Министерство науки и высшего образования Российской Федерации
Федеральное государственное автономное образовательное учреждение высшего образования
**«НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»**

Школа____________________Инженерная школа ядерных технологий________
Направление подготовки____14.04.02 Ядерные физика и технологии ________
ООП/ОПОП_______________Ядерная и радиационная безопасность_________
Отделение школы (НОЦ)___ОЯТЦ ИЯТШ______________________________

ВЫПУСКНАЯ КВАЛИФИКАЦИОННАЯ РАБОТА МАГИСТРАНТА

Тема работы
Исследование степени очищения атмосферы от радионуклидов дождевыми осадками

УДК 539.163:551.578.1:551.510.41

Обучающийся

Группа	**ФИО**	**Подпись**	**Дата**
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Руководитель ВКР

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Профессор ОЯТЦ ИЯТШ ТПУ	Яковлева В.С.	д.т.н.		

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Доцент ОЯТЦ	Передерин Ю.В.	к. т. н.		

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

Томск – 2023 г.

Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
"NATIONAL RESEARCH
TOMSK POLYTECHNIC UNIVERSITY"

School ____________________ School of Nuclear Engineering________________
Training direction___________14.04.02 Nuclear Physics and Technology ______
OOP/OPOPE _______________ Nuclear and radiation safety __________________
School division (NLC)_______ Nuclear Fuel Cycle Division____________________

GRADUATE QUALIFICATION WORK OF A MASTER STUDENT

Topic of work
Study of the degree of radionuclide removal from the atmosphere by rainfall

UDC 539.163:551.578.1:551.510.41

Student

Group	**FULL NAME**	**Signature**	**Date**
0AM13	Chuprina Anastasia Vladimirovna		

Scientific supervisor

Position	**FULL NAME**	**Academic degree, rank**	**Signature**	**Date**
Professor of NFCD of SNSE	V.S. Yakovleva	Doctor of technical sciences		

SECTION CONSULTANTS:

On the section "Financial Management, Resource Efficiency and Resource Saving"

Position	**FULL NAME**	**Academic degree, rank**	**Signature**	**Date**
Assistant professor of SSHD of SCEE	L.Y. Spitsyna	PhD in Economics		

On the section "Social Responsibility"

Position	**FULL NAME**	**Academic degree, rank**	**Signature**	**Date**
Assistant professor of NFCD of SNSE	Y. V. Perederin	PhD		

ADMISSION TO DEFEND:

Head of the OOP/OPOPE, position	**FULL NAME**	**Academic degree, rank**	**Signature**	**Date**
Head teacher of NFCD of SNSE	A.O. Semenov	PhD		

Tomsk - 2023.

Planned results of the educational program / educational program

Competency code	Name of competency
Universal competencies	
UK(U)-1	is able to critically analyze problem situations based on a systematic approach, to develop a strategy of action
UK(U)-2	is able to manage the project at all stages of its life cycle
UK(U)-3	is able to organize and lead a team, developing a team strategy to achieve the goal
UK(U)-4	is able to use modern communication technologies, including in a foreign language, for academic and professional interaction
UK(U)-5	is able to analyze and take into account the diversity of cultures in the process of intercultural interaction
UK(U)-6	is able to identify and implement the priorities of his/her own activities and ways to improve them on the basis of self-assessment
General professional competencies	
BPC(U)-1	is able to formulate goals and objectives of research, choose evaluation criteria, identify priorities for solving problems
BPC(U)-2	is able to apply modern methods of research, evaluate and present the results of the work performed
BPC(U)-3	is able to design the results of research activities in the form of articles, reports, scientific reports and presentations using a computer layout system and office software packages
Professional competencies	
PC(U)-1	Ability to create theoretical and mathematical models in nuclear physics and technology
PC(U)-2	Willingness to apply methods of research and calculation of processes occurring in modern physical facilities 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 plants and technologies, develop and analyze scenarios for potential accidents, and develop methods to reduce the risk of their occurrence
PC(U)-5	Ability to analyze technical and design-theoretical developments, to take into account their compliance with the requirements of RF laws in the field of nuclear and radiation safety, nuclear energy

PC(U)-6	Ability to objectively assess the proposed solution or project in relation to the current world level, to prepare an expert opinion
PC(U)-7	Ability to formulate technical tasks, to use information technologies and application software packages in the design and calculation of physical facilities, to use knowledge of methods of analysis of environmental and economic efficiency in the design
PC(U)-8	Willingness to apply methods of optimization, analysis of options, finding solutions to multi-criteria problems, accounting for uncertainties in design
PC(U)-9	Ability to solve problems in the development of science, engineering and technology, taking into account the normative legal regulation in the field of intellectual property
PC(U)-10	Willingness to teach under the main educational programs of higher education and additional professional education (AVE)
PC(U)-11	Ability to design and economic justification of the innovative project, the content, structure and order of its development

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Школа___________________Инженерная школа ядерных технологий________
Направление подготовки____14.04.02 Ядерные физика и технологии ________
ООП/ОПОП_______________Ядерная и радиационная безопасность_________
Отделение школы (НОЦ)___ ОЯТЦ ИЯТШ_____________________________

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

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

Обучающийся:

Группа	**ФИО**
0АМ13	Чуприна Анастасия Владимировна

Тема работы:

Исследование степени очищения атмосферы от радионуклидов дождевыми осадками	
Утверждена приказом директора	№ 33-46/с от 02.02.2023

Срок сдачи обучающимся выполненной работы:	22.06.2023

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе	Виды и характеристики (интенсивность, время выпадения) жидких атмосферных осадков
Перечень разделов пояснительной записки подлежащих исследованию, проектированию и разработке	- обзор литературы; - методы определения интенсивности дождевых осадков; - осадки, классификация, основные характеристики; - математическое моделирование динамики активности радона и ДПР, оказывающих наибольшее влияние на гамма-фон, в атмосфере и на поверхности грунта, с помощью Wolfram Mathematica, исследование степени освобождения атмосферы от радионуклидов; - финансовый менеджмент, ресурсоэффективность и ресурсосбережение; - социальная ответственность; - заключение

Перечень графического материала	Приложение А. Сцинтилляционный детектор; презентация для защиты ВКР

Консультанты по разделам выпускной квалификационной работы	
Раздел	**Консультант**
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	Спицына Л.Ю., доцент ОСГН, к. э. н.
Социальная ответственность	Передерин Ю.В., доцент ОЯТЦ, к. т. н.

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

Задание выдал руководитель:

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
профессор ОЯТЦ ИЯТШ ТПУ	Яковлева В.С.	д.т.н.		13.03.2023

Задание принял к исполнению обучающийся:

Группа	**ФИО**	**Подпись**	**Дата**
0АМ13	Чуприна Анастасия Владимировна		13.03.2023

Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
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TOMSK POLYTECHNIC UNIVERSITY"

School ____________________ School of Nuclear Engineering________________
Training direction____________14.04.02 Nuclear Physics and Technology _______
OOP/OPOPE _______________ Nuclear and radiation safety __________________
School division (NLC)________ Nuclear Fuel Cycle Division____________________

APPROVED:
Head of the OOP / OOPP
_____ ________ Semenov A.O.
(Sign) (Date) (Full name)

TASK
for a graduate qualification work

Student

Group	**FULL NAME**
0AM13	Chuprina Anastasia Vladimirovna

Theme of Work:

Study of the degree of radionuclide removal from the atmosphere by rainfall	
Approved by order of the director	No. 33-46/c of 02.02.2023

The deadline for students to turn in their work:	22.06.2023

TECHNICAL SPECIFICATIONS:

Initial data for the work	Types and characteristics (intensity, timing) of liquid precipitation
List of sections of the explanatory note to be researched, designed and developed	- literature review; - methods of determining the intensity of rainfall; - precipitation, classification, main characteristics; - mathematical modeling of the dynamics of activity of radon and DPR, which have the greatest influence on the gamma background, in the atmosphere and on the surface of the ground, using Wolfram Mathematica, the study of the degree of release of radionuclides from the atmosphere; - financial management, resource efficiency and resource conservation; - social responsibility; - conclusion

List of graphic material	Appendix A. Scintillation detector; presentation for the defense of the thesis

Consultants on the sections of the graduate qualification work	
Section	**Consultant**
Financial Management, Resource Efficiency and Resource Saving	L.Y. Spitsyna, Assistant professor of SSHD of SCEE, PhD in Economics
Social Responsibility	Y. V. Perederin, Assistant professor of NFCD of SNSE, PhD

Date of issue of the assignment for the final qualification work according to progress schedule chart	13.03.2023

The assignment was given by the supervisor:

Position	**FULL NAME**	**Academic degree, rank**	**Signature**	**Date**
Professor of NFCD of SNSE	V.S. Yakovleva	Doctor of technical sciences		

The assignment was accepted for execution by the student:

Group	**FULL NAME**	**Signature**	**Date**
0AM13	Chuprina Anastasia Vladimirovna		13.03.2023

Министерство науки и высшего образования Российской Федерации
Федеральное государственное автономное образовательное учреждение высшего образования
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ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»**

Школа___________________Инженерная школа ядерных технологий________
Направление подготовки____14.04.02 Ядерные физика и технологии ________
ООП/ОПОП_______________Ядерная и радиационная безопасность_________
Отделение школы (НОЦ)___ ОЯТЦ ИЯТШ______________________________
Период выполнения _________ весенний семестр 2022/2023 учебного года____

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Обучающийся:

Группа	ФИО
0АМ13	Чуприна Анастасия Владимировна

Тема работы:

Исследование степени очищения атмосферы от радионуклидов дождевыми осадками

Срок сдачи обучающимся выполненной работы:	22.06.2023

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
25.04.2023	Обзор литературы	10
25.04.2023	Методы определения интенсивности дождевых осадков	10
25.04.2023	Осадки, классификация, основные характеристики	10
27.05.2023	Математическое моделирование динамики активности радона и ДПР, оказывающих наибольшее влияние на гамма-фон, в атмосфере и на поверхности грунта, с помощью Wolfram Mathematica. Исследование степени освобождения атмосферы от радионуклидов	30
04.06.2023	Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	15
04.06.2023	Социальная ответственность	15
04.06.2023	Заключение	10

СОСТАВИЛ:

Руководитель ВКР

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Профессор ОЯТЦ ИЯТШ	Яковлева В.С.	д. т. н.		13.03.2023

СОГЛАСОВАНО:

Руководитель ООП/ОПОП

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Старший преподаватель ОЯТЦ	Семенов А.О.	к. т. н.		13.03.2023

