are presented below, and also the coefficients of its correlation with various weather factors were calculated.

Along with this, the results of modeling the radon flux density and comparing this model with the obtained experimental data are presented.

According to a Fick's law the density of radon flux was simulated in Wolfram mathematica using next formula:

$$q(z) = -D_e \frac{\partial\left(\eta A(z)\right)}{\partial z} + v\eta A(z)$$

Where K_{em} is emanation coefficient;

A_{Ra} - specific activity, Bq/kg;

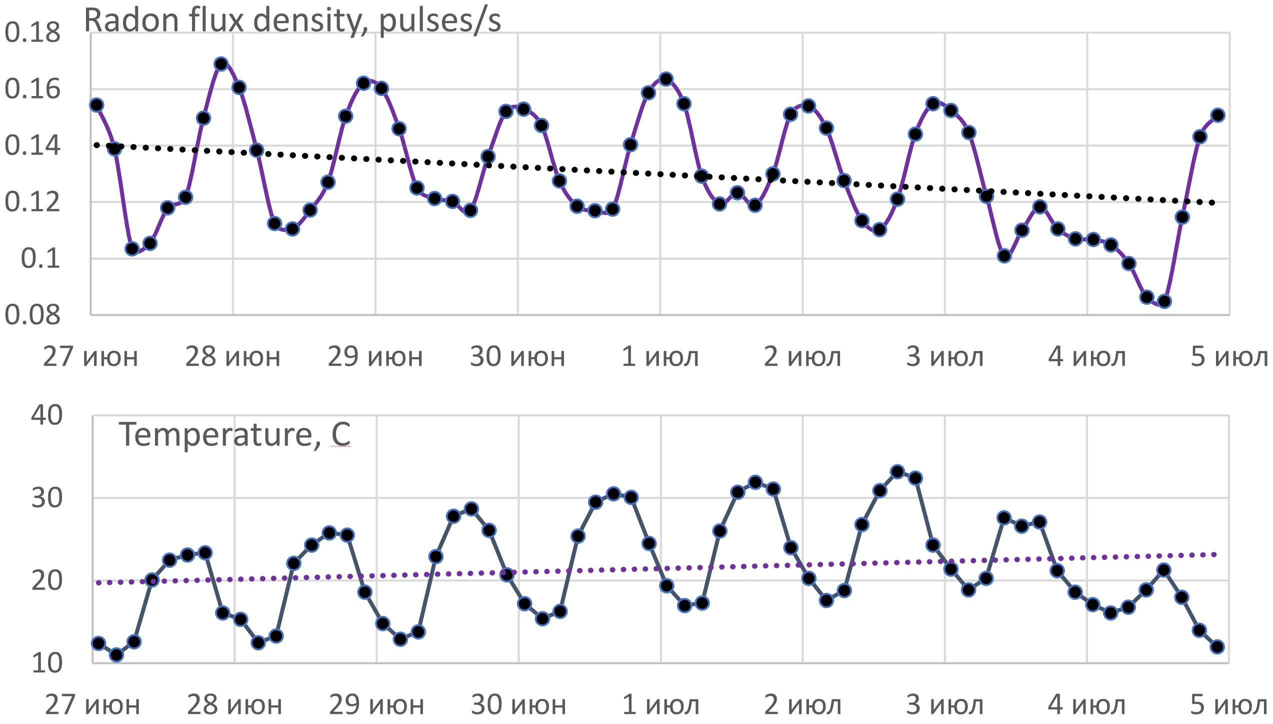
ρ_s - soil solid density, kg/m^3;

η - soil porosity, relative units.

The results of calculating flux density of radon are below in the table.

Table.3.4.1 Calculated values of radon flux density with different advection speed.

Advection speed, m/s	-10^{-5}	-10^{-6}	0	10^{-5}	10^{-6}
Radon flux density	11.54	15.29	18.63	22.71	30.10



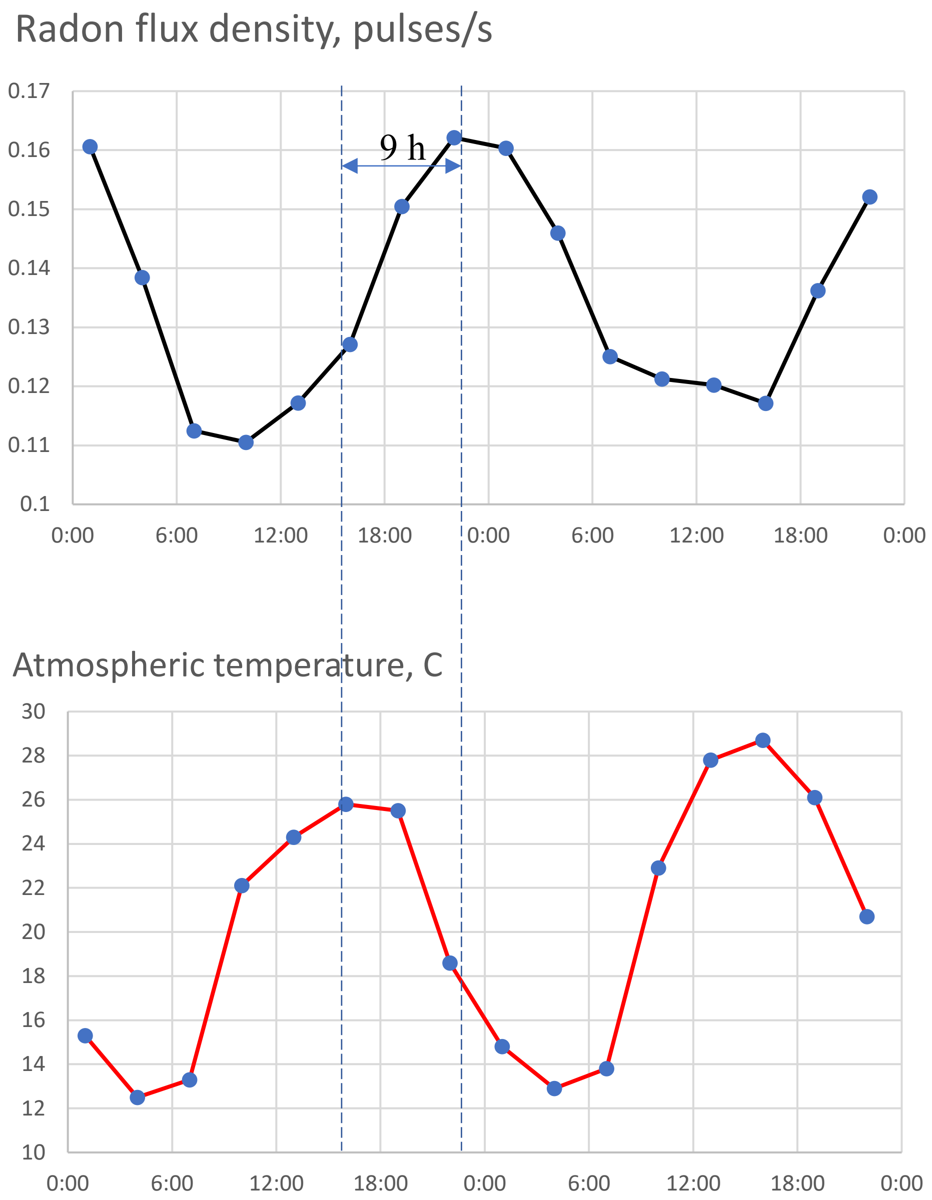
Pic. 3.3. Correlation between SPD and atmospheric temperature