Обучающийся

Группа	ФИО	Подпись	Дата
0АМ13	Чуприна Анастасия Владимировна		13.03.2023

Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
"NATIONAL RESEARCH
TOMSK POLYTECHNIC UNIVERSITY"

School ____________________ School of Nuclear Engineering________________
Training direction___________14.04.02 Nuclear Physics and Technology _______
OOP/OPOPE _______________ Nuclear and radiation safety __________________
School division (NLC)________ Nuclear Fuel Cycle Division___________________
Due date____________________spring semester of academic year 2022/2023_____

TIME SCHEDULE
of the graduate qualification work

Student

Group	FULL NAME
0AM13	Chuprina Anastasia Vladimirovna

Theme of Work:

Study of the degree of radionuclide removal from the atmosphere by rainfall

The deadline for students to turn in their work:	22.06.2023

Date control	Name of section (module) / type of work (research)	Maximum section (module) score
25.04.2023	Literature Review	10
25.04.2023	Methods for determining the intensity of rainfall	10
25.04.2023	Precipitation, classification, main characteristics	10
27.05.2023	Mathematical modeling of the dynamics of radon and DPR activity, which has the greatest influence on the gamma background, in the atmosphere and on the surface of the ground, using Wolfram Mathematica. Investigation of the degree of radionuclide release from the atmosphere	30
04.06.2023	Financial Management, Resource Efficiency and Resource Saving	15
04.06.2023	Social Responsibility	15
04.06.2023	Conclusion	10

CONTACTED:

Manager of the graduate qualification work:

Position	FULL NAME	Academic degree, rank	Signature	Date
Professor of NFCD of SNSE	V.S. Yakovleva	Doctor of technical sciences		

AGREED:

Head of the OOP / OOPP

Head of the OOP/OPOPE, position	FULL NAME	Academic degree, rank	Signature	Date
Head teacher of NFCD of SNSE	A.O. Semenov	PhD		

Student

Group	FULL NAME	Signature	Date
0AM13	Chuprina Anastasia Vladimirovna		13.03.2023

OVERVIEW

Graduate qualification work contains 106 p., 21 figures, 26 tables, 34 sources, 1 appendix.

Key words: liquid atmospheric precipitation, degree of atmospheric purification from radionuclides, degree of volume activity decrease, volume activity of radionuclides, radon daughter decay products, surface atmosphere, gamma background, intensity of liquid atmospheric precipitation.

The object of the study is liquid atmospheric precipitation and its influence on gamma-background in the atmosphere depending on the type of precipitation and their characteristics.

The aim of the work is to study the degree of purification of the atmosphere from radionuclides depending on the characteristics of liquid atmospheric precipitation.

The study of time dynamics of ^{222}Rn reduced activity during precipitation periods in the atmosphere and on the ground surface was carried out, the degrees of activity decrease for ^{218}Po, ^{214}Pb, ^{214}Bi depending on the duration, intensity and type of liquid precipitation was determined and the conclusions from the performed work were made.

Relevance of the topic is associated with the importance of controlling the radiation background of the near-surface atmosphere in the conditions of the development of nuclear power engineering and the difficult geopolitical situation in the world. Given above, it is necessary to identify the exact causes of the registered gamma background bursts.

In contrast to the control of gamma background on the Earth's surface, monitoring of radiation background by instrumental methods in the atmosphere is complicated, since the existing instruments are difficult to use at altitude, their error is large enough and it is also impossible to respond promptly to the outburst of gamma background.

Development of the methodology of predicting the degree of purification of the atmosphere from radionuclides is of interest for research institutes, as well as for operational radiological services performing radiation monitoring.

As a result of the conducted study, the economic efficiency of the work was proved.

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Appendix A. Scintillation detector

Introduction

Monitoring of the dose rate of γ-radiation around the world for a long time has unambiguously revealed that the atmospheric γ-background is never constant; its magnitude varies depending on turbulence, geopolis, season, time of day, and other factors. Also the γ-background fluctuations are related to atmospheric radon, atmospheric turbulence, and daily temperature dynamics.

In all regions of the globe, fluctuations, or rather bursts of various duration and form of radiation gamma background of surface atmosphere related to liquid atmospheric precipitation (rain, heavy rain, drizzle), were registered.

Control of the radiation background of the near ground atmosphere is relevant nowadays because of the development of nuclear power engineering. Besides there is a certain probability, connected first of all with geopolitical problems, of application of radioactive isotopes for terrorist purposes. Therefore we can conclude that the main task of radiation monitoring is as accurate as possible identification of causes and nature of the registered gamma background bursts.

Radon and thoron present in the ground in certain quantities are released from the ground through such processes as turbulent diffusion and wind flow, propagate in the atmosphere to high heights, where they decay into daughter decay products [13], which in turn increases the total γ background of the surface atmosphere.

Precipitation (both liquid and solid) plays the most important role in the formation of bursts of the atmospheric γ-background level, observed when recording the characteristics of the radiation fields. In foreign sources one can find such term as "radon washout" used to describe the mentioned phenomenon - washout of γ-emitting radon and thoron by precipitation to the earth surface, respectively, cleansing the atmosphere from radionuclides. However, there is still no clear understanding of the relationships between the intensity, types of precipitation (we consider liquid atmospheric precipitation) and gamma-radiation dose rate of the surface atmosphere. In addition, very few works have been carried out to study exactly the degree of purification of the atmosphere from radionuclides, as measurements of gamma-background parameters at high altitudes using instrumental methods are hardly feasible due to the complexity of operating devices at altitude, a fairly large error of these devices and the difficulty of organizing operational measurements of the responses in the form of gamma-background bursts.

In connection with the above, the purpose of this master's thesis is to study the degree of atmospheric clearance from radionuclides depending on the characteristics of rains and showers.

According to the purpose of the work, we outlined the following tasks to be solved:

- to analyze the data of long-term monitoring of gamma-background at the experimental site of TPU- IMCES SB RAS;
- to study the temporal dynamics of the volumetric activity of ^{222}Rn daughter decay products during precipitation periods in the atmosphere and on the earth surface;
- to determine the degree of decrease of volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi depending on duration, intensity, and type of liquid atmospheric precipitation.

1 Literature review

1.1 Natural Atmospheric Radiation Background

Radioactivity of the atmosphere depends on the surface layer of air, which contains radionuclides of cosmogenic and terrestrial origin and in which various processes of radionuclide migration to ground, to water, and to plants and animals take place.

A large number of radionuclides are in the ground, the most significant in the matter of radionuclides migration into the atmosphere are radon, thoron and their daughter decay products. Their movement into the atmosphere is associated with molecular and turbulent diffusion, by which these radionuclides enter the atmosphere, and it is mainly the daughter decay products of radon and thoron (thoron to a much lesser extent) that determine the dose of background radiation in the atmosphere. In general, the natural background atmosphere is determined by cosmic radiation and radiation of radioactive substances in the air and soil [3]. Sources of radon and thoron are radionuclides ^{238}U and ^{232}Th, which undergo radioactive transformations (Figure 1.1).

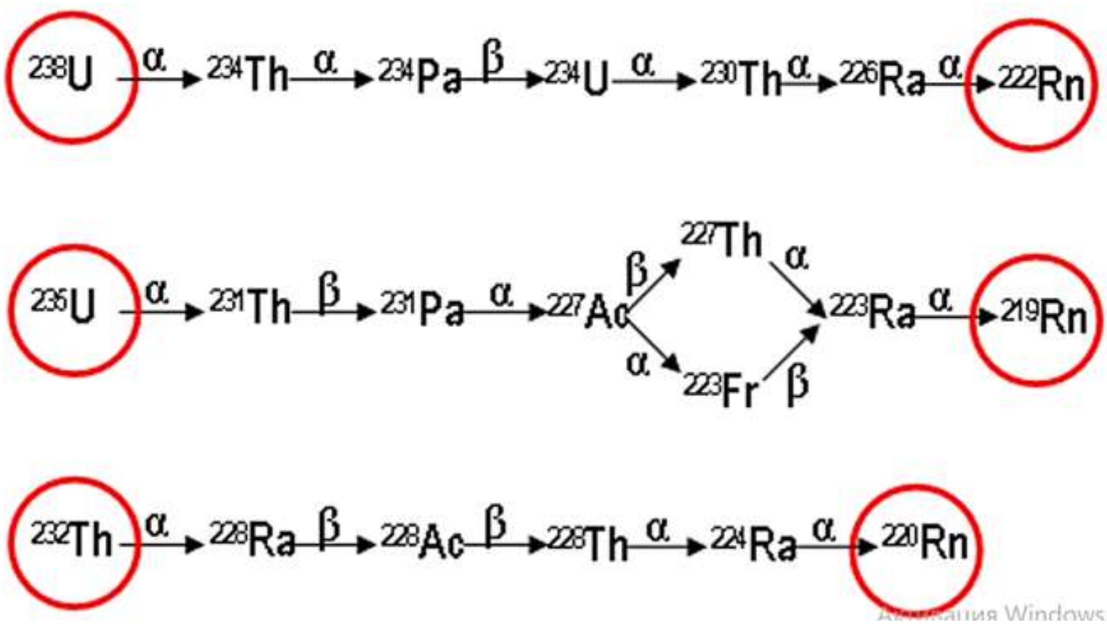


Figure 1.1 - Rows of natural radioactive families before the formation of radon, thoron and actinon [4]

We consider radon as the most significant radionuclide for the formation of the atmospheric gamma background; it is almost all dispersed in the strata of the earth and water. According to a rough estimate, there are almost 115 tons of radon in the upper layer of the earth's crust at a depth of 1.6 kilometers.

The content of radon in the atmosphere is much lower compared to the earth's crust, only 4.6 kilograms. Radon is found in almost everything around us: the waters of oceans and rivers, the depths of the earth's crust, soil, natural gases, and even in humans. The only place practically devoid of radon is the air and the glaciers of Antarctica.

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

Radon daughter products ^{214}Pb and ^{214}Bi make a decisive contribution to the total gamma background of the near-ground atmosphere, because the activity of these isotopes in the atmosphere considerably exceeds the activity of short-lived thoron daughter products (^{212}Pb, ^{212}Bi and ^{208}Tl) in the case when specific activities of ^{238}U (^{226}Ra) and ^{232}Th in soil differ insignificantly. However, there are regions where the ^{232}Th content in soil or elements of buildings and structures is significant, then an increase in the activity of thoron decay products in the atmosphere and the radiation background is generally observed [13].

1.2 Leaching of radon, thoron and their daughter decay products by rainfall

Figure 1.2 illustrates the process of radon and thoron leaching by rainfall.