Correlation coefficients:

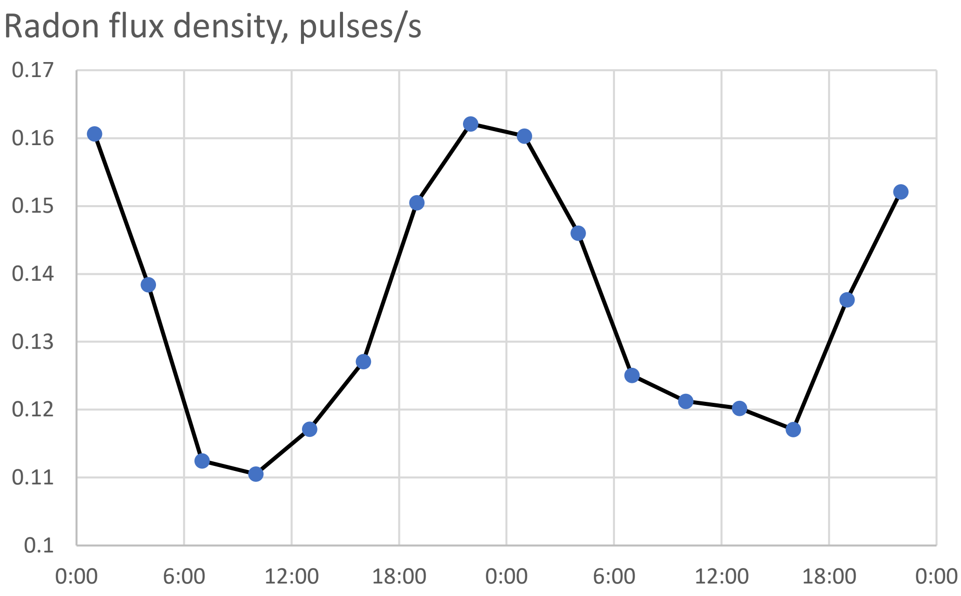
K = - 0.34(no shift)

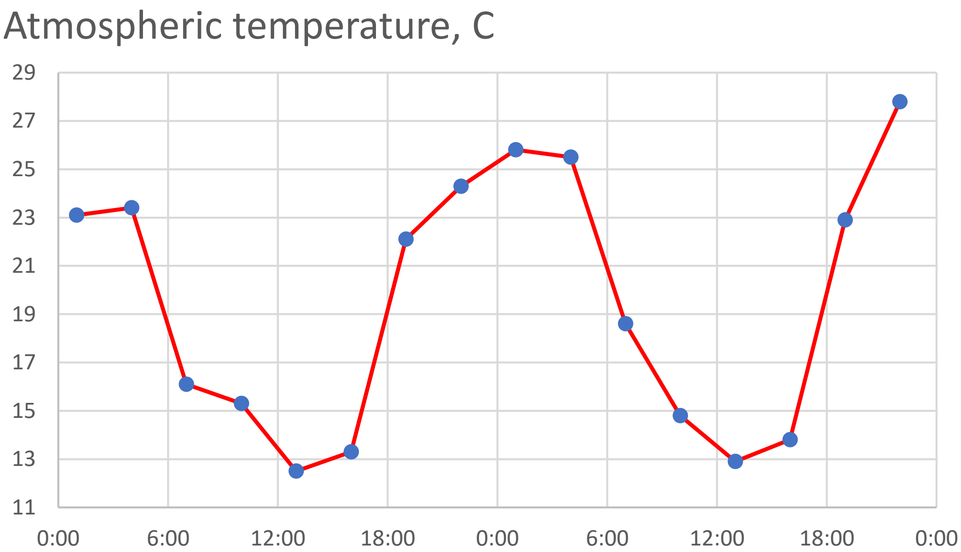
K = 0.63(with a shift, without taking into account the influence of precipitation)

K = 0.81(with shift, taking into account the influence of precipitation)

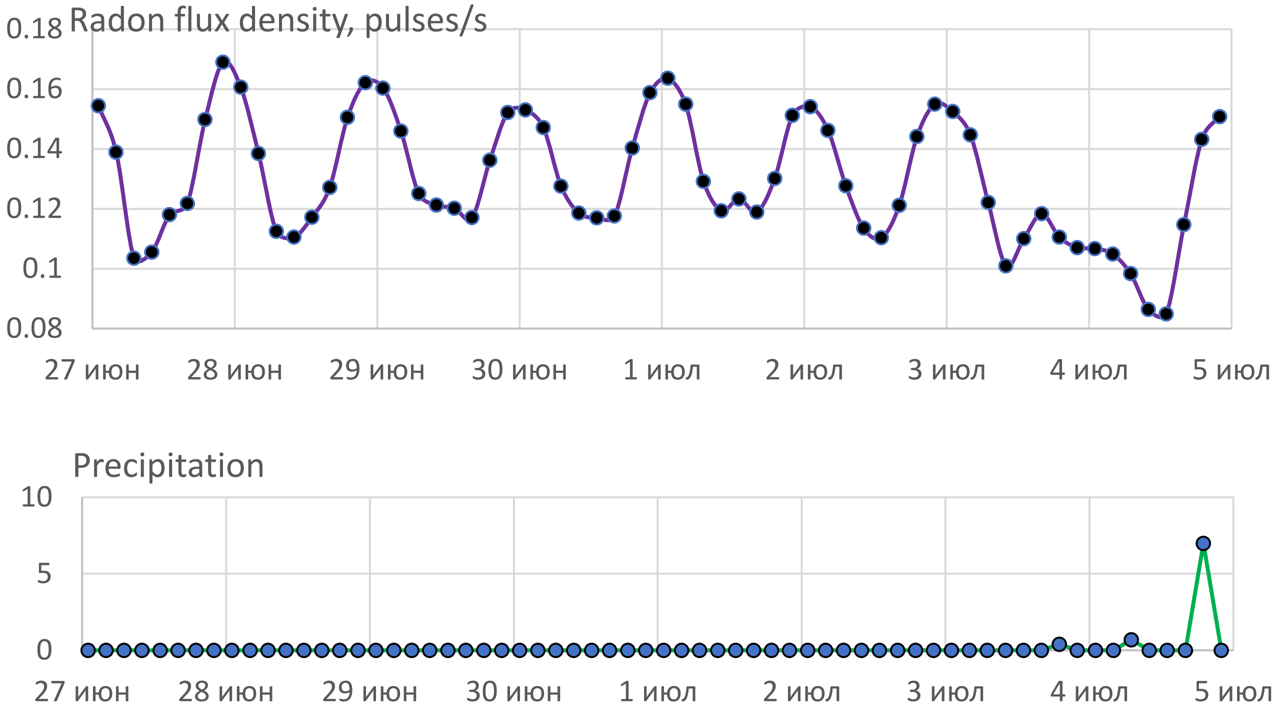


Pic.2.3.2 Correlation between FDR and temperature without shear

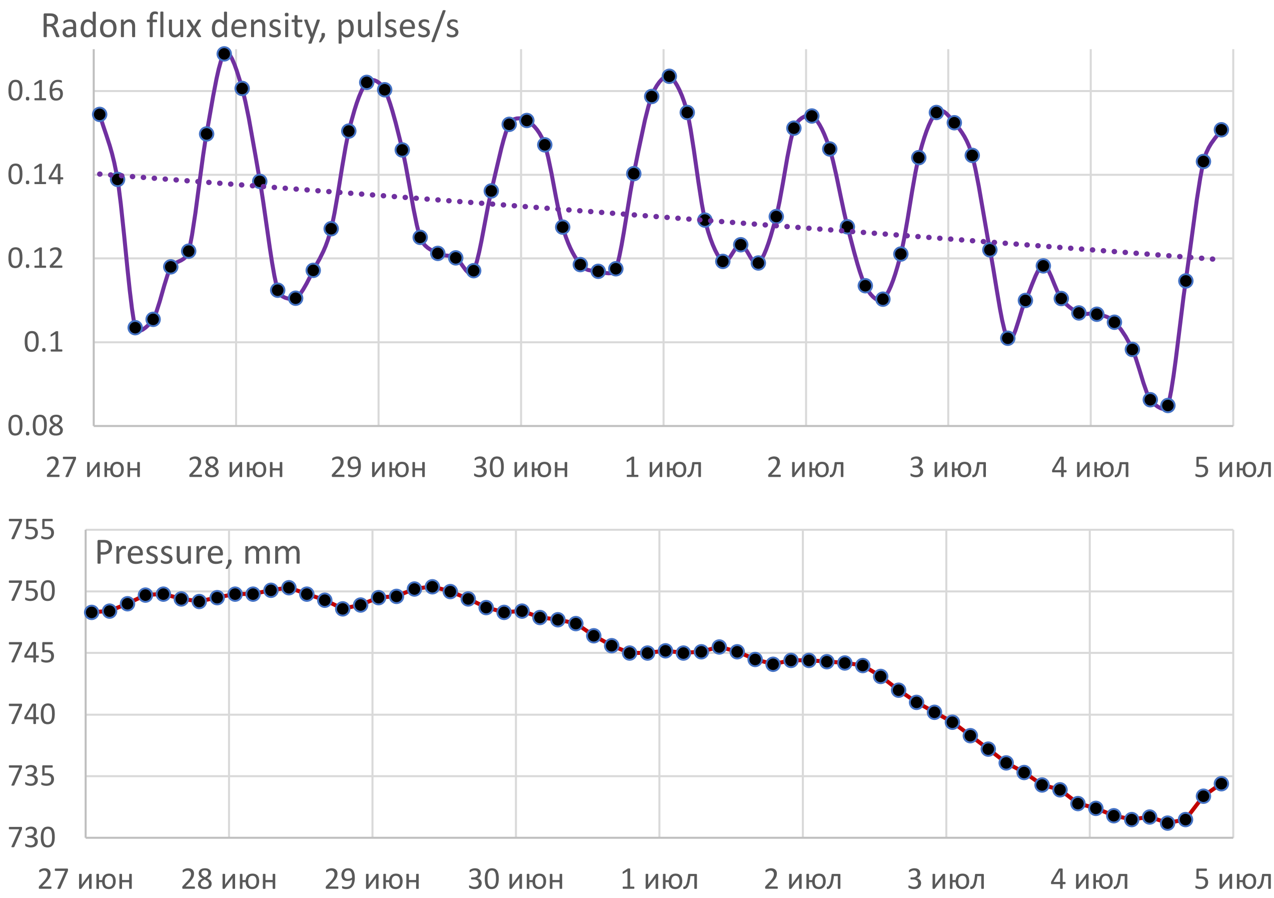




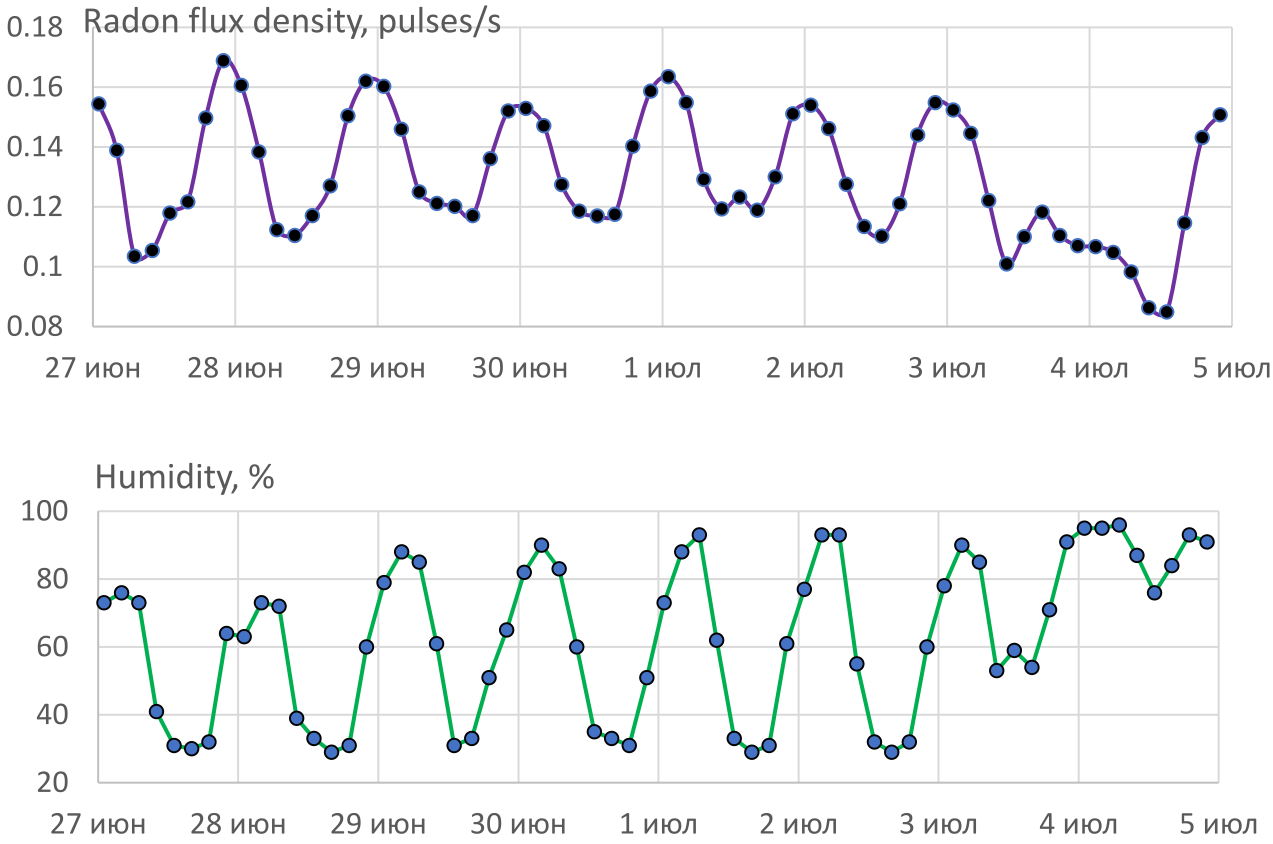
Pic. 2.3.3 Correlation between FDR and shear temperature



Pic. 2.3.4. Influence of precipitation on radon flux density



Pic. 3.3.5. Influence of pressure on the flux density of radon



Pic.3.3.6. Correlation between FDR and atmospheric humidity.

Correlation coefficients:

K=0.08(no shift)

K=-0.80 (with a shift, without taking into account the influence of precipitation)

K=-0.90 (with a shift, taking into account the influence of precipitation).

3.5 Simulation of radon flux density

An analysis of the experimental data showed that the radon flux density can be described by a sinusoidal function of the current atmospheric temperature.

$$\text{FDR} = \kappa \cdot \frac{Q_{ave}}{T_{a_i}} \cdot \sin(\omega t + \varphi) + Q_{ave}$$

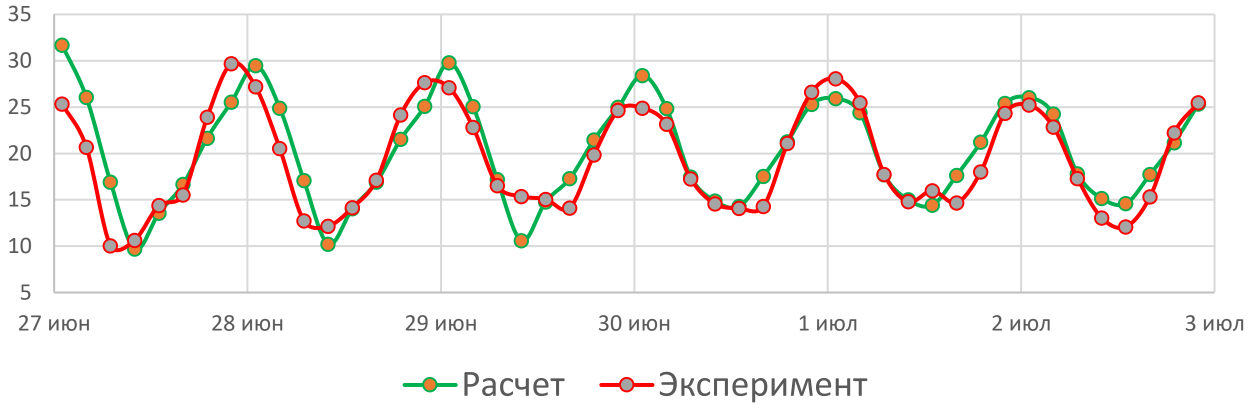
where k – conversion factor,

Q_{ave} – average FDR for the period under review;

T_a- current temperature of the atmosphere;

ω – oscillation period;

φ – initial phase of oscillations (shift).



Pic.3.3.7. Plot of calculated and experimental flux density

CHAPTER CONCLUSION

Figure 3.3.1 illustrates the dynamics of the radon flux density against the background of atmospheric temperature changes. On the right side of the figure, changes in the radon flux density and temperature associated with precipitation are observed. It can also be said that atmospheric temperature changes directly affect the radon flux density, while there is a noticeable delay in changes in the flux density values, which averaged 9 hours, which is confirmed by the calculations of the correlation coefficients for three cases: with a time shift, without a shift, and taking into account the influence of precipitation. Figure 3.3.2 shows the time shift between flux peaks and temperature. The correlation coefficient taking into account the temporal shift and precipitation was K=0.81. Figure 3.3.4 illustrates the changes in the dynamics of the radon flux density caused by precipitation.

A positive correlation was also found between the dynamics of the radon flux density and atmospheric pressure, when calculating the correlation coefficient of the average daily readings of the radon flux density and pressure, it turned out that K = 0.91.

Figure 3.3.6. the dynamics of the radon flux density and atmospheric humidity are shown, for this case the correlation coefficients were also calculated, taking into account the temporal shift and precipitation, it was K = -0.90. The figure and

calculations allow us to speak of an anti-correlation between the radon flux density and atmospheric humidity.

Based on the results, the radon flux density was simulated in the Wolfram Mathematica software package and the function defined the radon flux density as a function of the current temperature. Figure 3.3.7 presents the experimental and calculated values for the radon flux density.