Radioactive radon and thoron gases enter the atmosphere from the soil by molecular and turbulent diffusion. Being in the atmosphere they undergo radioactive decay and their daughter decay products are released into the air. As a consequence, radioactive aerosols are formed, that is, aerosols which consist of particles composed in whole or in part of radionuclides that are either incorporated into the particle material or are attached to inactive particles. During rainfall, radioactive aerosols are deposited on the surface of the ground along with droplets of water.

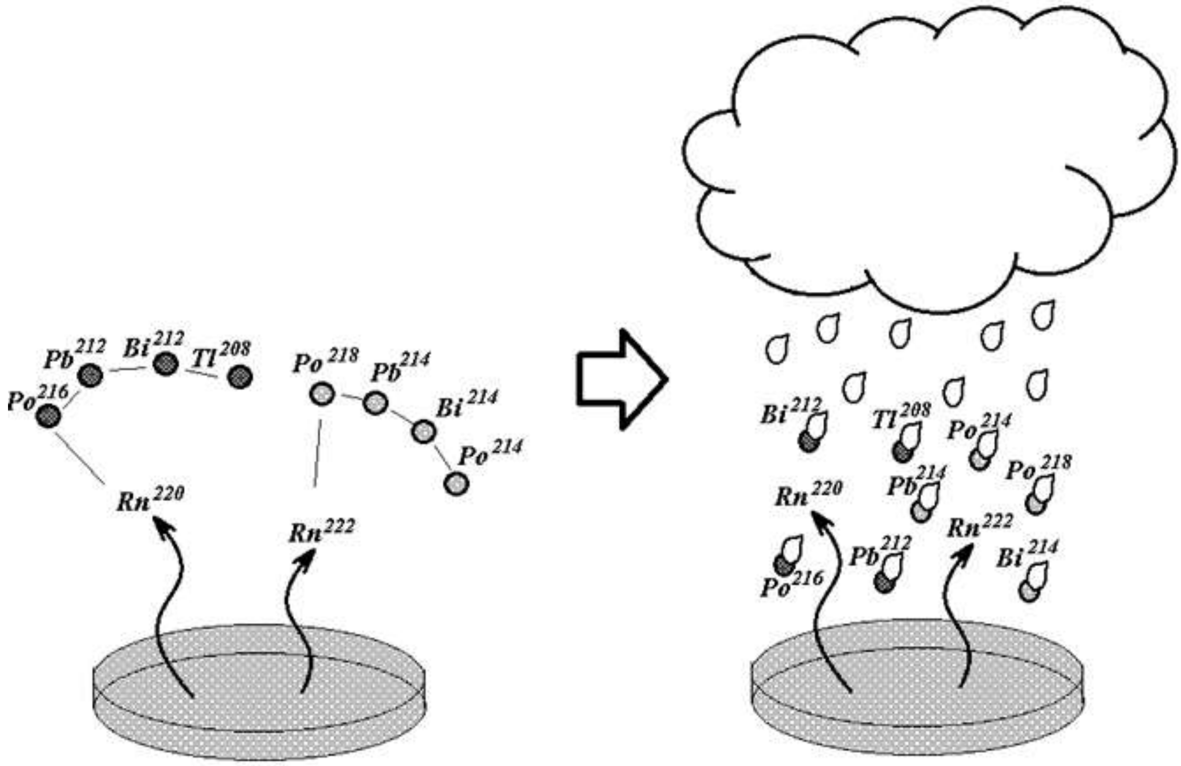


Figure 1.2 - Illustration of radon and thoron leaching by rainfall

It was revealed that physical state of radon and thoron decay products first of all influences the processes of their transfer from atmosphere to soil, i.e. radioactive aerosols are easier captured by drops of liquid atmospheric precipitation and wind streams. In addition, the transfer processes are also significantly affected by the state and alterations of surface atmosphere, lithosphere. The factors of space weather should not be excluded, either.

Process of daughter decay products of radon and thoron washout causes anomalous bursts of gamma-radiation dose rate, with long-lasting precipitation leading to prolonged response, and short-lived very intensive precipitation - to abrupt bursts of dose rate [5].

Let us highlight the main points from all of the above.

^{218}Po, the first decay product of ^{222}Rn, is α-active, so it does not affect the γ-background of the near ground atmosphere. During periods of liquid precipitation, the increase in dose rate of γ-radiation on the ground is associated with the washout from the atmosphere onto the ground of γ-radon short-lived decay products ^{214}Pb and ^{214}Bi, contained in the atmosphere as aerosols. Other natural radionuclides such as γ-emitting thoron decay products practically do not influence the dose rate value of γ-radiation due to their considerably lower activity in the near ground atmosphere as compared to ^{214}Pb and ^{214}Bi [14].

The influence of atmospheric precipitation, both liquid and solid, on the surface atmosphere radiation background is studied by scientists from different countries. Dependence of γ-background increase on different precipitation was found in low latitudes of tropical zone [6].

At the famous Ranger uranium mine in Australia, for example, soil moisture and porosity play a decisive role in the formation of the surface atmosphere γ-background. When soil moisture increases due to liquid precipitation, radon yield from the soil increases significantly, which in turn contributes to an increase in the surface atmosphere gamma-background [7]. Observations of γ-background in the surface atmosphere of Arctic regions also confirm the influence of precipitation, such as rain or snowfall, on the increase of γ. The reason for this effect in these regions is the braking X-ray emission of energetic electrons accelerated by electric fields inside rain (snow) clouds, since no characteristic lines of any radionuclides were detected in the γ-background during the increase and no radionuclides were present in the rainwater. Meanwhile, we should not forget about short-lived atmospheric radionuclides, which are difficult to detect, as they can decay significantly during sample preparation [8].

For example, the Oak Ridge Laboratory found that it is short-lived radionuclides that make a decisive contribution to the bursts of the γ-background atmosphere [9].

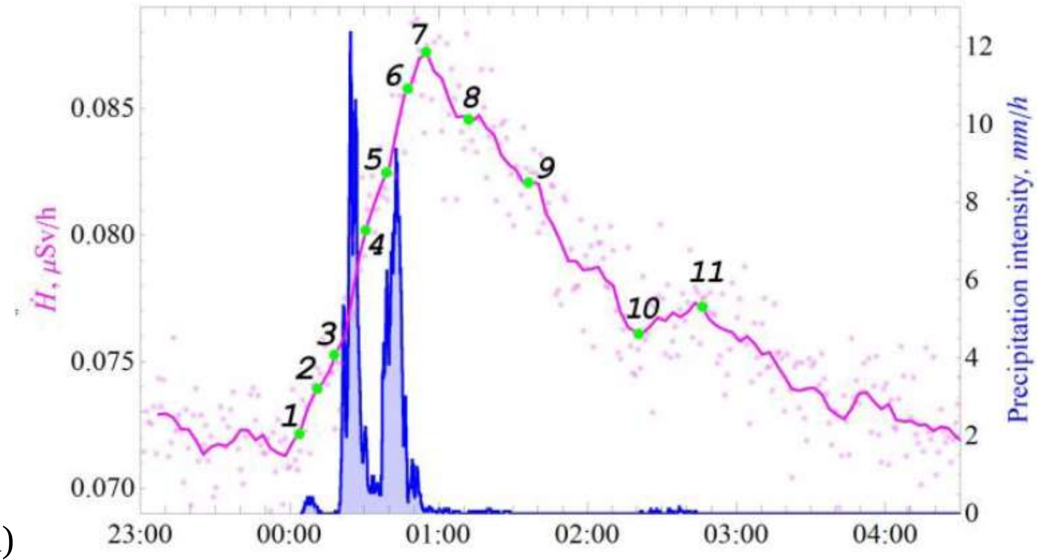
The connection between precipitation and an increase in the radiation background in the atmosphere was questioned by scientists from Great Britain, who, after studying this relationship at various stations, could not determine whether it was the precipitation that influenced the increase in the background or the air masses carrying radon fluxes. Moreover, after 1 – 2 hours the radiation background of the surface atmosphere decreased again [10]. Most likely, short-lived daughter decay products of radon were not taken into account, since the half-life of such nuclei is less than one hour. Cosmogenic radionuclides, such as ^{7}Be, also increase on the ground surface during liquid precipitation, which can contribute to increasing the radioactivity of the surface atmosphere. In Japan, the increase of ^{7}Be and ^{214}Pb on the earth's surface has been investigated since 1991. This occurs during winter and summer precipitation. It was found that this phenomenon has not temporary but stationary character [11].

Similar studies carried out in Spain also confirm an increase in the quantity of these radionuclides during precipitation. It should be noted that cosmogenic component of radiation also depends on precipitation and increases γ-background atmosphere [6].

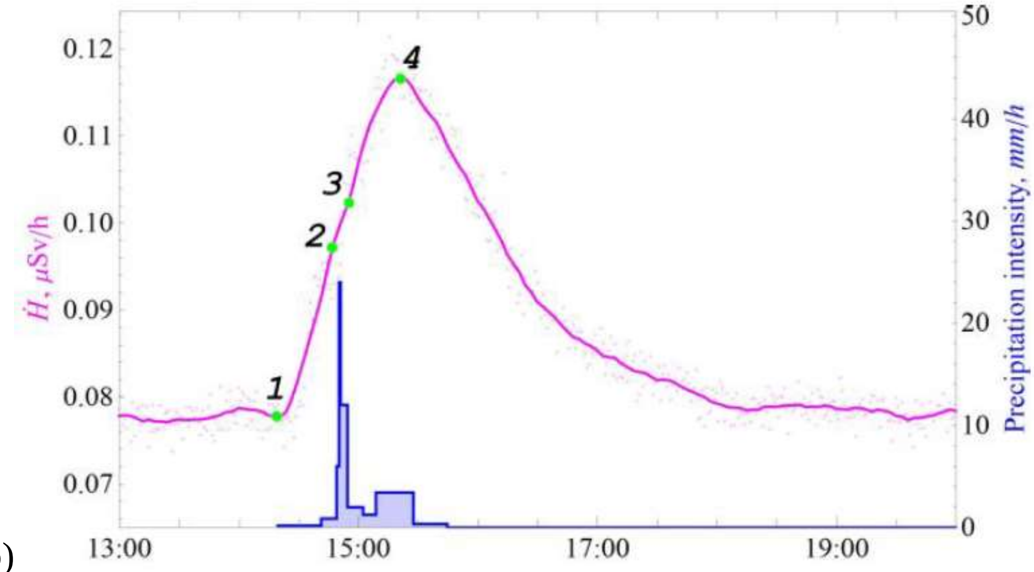
TPU scientists also conducted seasonal studies of this effect and observed bursts of γ-radiation during precipitation. Measurements were taken at different heights from 10 cm to 25 m. The time of existence of the effect lasted from a few hours to half a day. A detailed review and analysis of 2009-2019 data for the presence of bursts during precipitation was also conducted.

Analysis of long-term data on gamma-background responses to liquid atmospheric precipitation and the developed databases already make it possible to interpret in detail the form and duration of the recorded γ-background burst by characteristic signs of change in intensity and type of precipitation.

The point at which the level of γ-background begins to rise fixes the time of the beginning of liquid precipitation (point 1 in Figure 1.3); the precipitation intensity is characterized by the slope of the growth curve, with inflection points, that is, changes in the slope angle indicating changes in the intensity of precipitation; the maximum point (in case of several maxima we consider the first of them) indicates the time of the end of precipitation (points 7 in Figure 1.3 (a) and 4 in Figure 1.3 (b)).



a)



b)

Figure 1.3 - Dynamics of γ-background in the surface atmosphere depending on the intensity and duration of liquid precipitation [14]

The exponential decrease in γ-background after the maximum that we can observe in the graph indicates that the radioactive decay of the radon decay products ^{214}Bi and ^{214}Pb deposited on the ground has begun. As a rule, after about 3 hours the activity of these radionuclides in the near ground atmosphere decreases by more than two orders of magnitude.

If after reaching the maximum we observe some plateau or a weakly undulating shape, this indicates that liquid atmospheric precipitation continues with constant or slightly variable intensity.

Liquid atmospheric precipitation of short duration (about half an hour), according to the observations, leads to sharp bursts in γ-background. For series of successive short-term heavy rainfalls with duration of series of more than 3 hours, the notched form of gamma-background dependence is characteristic. [14].

In conclusion, we note that the best dependence of gamma-radiation dose rate bursts with precipitation time is observed in summer season.

1.3 Degree of atmospheric purification from radionuclides

In [5] it was reliably established that the activity of radon daughter decay products in the air column changes inversely symmetrically to the activity of these daughter radon decay products that get to the soil surface under this air column in the process of aerosol washout of these radionuclides by liquid atmospheric precipitation.

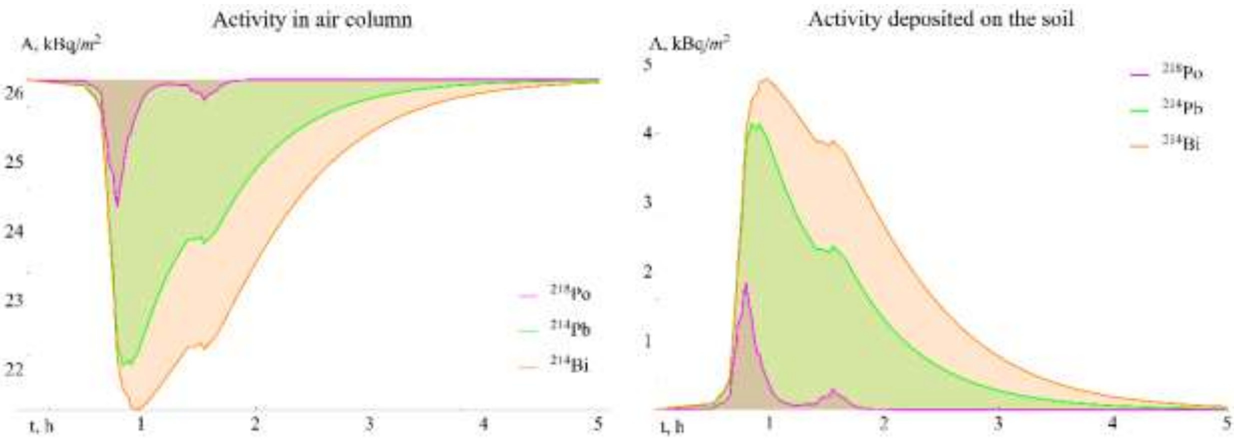


Figure 1.4 - Dynamics of activity of daughter radon decay products in the atmospheric column and on the surface of the soil under the considered air column during liquid atmospheric precipitation

It is obvious that γ-background atmosphere during liquid precipitation increases, while γ-background in the atmospheric column above the site in question decreases. The atmospheric column is cleared of radionuclides.

As applied to this work, the degree of radionuclide clearance of the atmosphere is the fraction (percentage) of reduction in natural radionuclide activity in the atmosphere during the rainfall relative to the maximum activity at the beginning of the rainfall.

1.4 Conclusion of Chapter One

The main contribution to the radiation gamma background of the surface layer of atmosphere is made by the natural background, which contains soil and atmospheric radionuclides. The increase in the γ-background of the atmospheric surface layer takes place at the time of rainfall, which is explained by the washout of daughter decay products of radon and thoron. At the same time, natural radionuclides and their decay products, being in the form of aerosols in the air, are washed out of the atmospheric column, therefore, the atmosphere is liberated.

It should be understood that instrumental measurements of radionuclide activity and γ-background on the height of the air column is complicated due to the difficulty of using devices at heights, their inaccuracy, the difficulty of fixing by measured points, the impossibility of conducting prompt measurements. Therefore, the topic under consideration concerning the degree of atmospheric purification is of interest, first of all, for radiation monitoring.

2 Methods for determining the intensity of rainfall

Currently, there are a large number of different methods and instruments to measure rainfall intensity.

2.1 Determination of rainfall intensity with the pluviograph

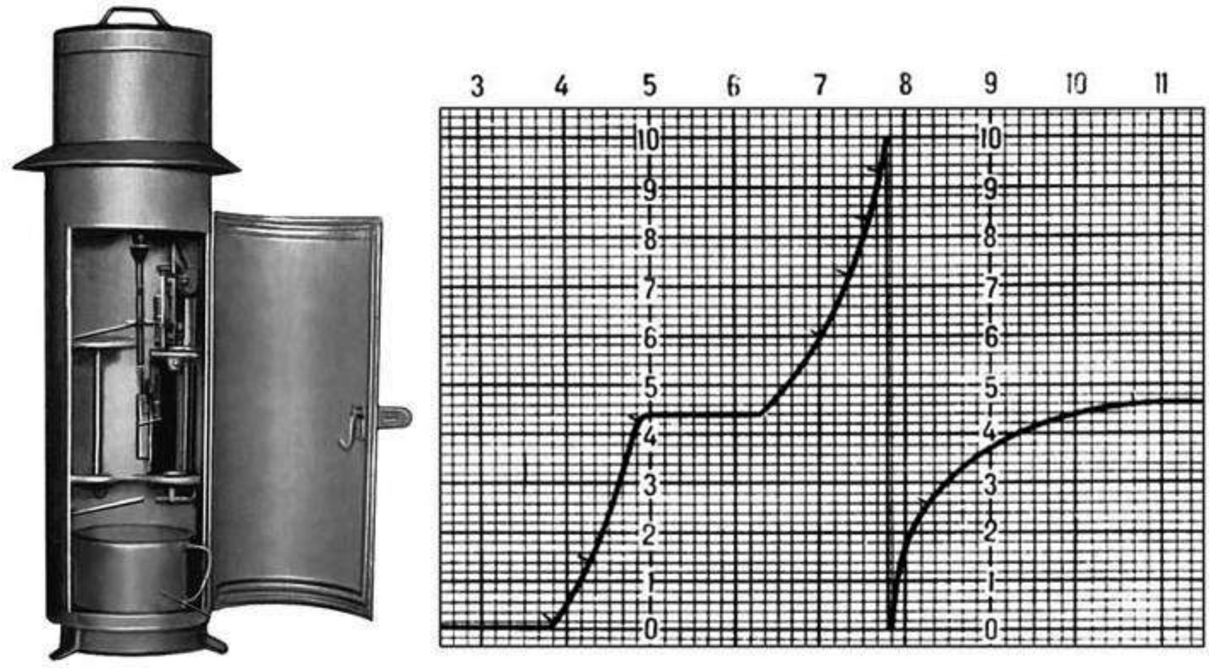


Figure 2.1 - Pluviograph and rainfall intensity data recorded by the pluviograph recorder

The pluviograph consists of a chamber designed for the collection of precipitation, equipped with a funnel for water intake, a siphon and a float, which is connected to the writing device and a drainage unit. The drain node, in turn, is designed as a tipping tank on a rotary axis and is rigidly connected with the chamber stop, the float is attached to the bottom of the tipping tank, with the center of gravity of the float and the stop located on opposite sides of the rotary axis.

Each tipping of the tank is recorded by a writing device. And as a result, the amount and intensity of liquid precipitation is judged by the water entering the receiving funnel, or rather, by the density of the chart made by the writing device for a certain time.

However, as it is known, the presence of mechanical and kinematic links in measuring instruments leads to the reduction in reliability of the measurement method. Besides, mechanical parts of the instrument can fail reducing the service life of this instrument.

The disadvantages of pluviograph can also include the probability of decreasing reliability of measurement results due to a rather high inaccuracy caused by the fact that this device does not record the very fact of the beginning of the tipping tank; this moment is not recorded by the writing device, thus, the time of the rain start is unknown.

2.2 Determination of the intensity of liquid precipitation by means of a precipitation gauge

The method indicated is based on a change in the capacitance of a capacitor, representing a sectional winding formed by two insulated conductors whose resistance is dependent on temperature, under the action of liquid precipitation that falls within the winding of the gauge, resulting in a sequence of electrical impulses whose frequency is proportional to the intensity of the liquid precipitation in question. The device includes a signal processing unit and a recording device.

The method is simple enough, however, there is a sufficiently large error in measuring the intensity of precipitation, as it is determined only by the variable frequency of electrical impulses of equal duration and does not depend on the size of the drops.

2.3 Method for determining the intensity of liquid precipitation based on the use of an optical-acoustic-electronic device

This method of determining the intensity is based on the transformation of the number of liquid drops and the sound signal into electrical pulses inside the optical-acoustic-electronic device, a laser is used to convert the number of drops into pulses, this is done by interrupting the laser beam by drops, and the sound signal is converted into electrical signal by using a microphone and a membrane.

The disadvantages of using the device include:

- in case of prolonged contact of liquid with the optics of the device, there is a possibility of its clouding, which in turn reduces the reliability of the entire device as a whole;
- influence of extraneous noise leads to increased inaccuracy of determining the intensity of precipitation;
- complexity of measuring units and power consumption with different voltages.