TASK FOR SECTION

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

Student:

Group	Full name
0AM13	Tolmachev Nikita Sergeevich

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

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

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

The assignment was given by the consultant:

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

The student accepted the assignment:

Group	Full name	Signature	Data
0AM13	Tolmachev Nikita Sergeevich		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА «ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

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

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

Перечень графического материала *(с точным указанием обязательных чертежей):*

1. *«Портрет» потребителя результатов НТИ*
2. *Оценка конкурентоспособности технических решений*
3. *Матрица SWOT*
4. *Диаграмма Ганта*
5. *График проведения и бюджет НТИ*
6. *Оценка ресурсной, финансовой и экономической эффективности НТИ*

Дата выдачи задания для раздела по линейному графику	13.03.23

Задание выдал консультант:

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0АМ13	Толмачёв Никита Сергеевич		

4 FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING

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

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

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

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

4.1 Consumer portrait

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

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

4.2 Competitiveness analysis of technical solutions

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

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

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

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

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

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

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

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

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

C - the competitiveness of research or a competitor;

Wi– criterion weight;

Pi – point of i-th criteria.

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

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

Table 4.1 Evaluation card for comparison of competitive technical solutions

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

4. Functional capacity	0.1	5	5	0.5	0.5
Economic criteria for performance evaluation					
1. Development cost	0.1	5	4	0.5	0.4
2. Market penetration rate	0.1	3	4	0.3	0.4
3. Expected lifecycle	0.2	5	4	1	0.8
Total	**1**	**32**	**28**	**4.7**	**4.0**

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

4.3 SWOT analysis

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

Table 4.2 SWOT analysis

	Strengths: S1. Low cost. S2. Simplicity of method. S3. Reliability of results obtained. 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 getting data the actual temperature in different places. W3. Need to know how to operate the detector and climatic chamber technically. W4. Software sometimes take long to open.
Opportunities: O1.Data can be used to calculate dose rate for low background radiation in BDKG -03 scintillation detector. O2. Research institute could use the method to find the influence of ambient temperature on gamma background radiation of any radiation detector used outdoor. O3. Researchers can use the method can be used to estimate the algorithm for calculating dose rate under the influence of different temperature range.	***Strategy which based on strengths and opportunities:*** 1. Obtained a method, which can be used to calibrate dose rate in radiation detectors.	***Strategy which based on weaknesses and opportunities:*** Using open sources with data of temperature for measurement.
Threats: T1. Lack of financial support in purchasing of equipment. T2. Lack of demand since it is needed only after development of a radiation detector.	***Strategy which based on strengths and threats:*** Finding another equipment that can replace the climatic chamber to depict the environmental condition accurately.	***Strategy which based on weaknesses and threats:*** Not being able to complete project due to lack of financial support and lack weather data.

T3. Need of a climatic chamber to depict the environmental weather conditions.		

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

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

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

4.4 Project Initiation

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

4.4.1 Project Stakeholders

Table 4.3 Stakeholders of the project

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

4.4.2 Objectives and Outcomes of Project

Table 4.4 Purpose and results of the project

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

4.4.3 Project Participants

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

1. Scientific supervisor
2. Engineer

Table 4.5 Structure of the project

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

4.4.4 Project limitations and Assumptions

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

Table 4.6 Project limitations

Factors	Limitations / Assumptions
3.1. Project's budget, rubles	326530.74
3.1.1. Source of financing	TPU
3.2. Project timeline:	25/05/2022 to 25/05/2023

3.2.1. Date of approval of plan of project	25/05/2022
3.2.2. Completion date	25/05/2023

4.4.5 Project Schedule

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

Table 4.7. Project Schedule

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

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

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

Table 4.8 A Gantt chart

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

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

Scientific Supervisor   Engineer

4.5 Scientific and technical research budget

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

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

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

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

4.5.1 Calculation of material costs

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

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

where

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

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

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

k_T – coefficient taking into account transportation costs.

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

Table 4.9 Material costs

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

4.5.2 Calculation of the depreciation.

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

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

$$A = \frac{С_{перв} * Н_а}{100} \tag{4.3}$$

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:

Radiometer:

$$D = \frac{\text{Cost}}{\text{Time}} \quad (4.4)$$

$$D = \frac{118000}{5 \times 365} = 64.66 \frac{\text{rubles}}{\text{day}} \quad (4.5)$$

Since the equipment was used for 3 days

$$A = 64.66 \times 3 = 193.97 \text{ rubles} \quad (4.6)$$

Storage chamber:

$$D = \frac{\text{Cost}}{\text{Time}} \quad (4.7)$$

$$D = \frac{400000}{10 \times 365} = 109.589 \frac{\text{rubles}}{\text{day}} \quad (4.8)$$

Since the equipment was used for 3 days

$$A = 109.589 \times 3 = 328.767 \text{ rubles} \quad (4.9)$$

Table 4.10 Depreciation of special equipment (+software)

№	**equipment identification**	**Quantity of equipment**	**Total cost of equipment, rub.**	**Life expectancy, year**	**Depreciation for the duration of the project, rub.**
1.	Radiometer Alpharad	1	118000	10	193.97
2.	Climatic chamber	1	400000	10	328.77
3	Laptop	1	30000	-	30000
Total					30522.74

4.5.3 Basic salary

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

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

$$S_b = S_a \cdot T_w \,, \qquad (4.10)$$

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:

$$S_d = \frac{S_m \cdot M}{F_v} \,, \qquad (4.11)$$

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	48

- isolation period - sick absence	
The valid annual fund of working time	251

Monthly salary is calculated by formula:

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

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

$k_{premium}$ – premium rate;

k_{bonus} – bonus rate;

k_{reg} – regional rate.

Table 4.12 Calculation of the base salaries

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

4.5.4 Additional salary

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

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

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

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

4.5.5 Labor tax

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

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

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

where,

k_b – coefficient of deductions for labor tax.

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

Table 4.14 Labor tax

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

4.5.6 Overhead costs

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

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

Overhead is calculated according to the formula:

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

where,

k_{ov} – overhead rate.

Table 4.15 Overhead

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

4.5.7 Other direct costs

Energy costs for equipment are calculated by the formula:

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

where,

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

P − power of equipment, kW;

F_{eq} − equipment usage time, hours.

Table 4.16 Other direct costs

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

4.5.8 Formation of budget costs

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

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

Table 4.17 Items expenses grouping

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

4.6 Evaluation of the comparative effectiveness of the project

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

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

The integral financial measure of development is defined as:

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

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:

$$I^d{}_f = \frac{C_i}{C_{max}} \tag{4.18}$$

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

$$I^d{}_f = \frac{325707.14}{400000.00} \tag{4.19}$$

$$I^d{}_f = 0.814 \tag{4.20}$$

and

$$I^a{}_f = \frac{C_i}{C_{max}} \tag{4.21}$$

$$I^{a}{}_{f} = \frac{400000.00}{400000.00} \tag{4.22}$$

$$I^{a}{}_{f} = 1 \tag{4.23}$$

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:

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

where,

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

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

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

n – number of comparison parameters.

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

Table 4.18 – Evaluation of the performance of the project

Criteria	**Weight criterion**	**Points**	
		I_m^a	I_m^p
1. Energy efficiency	0.2	5	3

2. Reliability	0.1	4	4
3. Safety	0.2	5	5
4. Functional capacity	0.1	4	4
Economic criteria for performance evaluation			
1. The cost of development	0.1	4	4
2. Market penetration rate	0.1	5	5
3. Expected life	0.1	4	4
4. After-sales service	0.1	4	5
Total	**1**	**4.5**	**4.2**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 4.19 Efficiency of development

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

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

4.7 Conclusion

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.

ЗАДАНИЕ К РАЗДЕЛУ
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Обучающемуся:

Группа	**ФИО**
0АМ13	Толмачёву Никите Сергеевичу

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

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

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

Задание выдал консультант по разделу «Социальная ответственность»:

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

Задание принял к исполнению обучающийся:

Группа	**ФИО**	**Подпись**		**Дата**
0АМ13	Толмачёв Никита Сергеевич			

TASK FOR SECTION "SOCIAL RESPONSIBILITY"

To the student:

Group	Full name
0AM13	Tolmachev Nikita Sergeevich

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

Subject FQW:

Investigation of seasonal trends in density dynamics radon flow from the earth's surface	
Initial data for the section "Social responsibility":	
1. Characteristics of the research object (substance, material, device, algorithm, technique, working area) and its scope	*Object of research: dynamics of radon flux density in the surface atmosphere.* *Stakeholders: Radiation safety services.*
List of questions to be researched, designed and developed:	
1. Legal and organizational security issues: - special (typical for the operation of the research object, the projected working area) legal norms of labor legislation; -organizational measures for the layout of the working area.	*− Трудовой кодекс Российской Федерации от 30.12.2001 N 197-ФЗ (ред. от 24.04.2020);* *− ГОСТ 22269-76. Система «человек-машина». Рабочее место оператора. Взаимное расположение элементов рабочего места. Общие эргономические требования*
2. Industrial safety: **2.1. Analysis of the identified harmful and dangerous factors** **2.2. Rationale for mitigation measures**	Harmful and dangerous factors: - deviation of microclimate indicators; - increased noise level; - insufficient illumination of the working area; - increased level of electromagnetic radiation; - danger of electric shock.

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

The assignment was given by the consultant:

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

The student accepted the assignment:

Group	Full name	Signature	date
0AM13	Tolmachev Nikita Sergeevich		

5 SOCIAL RESPONSIBILITY

5.1 Introduction

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

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

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

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

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

5.2. Legal and organizational issues of security

5.2.1. Organizational events

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

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

5.2.2. Technical measures

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

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

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

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

It should be possible to adjust the screen:

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

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

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

5.3 Industrial safety

5.3.1 Analysis of harmful and dangerous factors

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

Table 5.1 – Harmful and dangerous factors

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

5.3.2. Microclimate

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

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

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

Table 5.2 – Optimal values of microclimate indicators

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

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

Table 5.3 – Permissible values of microclimate indicators

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

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

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

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

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

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

Fan "Event 150C" is able to provide the required air extraction performance for a given room. [24].

Table 5.4 Fan specifications of “Эвент 150C”.

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

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

5.3.3 Artificial lighting

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

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

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

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

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

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

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

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

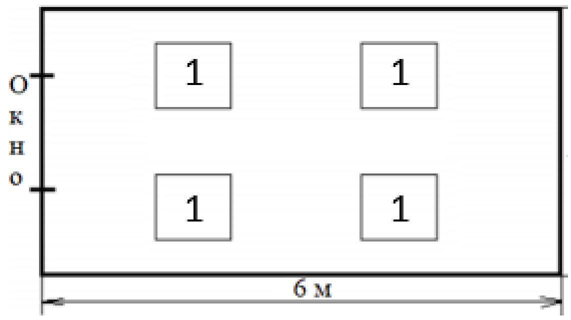

Figure 5.1 - Layout of fixtures at the workplace of a lighting engineer: 1- fixtures.

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

- power 40 W;

- luminous flux 4240 lm;

- light temperature 4000 K;

- IP 40.

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

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

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

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

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

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

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

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

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

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

$$-10 \leq 8.44 \leq 20$$

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

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

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

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

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

5.3.4 Electrical safety

Electrical safety is a system of organizational and technical measures and means to protect people from harmful and dangerous effects of electric current, electric arc, electromagnetic field and static electricity.

The premises for electrical safety are divided into 3 groups:

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

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

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

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

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

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

Also, personal protective equipment is divided into basic and additional. The main protective insulating means include insulating rods, insulating pliers and electrical voltage indicators, dielectric gloves, fitting and assembly tools with insulating handles. Additional insulating protective equipment includes means that supplement the main ones, and can also serve to protect against touch voltage and step voltage. Dielectric galoshes, dielectric rugs, insulating supports [10] serve as additional protective equipment.

5.3.5 Noise

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

In accordance with SanPiN 1.2.3685-21 [11], the standardized indicators in the workplace are:

- equivalent sound level per work shift;
- maximum sound level;
- peak sound level.

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

Collective protection means [12]:

- elimination of the causes of noise or its significant attenuation in the source of education;
- isolation of noise sources from the environment by means of sound vibration isolation, sound and vibration absorption;
- the use of means that reduce noise and vibration along the path of their propagation.

Personal protective equipment [12]:

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

5.3.6 Static electricity

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

5.4 Fire and explosion safety

Depending on the characteristics of substances and materials in the room, according to the explosion and fire hazard, the premises are subdivided into categories A, B, C, D and F in accordance with [20]. The room in question belongs to category C, since it contains solid combustible substances in a cold state. Possible causes of fire:

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

In order to reduce the risk of fire and minimize possible damage, preventive measures are taken, which are subdivided into organizational, technical, operational and regime. Organizational and technical measures consist in conducting regular briefings of employees responsible for fire safety, training employees in the proper operation of equipment and the necessary actions in the event of a fire, certification of substances, materials and products in terms of ensuring fire safety, production and use of visual agitation tools to ensure fire safety [20]. 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.[20] Fire extinguishers should be located at the protected object in accordance with the requirements so that they are protected from direct sunlight, heat flows, mechanical influences and other adverse factors (vibration, aggressive environment, high humidity, etc.). They must be clearly visible and easily accessible in the event of a fire. It is preferable to place fire extinguishers near the places where fire is most likely to occur, along the paths of the passage, as well as near the exit from the premises. Fire extinguishers should not interfere with the evacuation of people during a fire. According to fire safety requirements, there are 2 OP 3 fire extinguishers (portable powder fire extinguishers) on the floor, stairwells are equipped with hydrants, and there is a fire alarm button[20].