3 Precipitation, classification, main characteristics

3.1 Classification of precipitation

Precipitation is water droplets or crystals falling out of clouds for whatever reason that prevents them from remaining suspended in the atmosphere.

Classification of precipitation by genetic feature (depending on the physical conditions of formation):

1) Cloudy precipitation falls from layered and highly layered clouds associated with fronts. The distinctive feature of these precipitation is the coverage of large territories, long duration, which can reach tens of hours, and such precipitation can fall both continuously and with some interruptions, medium or moderate intensity [16]. Such precipitation is most typical for temperate latitudes [15].

Cloudy precipitation can be weak, close to drizzle, moderate, and heavy [17].

2) Stormy precipitation is intense, and its intensity varies greatly even during a single rainfall, but it is short in duration and is the main type of precipitation in low tropical and equatorial latitudes. Such precipitation falls from cumulonimbus clouds associated with convection. The duration of their fall is usually always short, but in special conditions with the passage of fronts, sometimes there are cases of very long showers of up to several hours. Short showers have the greatest intensity [15]. Rain showers cover a relatively small territory, often occur in "streaks" and are accompanied by strong winds [16].

Storms can be weak, moderate, and heavy (sometimes catastrophic), but they are always short-lived and sudden, although they can fall repeatedly at short intervals [17].

3) Drizzling precipitation - precipitation that does not produce significant daily amounts of moisture within a mass, falling from layered and layered-cumulus clouds, which usually have a small vertical extent. Precipitation from such clouds at plus temperature is usually due to the merging of droplets in them. Drizzle consists of very small droplets, drizzle droplets do not form circles when falling on the water

surface. It should be noted that drizzle can be more intense and abundant, but only in special conditions, such as in the mountains [15].

Translated with www.DeepL.com/Translator (free version)Drizzle is sometimes the result of enlargement of fog particles. In some cases, at warm fronts and warm occlusion fronts, drizzle precipitation is formed as a result of degeneration of cover precipitation, even more rarely (in autumn) as a result of degeneration of storm precipitation; such precipitation can fall for a long time (several hours) [17].

In [15] definitions of the main types of precipitation depending on their form are given: drizzle is defined as liquid precipitation, which includes small drops ranging in size from 0.05 mm to 0.5 mm, the rate of deposition of drops of this size in the atmosphere is very low, so such precipitation is easily transported in the horizontal direction under the influence of the wind; rains are characterized by larger droplets, on the order of 0.5 to 6 mm, such droplets may break into several pieces when falling to the ground; heavy showers are characterized by even larger droplet sizes, and at the beginning of heavy rainfall the droplet sizes may be even larger.

3.2 Precipitation characteristics

Precipitation categories according to the amount and duration are given below in Table 3.1 according to one of the classifications [16].

Table 3.1 - Categories of liquid precipitation depending on the amount and duration of precipitation (by W. Zoufal)

Category	Precipitation duration, h		
	1	2	3
	Precipitation, mm		
Faint rain	1.0	1.5	2.0
Moderate rain	1.1-5.0	1.6-7.5	2.1-9.0
Heavy rain	5.1-10.0	7.6-14.0	9.1-11.0
Very heavy rain	10.1-15.0	14.1-21.0	11.1-23.5
Drench	15.1-23.0	21.1-30.5	23.6-33.0
Downpour	23.1-58.0	30.6-64.0	33.1-72.0
Heavy downpour	≥58.1	≥64.1	≥72.1

Further, the basic characteristics of liquid precipitation in warm seasons for the West Siberian region are summarized in Table 3.2 [18].

Table 3.2 - List and main characteristics of liquid precipitation in the warm season for the West Siberian region

Type of precipitation	Characteristics	
Frost	Droplet radius - no more than 0.25 mm	intensity - less than 0.25 mm/h; duration - several hours
Faint rain	Droplet radius - 0.25 to 3.2 mm	intensity - from 0.25 to 2.5 mm/h; duration - from a few hours to a day or more
Moderate rain		intensity - from 2.6 to 8 mm/h; duration - from a few hours to a day or more
Heavy rain		intensity - more than 8 mm/h; number - at least 35 mm in a period not exceeding 12 hours; duration - several hours
Very heavy rain		intensity - more than 8 mm/h; number - at least 50 mm in a period not exceeding 12 hours; duration - several hours
Prolonged heavy rain		rain with short interruptions (not more than 1 hour) with at least 100 mm of rainfall over a period of time greater than 12 hours, but less than or equal to 48 hours, or 120 mm over a period of time greater than 2 days.
Downpour		amount - at least 20 mm for a period of not more than 1 hour
Heavy downpour		amount - not less than 30 mm for a period not exceeding 1 hour

3.3 Conclusion of the section

This section presents the main types, their classification and characteristics, and lists the sediments typical of the West Siberian region.

Having analyzed the basic characteristics of liquid atmospheric precipitation, their types have been selected, which will be considered further.

4 Mathematical modeling of activity dynamics of radon and its daughter decay products, which have the greatest influence on gamma background, in the atmosphere and on the surface of the ground, using Wolfram Mathematica. Investigation of the degree of radionuclide release from the atmosphere

To solve our problems, we consider the transfer of radon, thoron, and short-lived BWR isotopes only in the vertical direction, along the z axis, taking into account the processes of radionuclide generation, transfer in the atmosphere and the ground, and atmospheric liberation from them:

1) migration of radioactive gases from the earth's strata into the atmosphere;

2) radioactive transformations;

3) molecular and turbulent diffusion;

4) wind transport;

5) sedimentation (settling by gravity);

6) release of radionuclides from the atmosphere in the form of aerosols under the influence of liquid atmospheric precipitation.

Using a system of differential equations, we represent the change by height and time of volumetric activity of radon and thoron, as well as their DPR in surface atmosphere; this system for description of mathematical model of transfer includes 11 differential equations, general view of the system is presented below:

$$\left.\begin{aligned}\frac{\partial A_i}{\partial t} &= \nabla((D_M + D_T)\nabla A_i) - \nabla \vec{v}_W A_i - \lambda_i A_i; i = 1,6 \\ \frac{\partial A_i}{\partial t} &= \nabla((D_M + D_T)\nabla A_i) - \nabla(\vec{v}_W + v_F + v_R)A_i + \lambda_i A_{i-1} - \lambda_i A_i; i = 2-5, 7-11\end{aligned}\right\} \quad (4.1)$$

When considering the above case of transport in the vertical direction only, the system takes the following form:

$$\left.\begin{aligned}&\frac{\partial A_i(z,t)}{\partial t}=\frac{\partial}{\partial z}((D_{M_i}+D_T(z,t))\frac{\partial A_i(z,t)}{\partial z})-\frac{\partial}{\partial z}(v_W(z,t)A_i(z,t))-\lambda_i A_i(z,t);i=1,6\\&\frac{\partial A_i(z,t)}{\partial t}=\frac{\partial}{\partial z}\left((D_{M_i}+D_T(z,t))\frac{\partial A_i(z,t)}{\partial z}\right)-\frac{\partial}{\partial z}(v_W(z,t)+v_F+v_R(t))A_i(z,t)+\\&+\lambda_i A_{i-1}(z,t)-\lambda_i A_i(z,t),i=2-5,7-11\end{aligned}\right\}\qquad(4.2)$$

Then we denote the initial $A_i(z,0)=0$ and boundary conditions:

$$\left.\begin{aligned}&(D_{M_i}+D_T(z,t))\frac{\partial A_i(z,t)}{\partial z}\bigg|_{z=0}-v_W(z,t)A_i(z,t)\big|_{z=0}=q_i(t);i=1,6\\&(D_{M_i}+D_T(z,t))\frac{\partial A_i(z,t)}{\partial z}\bigg|_{z=0}-(v_W(z,t)+v_F+v_R(t))A_i(z,t)\big|_{z=0}=0;i=2-5,7-11\\&A_i(z,t)\to 0,z\to\infty\end{aligned}\right\}\qquad(4.3)$$

Here $A_i(z,t)$ is the volumetric activity function of the *i*-th radionuclide, Bq/m^3; indices *i*=1-5 correspond to radon ^{222}Rn and its decay products, respectively: ^{218}Po (RaA), ^{214}Pb (RaB), ^{214}Bi (RaC) and ^{214}Po (RaC'); indices *i*=6-11 correspond to thoron ^{220}Rn and its decay products, respectively: ^{216}Po (ThA), ^{212}Pb (ThB), ^{212}Bi (ThC), ^{212}Po (ThC'), and ^{208}Tl (ThC");

q_i(t) - radon (*i*=1) and thoron (*i*=6) flux density function from the ground surface, Bq/м2·c-^{1};

D_M - molecular diffusion coefficient, m^2/s;

D_T(z,t) - atmospheric turbulence coefficient function, m^2/s;

v_W(z,t) - function of the vertical component of wind speed, m/s;

v_F- velocity of deposition under the action of gravity, m/s;

v_R(t) - function of the velocity of aerosol particles washing out of the atmosphere by precipitation, m/s;

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

The component v_W is positive when the wind is upward away from the ground, and negative when the wind is toward the ground. In contrast to the transport in the air of the premises, the deposition velocity on the surface is not taken into account here.

The nuclear-physical characteristics used in the calculations are given in Table 4.1.

Table 4.1 – Nuclear-physical characteristics of nuclides

	Index	Decay constant, s^{-1}	D_M, m^2/s
^{222}Rn	1	2.100E-06	1.20E-05
^{218}Po	2	3.790E-03	1.00E-06
^{214}Pb	3	4.310E-04	1.20E-05
^{214}Bi	4	5.860E-04	1.20E-05
^{214}Po	5	4.230E+03	1.20E-05
Tn (^{220}Rn)	6	1.250E-02	1.20E-05
^{216}Po	7	4.780E+00	1.20E-05
^{212}Pb	8	1.810E-05	1.20E-05
^{212}Bi	9	1.910E-04	1.20E-05
^{212}Po	10	2.320E+06	1.20E-05
^{208}Tl	11	3.790E-03	1.20E-05

During the precipitation period, the integral values of radionuclide activity (column height h) are expressed using the following system of equations [5]:

$$\begin{cases} \dfrac{dA^h_{Rn}(t)}{dt} = q_{Rn} - \lambda_{Rn} \cdot A^h_{Rn}(t); \\ \dfrac{dA^h_{Po}(t)}{dt} = \lambda_{Po} \cdot A^h_{Rn}(t) - (\lambda_{Po} + L(t)) \cdot A^h_{Po}(t); \\ \dfrac{dA^h_{Pb}(t)}{dt} = \lambda_{Pb} \cdot A^h_{Po}(t) - (\lambda_{Pb} + L(t)) \cdot A^h_{Pb}(t); \\ \dfrac{dA^h_{Bi}(t)}{dt} = \lambda_{Bi} \cdot A^h_{Pb}(t) - (\lambda^t_{Bi} + L(t)) \cdot A^h_{Bi}(t), \end{cases} \quad (4.4)$$

where $\lambda_{Rn}, \lambda_{Po}, \lambda_{Pb}, \lambda_{Bi}$ - radioactive decay constants of the corresponding isotopes, s^{-1}; L - washout constant, s^{-1}.

The washout constant (s^{-1}) depends on the type of precipitation, the spectrum of rain drops, and the intensity of precipitation. It is calculated by the formula:

$$L = k_r k_0 I, \quad (4.5)$$

where I - precipitation intensity, mm/h; k_r - is the standard value of the absolute leaching capacity of rain (for all nuclides except noble gases it is taken equal to 10^{-5} h/(мм·с)); k_0 - relative leaching capacity of other types of precipitation, given in Table 4.2.

Table 4.2 – Relative leaching capacity for different types of sediments

Type of precipitation	k_0
Rain	1.0
Rain and Thunderstorms	1.1
Snow and rain	2.4
Downpour	2.8
Snow	3.0
Frost	4.5
Fog	5.0

Equations (4.4) and (4.6), whose solution makes it possible to determine the activity of radionuclides deposited during liquid atmospheric precipitation in the atmosphere and on the ground surface, take into account the processes of radioactive transformations of short-lived radon DPR in the atmosphere and on the ground surface as well as the atmospheric clearance of radionuclides.

We assume that at the moment of the beginning of atmospheric precipitation

$$A^{s0}_{Po} = A^{s0}_{Pb} = A^{s0}_{Bi} = 0 .$$

The logic in system (4.6) is that it describes the increase of activity at the soil surface. Therefore, the washout constant in the system (4.6) in the right part of the equation has a positive sign because it reflects the increase of activity on the soil surface due to the washout of substances from the air environment.

$$\begin{cases} \dfrac{dA^{s}_{Po}(t)}{dt} = L(t) \cdot A^{h}_{Po}(t) - \lambda_{Po} \cdot A^{s}_{Po}(t); \\ \dfrac{dA^{s}_{Pb}(t)}{dt} = L(t) \cdot A^{h}_{Pb}(t) + \lambda_{Pb} \cdot A^{s}_{Po}(t) - \lambda_{Pb} \cdot A^{s}_{Pb}(t); \\ \dfrac{dA^{s}_{Bi}(t)}{dt} = L(t) \cdot A^{h}_{Bi}(t) + \lambda_{Bi} \cdot A^{s}_{Pb}(t) - \lambda_{Bi} \cdot A^{s}_{Bi}(t). \end{cases} \tag{4.6}$$

Let's imagine $A^{s}_{Pb^{214}}(t)$ and $A^{s}_{Bi^{214}}(t)$ in the following way:

$$A^{s}_{Pb^{214}}(t) = A^{h}_{Pb^{214}}(t=0) - A^{h}_{Pb^{214}}(t) = \frac{q_{Rn}}{\lambda_{Rn}} - A^{h}_{Pb^{214}}(t);$$

$$A^{s}_{Bi^{214}}(t) = A^{h}_{Bi^{214}}(t=0) - A^{h}_{Bi^{214}}(t) = \frac{q_{Rn}}{\lambda_{Rn}} - A^{h}_{Bi^{214}}(t).$$

The activity of radon daughter decay products precipitated by liquid precipitation from the atmosphere onto the ground surface changes symmetrically and mirror-like in the atmosphere with respect to the activity of these daughter radon decay products on the ground surface, which can be observed in Figure 4.1 [5].

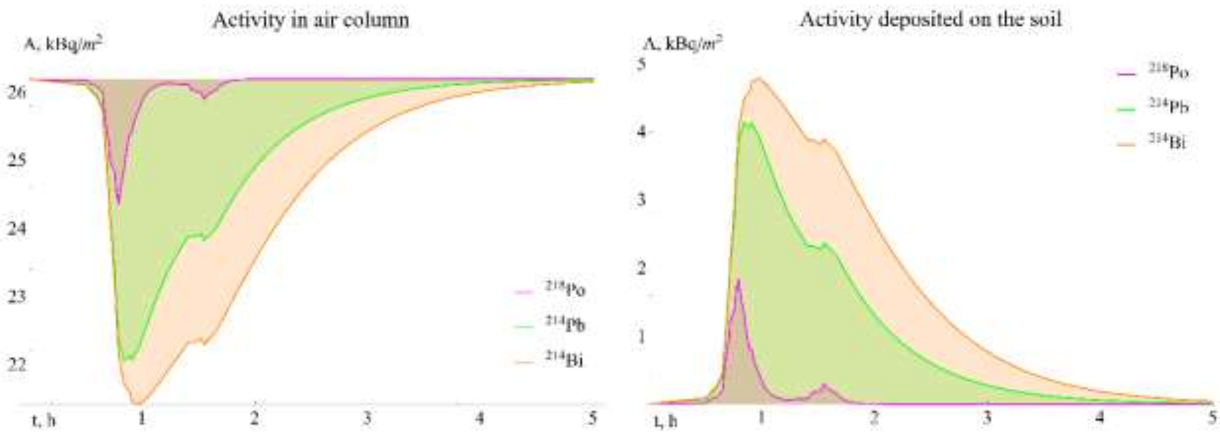


Figure 4.1 – Dynamics of activity of daughter radon decay products in the atmosphere and on the soil surface during precipitation

The system of equations (4) is solved with constant coefficients and initial conditions:

$$A^{h}_{Rn^{222}}(t=0) = A^{h}_{Po^{218}}(t=0) = A^{h}_{Pb^{214}}(t=0) = A^{h}_{Bi^{21}}(t=0) = \frac{q_{Rn}}{\lambda_{Rn}}. \quad (4.7)$$

As part of the simulation in Wolfram Mathematica, the following dependencies were plotted:

1) frost

For the analysis we model the case of drizzle with intensities of 0.1 and 0.25 mm/h. To compare the degrees of decrease in the volumetric activity of ^{218}Po, 214Pb, ^{214}Bi depending on the time of precipitation, we consider the duration of 3 and 6 hours.

The results of modeling are shown in Figures 4.2-4.5.

The results of determining the degrees of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi are summarized in Table 4.3.

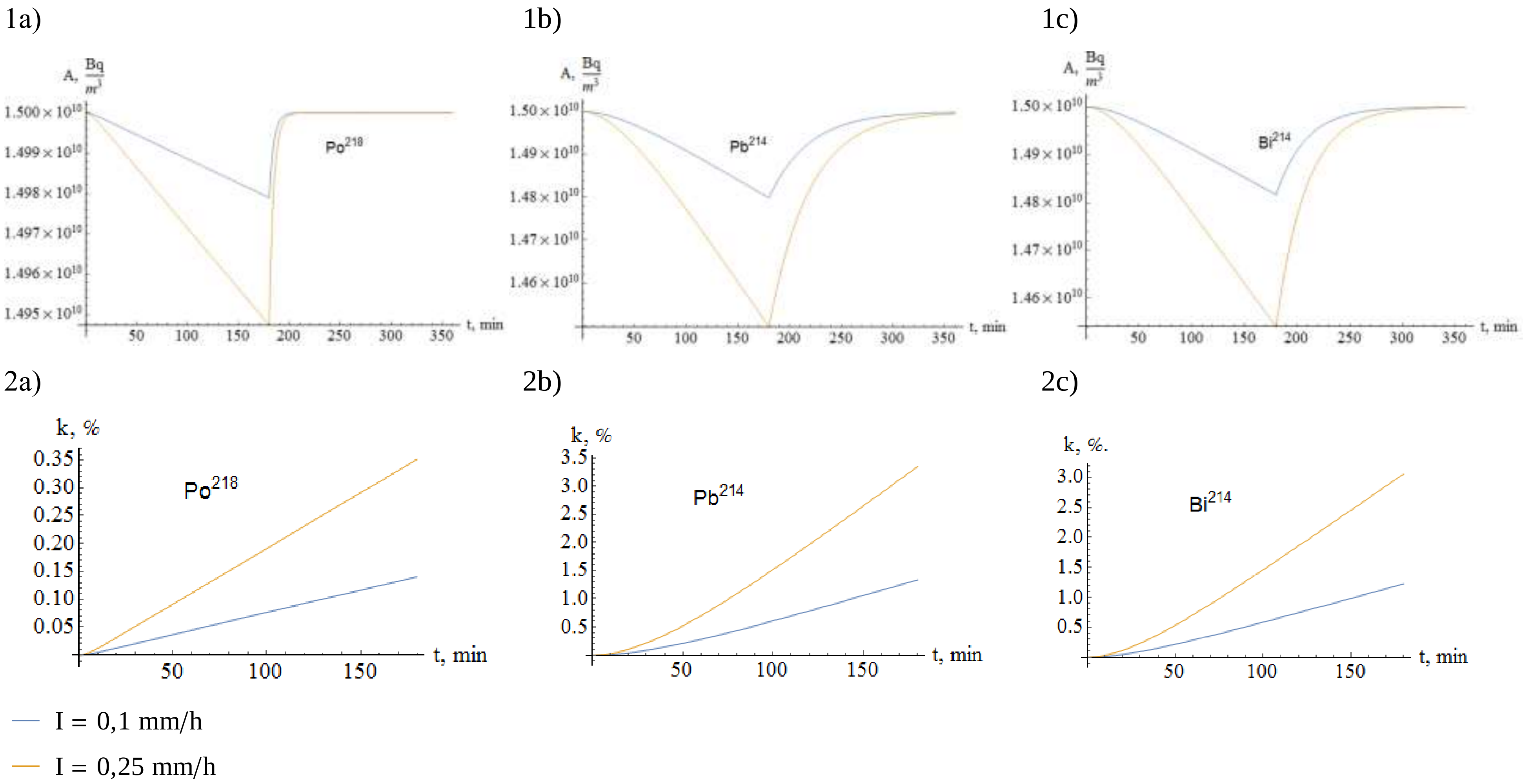


Figure 4.2 - Dynamics of temporal activity of ^{222}Rn daughter decay products in the atmosphere, at different drizzle intensities, precipitation time - 3 h (1a, 1b, 1c) with corresponding degrees of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