5.4 Safety in emergencies

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

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

Table 5.5 - Emergency situations, measures to prevent emergencies and eliminate the consequences of an emergency

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

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

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

1. Organize a checkpoint.

2. Hire a security guard to bypass the building.

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

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

Second case: fire. Possible causes of sunburn:

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

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

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

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

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

- elimination of the formation of a combustible environment (equipment sealing, air control, working and emergency ventilation);

- the use of non-combustible or hardly combustible materials in the construction and decoration of buildings; correct operation of equipment (correct connection of equipment to the power supply network, control of equipment heating);

- correct maintenance of buildings and territories (exclusion of the formation of an ignition source - prevention of spontaneous combustion of substances, limitation of hot work);

- training of production personnel in fire safety rules;

- publication of instructions, posters, availability of an evacuation plan;

- observance of fire safety rules, norms in the design of buildings, in the installation of electrical wires and equipment, heating, ventilation, lighting;

- correct placement of equipment;

- timely preventive inspection, repair and testing of equipment.

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

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

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

5.5 Conclusions to the section social security

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

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

The chapter discusses harmful and dangerous factors:

- microclimate [13];
- noise [12];
- illumination [16];
- fire hazard [20];
- electrical safety [23];

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

The audience in question is assigned to class B for fire hazard [21] and 1 for the electrical safety [17].

Conclusion

In the course of this final qualification work, the literature on topics related to the topics of the FQW was studied. Methods for detecting radon and physical methods for measuring its flux density in the surface atmosphere have been studied. Mathematical methods for modeling the transport of radon in media with given parameters of thickness, specific activity, porosity, and advection velocity in the layers were also studied.

The values of the radon flux density in the surface atmosphere were experimentally obtained, as well as the accompanying weather conditions such as temperature, pressure, precipitation and humidity.

In the work, it was possible to evaluate the influence of weather conditions on the dynamics of the radon flux density in the surface atmosphere.

As a result, it was found that atmospheric temperature changes directly affect the radon flux density, with a noticeable delay in changes in flux density values, which averaged 9 hours. At the same time, the correlation coefficient, taking into account the temporal shift and precipitation, was K=0.81. A positive correlation was also found between the dynamics of the radon flux density and atmospheric pressure, when calculating the correlation coefficient of the average daily readings of the radon flux density and pressure, it turned out that K = 0.91.

On the basis of the studied material, a model was created that describes the density of the radon flux in the surface atmosphere from the values of the atmospheric temperature.

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Application A (required)

Table A.1 - Experimental data of measurement of radon flux density.

Date	Atmospheric temperature, C	Atmospheric pressure	Humidity, %	Precipitation	puls/sec
27.06. 1:00	12,4	748,3	73	0	0,154444
27.06. 4:00	11	748,4	76	0	0,138926
27.06. 7:00	12,6	749	73	0	0,1035
27.06. 10:00	20,1	749,7	41	0	0,105472
27.06. 13:00	22,5	749,8	31	0	0,118028
27.06. 16:00	23,1	749,4	30	0	0,121778
27.06. 19:00	23,4	749,2	32	0	0,14975
27.06. 22:00	16,1	749,5	64	0	0,168944
28.06. 1:00	15,3	749,8	63	0	0,160639
28.06. 4:00	12,5	749,8	73	0	0,138444
28.06. 7:00	13,3	750,1	72	0	0,112472
28.06. 10:00	22,1	750,3	39	0	0,110528
28.06. 13:00	24,3	749,8	33	0	0,117167
28.06. 16:00	25,8	749,3	29	0	0,127111
28.06. 19:00	25,5	748,6	31	0	0,1505
28.06. 22:00	18,6	748,9	60	0	0,162111
29.06. 1:00	14,8	749,5	79	0	0,160333
29.06. 4:00	12,9	749,6	88	0	0,146
29.06. 7:00	13,8	750,2	85	0	0,125056
29.06. 10:00	22,9	750,4	61	0	0,12125
29.06. 13:00	27,8	750	31	0	0,120222
29.06. 16:00	28,7	749,4	33	0	0,117111
29.06. 19:00	26,1	748,7	51	0	0,136194

Continuation of table A.1.

29.06. 22:00	20,7	748,3	65	0	0,152111
30.06. 1:00	17,2	748,4	82	0	0,152972
30.06. 4:00	15,4	747,9	90	0	0,147167
30.06. 7:00	16,3	747,7	83	0	0,127556
30.06. 10:00	25,4	747,4	60	0	0,118583
30.06. 13:00	29,5	746,4	35	0	0,117
30.06. 16:00	30,5	745,6	33	0	0,117583
30.06. 19:00	30,1	745	31	0	0,140306
30.06. 22:00	24,5	745	51	0	0,15875
01.07. 1:00	19,4	745,2	73	0	0,163556
01.07. 4:00	17	745	88	0	0,154889
02.07. 13:00	30,9	743,1	32	0	0,110306
02.07. 16:00	33,2	742	29	0	0,121111
02.07. 19:00	32,4	741	32	0	0,144139
02.07. 22:00	24,3	740,2	60	0	0,154889
03.07. 1:00	21,4	739,4	78	0	0,152444
03.07. 4:00	18,9	738,3	90	0	0,144667
03.07. 7:00	20,3	737,2	85	0	0,122111
03.07. 10:00	27,6	736,1	53	0	0,100972
03.07. 13:00	26,6	735,3	59	0	0,110028
03.07. 16:00	27,1	734,3	54	0	0,118306
03.07. 19:00	21,2	733,9	71	0,4	0,1105
03.07. 22:00	18,6	732,8	91	0	0,107028
04.07. 1:00	17,1	732,4	95	0	0,10675

Continuation of table A.1.