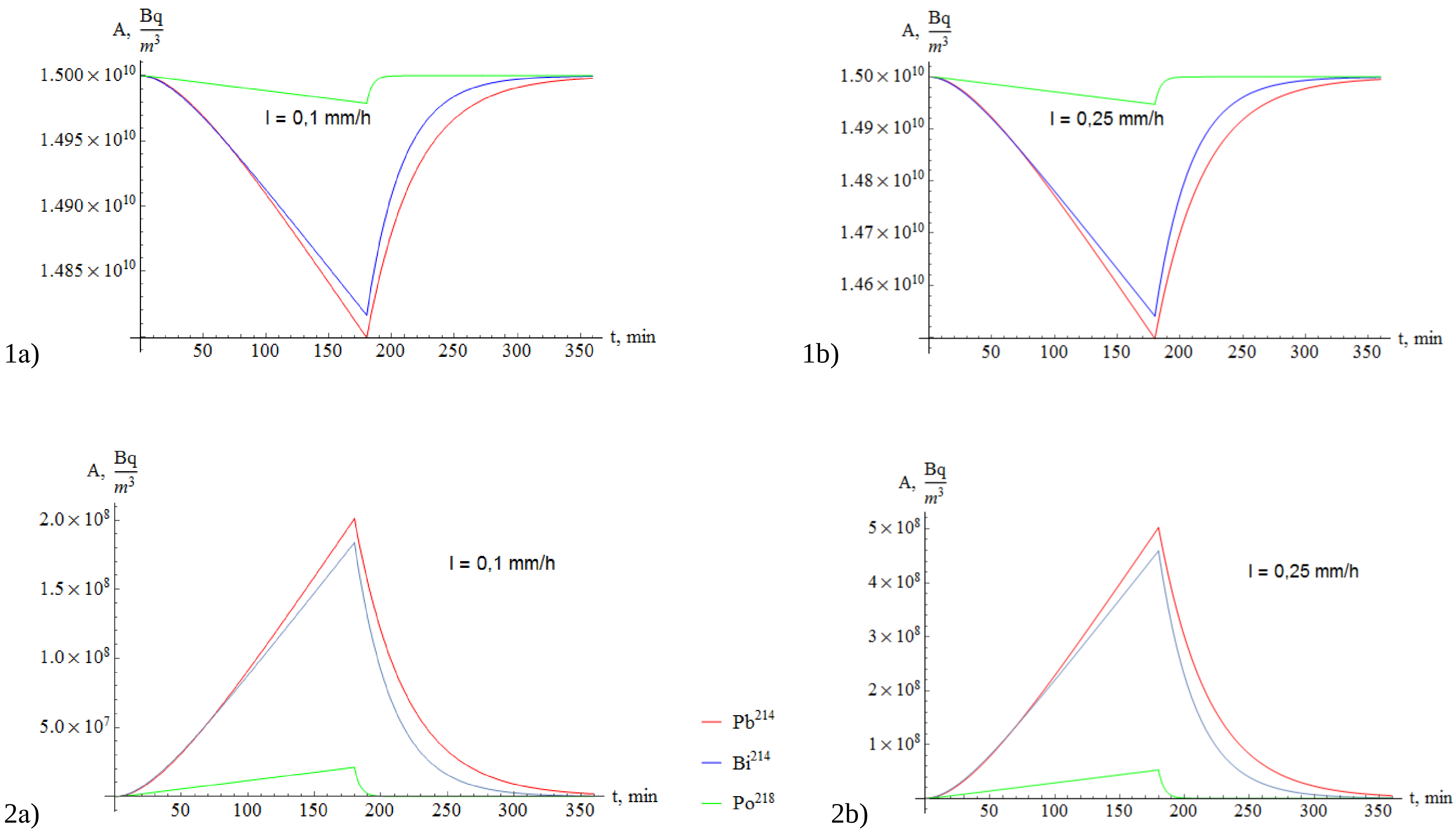


Figure 4.3 - Dynamics of temporal activity of ^{222}Rn daughter decay products, in the atmosphere (1a, 1b) and on the ground surface (2a, 2b), at different drizzle intensities, precipitation time - 3 h

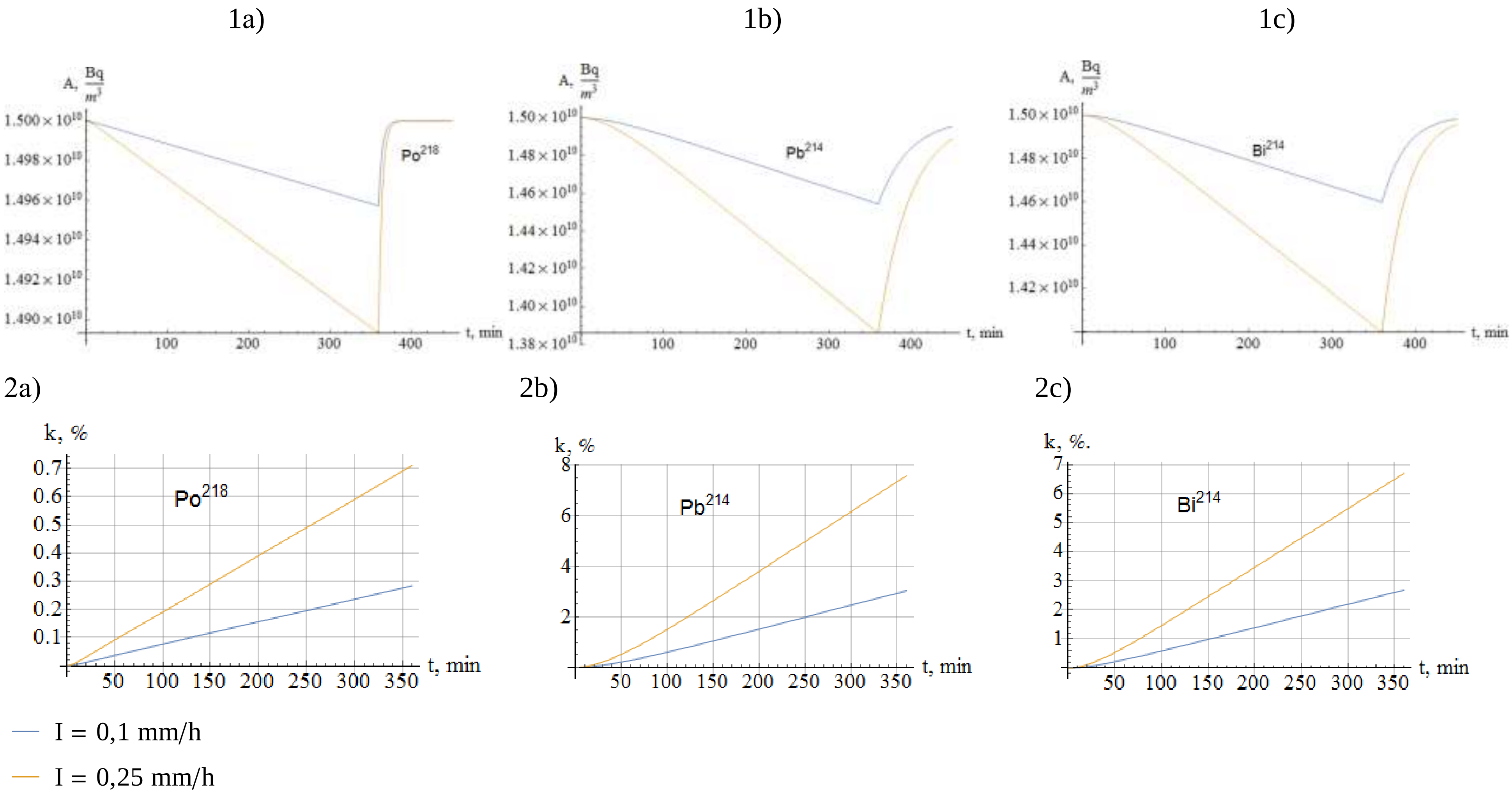


Figure 4.4 - Dynamics of temporal activity of ^{222}Rn daughter decay products in the atmosphere, at different intensity of drizzle, precipitation time - 6 h (1a, 1b, 1c) with corresponding degrees of decrease in volumetric activity ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

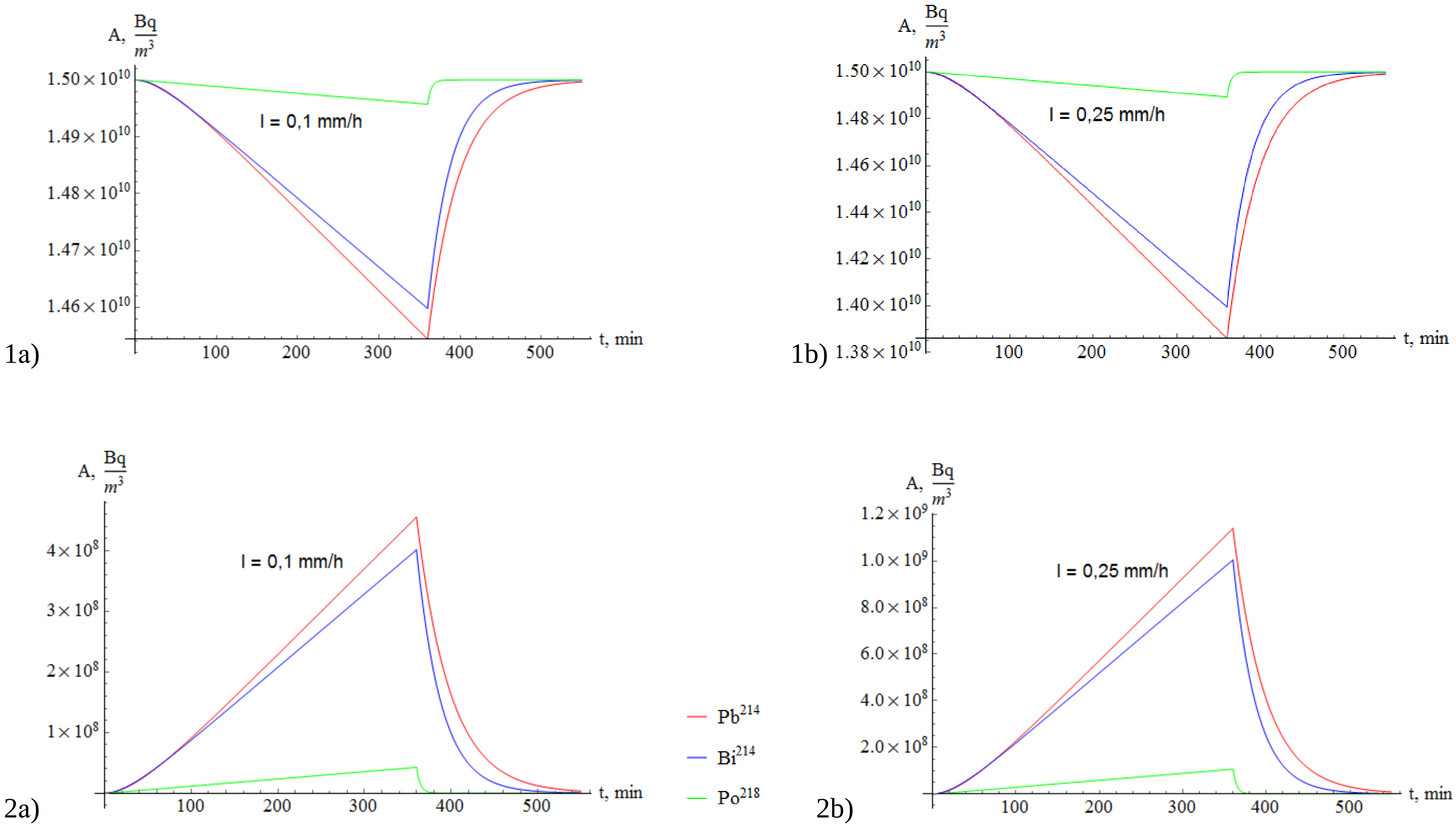


Figure 4.5 - Dynamics of temporal activity of ^{222}Rn daughter decay products, in the atmosphere (1a, 1b) and on the ground surface (2a, 2b), at different intensities of drizzle, precipitation time - 6 h