04.07. 4:00	16,1	731,8	95	0	0,104833
04.07. 7:00	16,8	731,5	96	0,7	0,098306
04.07. 10:00	18,9	731,7	87	0	0,086333
04.07. 13:00	21,3	731,2	76	0	0,084917
04.07. 16:00	18	731,5	84	0	0,114694
04.07. 19:00	14	733,4	93	7	0,143194
04.07. 22:00	12	734,4	91	0	0,150806

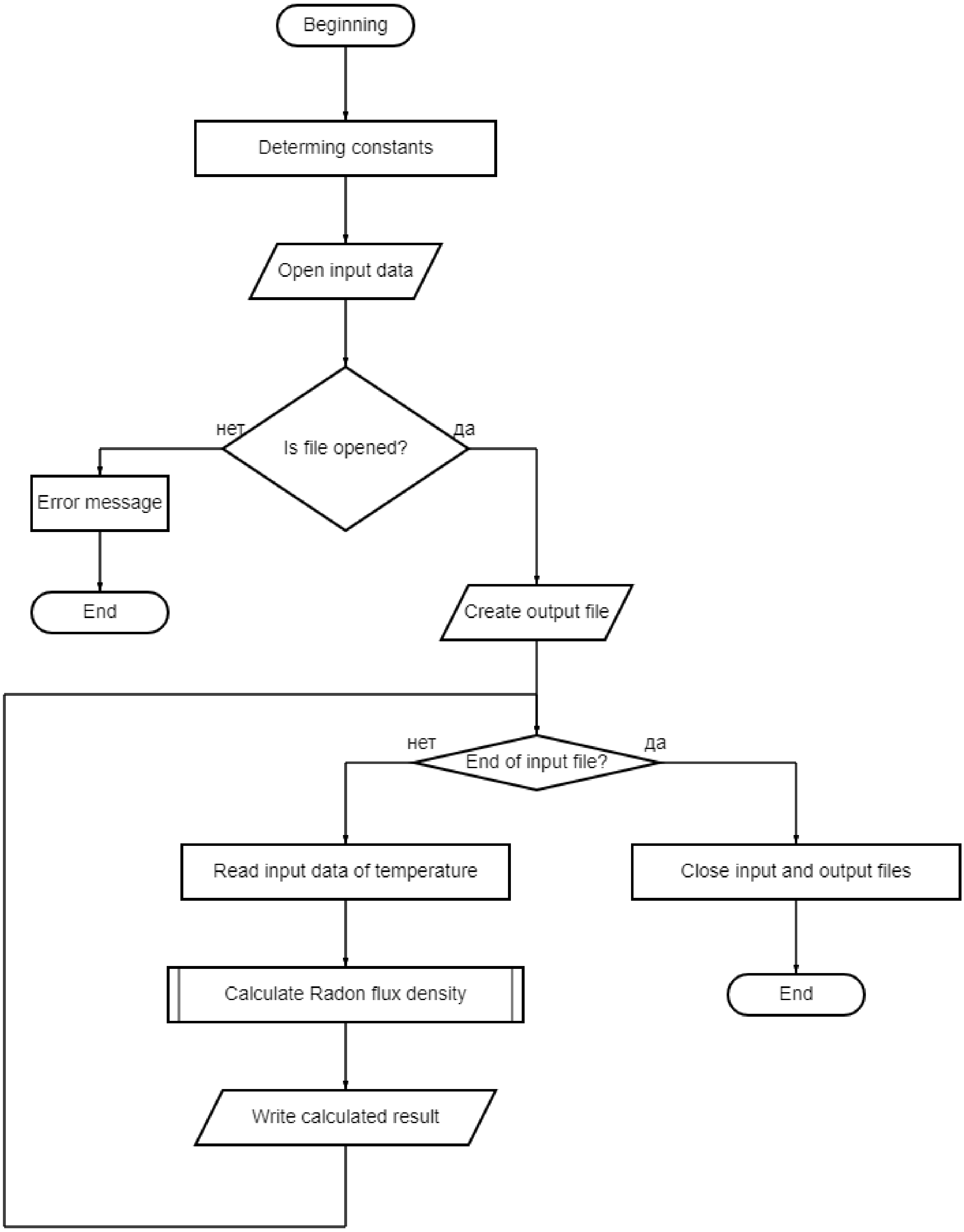
Table A.2 – Calculated radon flux density with obtained formula.

Date	Radon flux density, $mBq/m^2 \cdot s$
27.06. 1:00	31,68459
27.06. 4:00	26,04839
27.06. 7:00	16,91882
27.06. 10:00	9,690174
27.06. 13:00	13,56049
27.06. 16:00	16,66667
27.06. 19:00	21,6591
27.06. 22:00	25,55144
28.06. 1:00	29,46986
28.06. 4:00	24,90196
28.06. 7:00	17,08099
28.06. 10:00	10,2328
28.06. 13:00	14,03749
28.06. 16:00	16,91358
28.06. 19:00	21,52246
28.06. 22:00	25,09427

Continuation of table A.2.

29.06. 1:00	29,78979
29.06. 4:00	25,06757
29.06. 7:00	17,18675
29.06. 10:00	10,58668
29.06. 13:00	14,78817
29.06. 16:00	17,30216
29.06. 19:00	21,48747
29.06. 22:00	24,97716
30.06. 1:00	28,42377
30.06. 4:00	24,87013
30.06. 7:00	17,47904
30.06. 10:00	14,88568
30.06. 13:00	14,29571
30.06. 16:00	17,54098
30.06. 19:00	21,27288
30.06. 22:00	25,3022
01.07. 1:00	25,91383
01.07. 4:00	24,41176
02.07. 13:00	17,7163
02.07. 16:00	15,0037
02.07. 19:00	14,42735
02.07. 22:00	17,6489

Application B.1 (required)



Pic B.1 Block diagram of the program

Application B.2 (required)

Code of the used program written in C++:

```
#include <iostream>
#include <fstream>
#include <cmath>
using namespace std;

double w = 0.261799;  //Defined as Pi*2/24   //
double f = 1.570796;  //Defined as Pi*2/0.25 //
double k = 7.50;
double q = 20.0;
double t = 1.0;
double Flux;
double Tave;

double model(double Ta) {
        Flux = sin(t * w + f) * k * q / Ta + q;
        t = t + 3;
        return Flux;
}

int main()
{
        ofstream out("result.txt");
        if (!out) {
                cout << "File cannot be opened";
                return 1;
        }
        else cout << "File opened!" << endl;

        ifstream in("t_data.txt");
        if (!in) {
                cout << "File with data is not opened";
                return 1;
        }
        else cout << "File with data is opened" << endl;

        while (in)
        {
                in >> Tave;
                out << "time: "<< t-3 <<" RFD: " << model(Tave) << endl;

        }
                out.close();
                in.close();

        return 0;
  }
```