2) rain

For the analysis, we model the case of rain with intensities of 2.5, 5, and 10 mm/h. To compare the degrees of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi depending on the time of precipitation we consider the duration of 1, 3 and 6 hours.

The results of modeling are shown in Figures 4.6 - 4.9.

The results of determining the degrees of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi are summarized in the general Table 4.3.

3) downpour

For the analysis, we simulate the following cases of a downpour: downpour intensity 120 mm/h, duration 10 min; downpour intensity 40 mm/h, duration 30 min; downpour intensity 20 mm/h, duration 60 min.

Simulation results are presented in Figures 4.10 to 4.13.

The results of determining the degrees of ^{218}Pho, ^{214}Pb, ^{214}Bi volumetric activity decrease are summarized in the general Table 4.3.

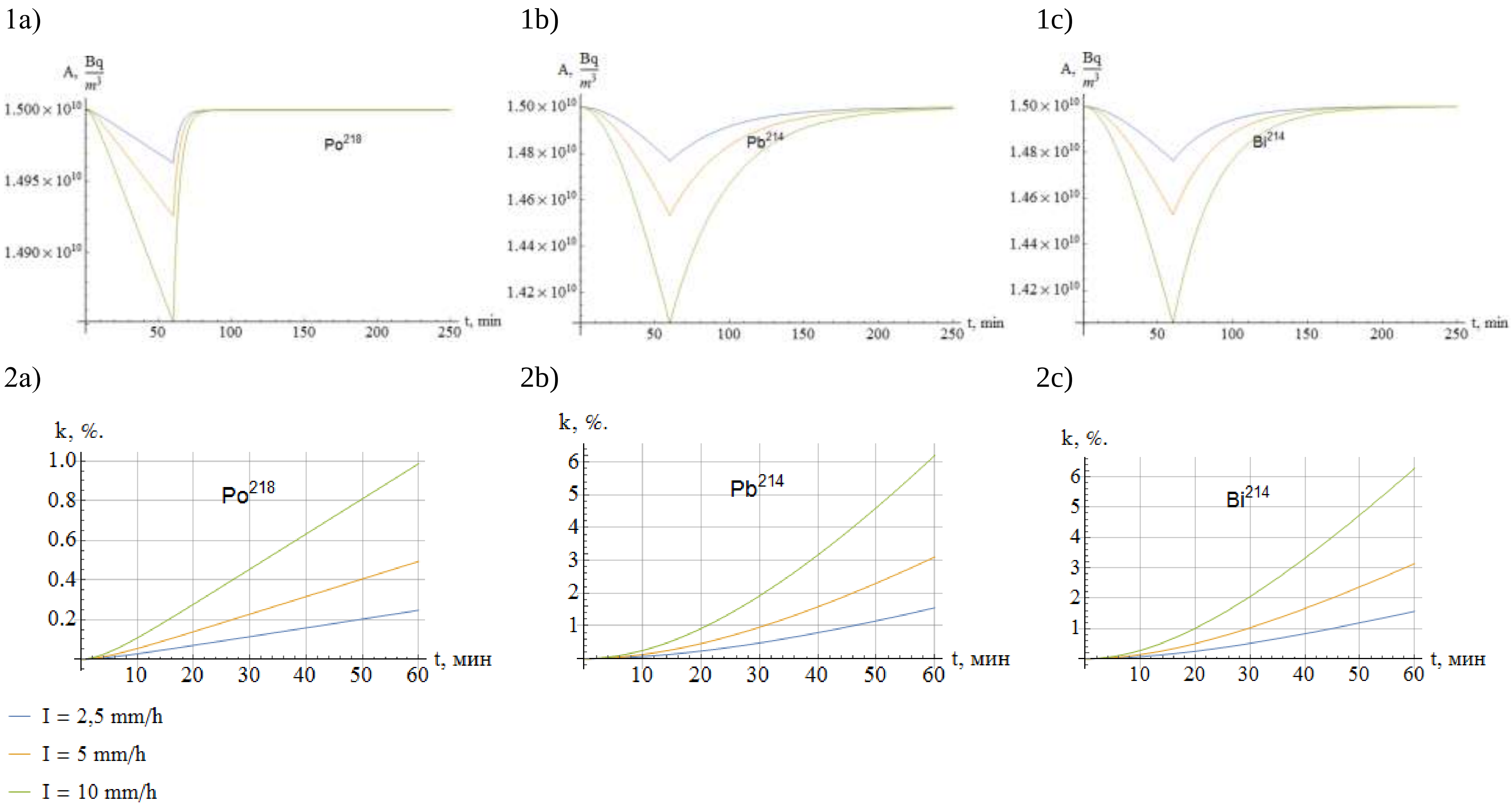


Figure 4.6 - Dynamics of temporal activity of ^{222}Rn daughter decay products in the atmosphere, at different rain intensities, precipitation time - 1 h (1a, 1b, 1c) with corresponding degrees of decrease in volumetric activity ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

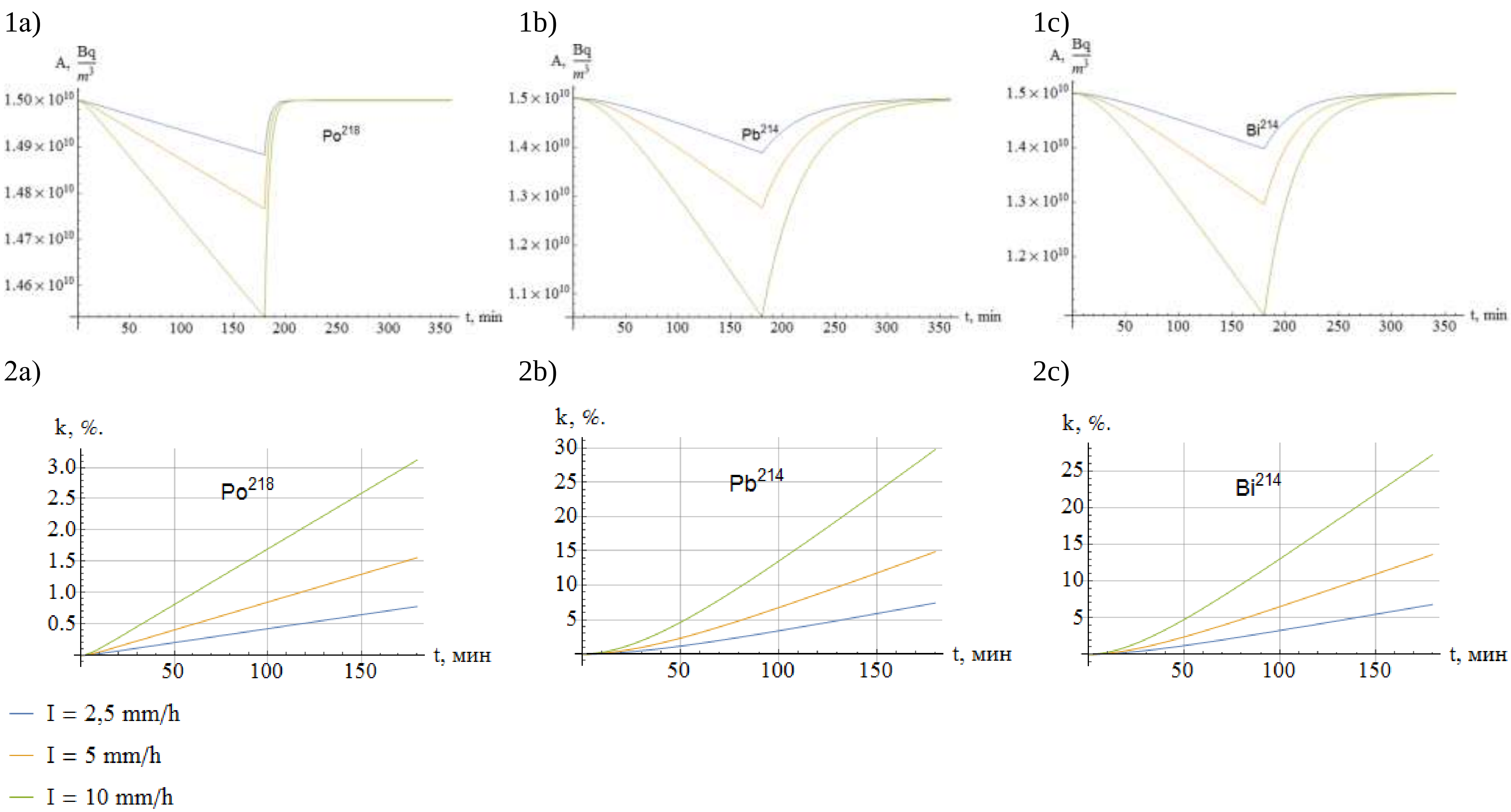


Figure 4.7 - Dynamics of temporal activity of ^{222}Rn daughter decay products in the atmosphere, at different rain intensities, precipitation time - 3 h (1a, 1b, 1c) with corresponding degrees of decrease in volumetric activity ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

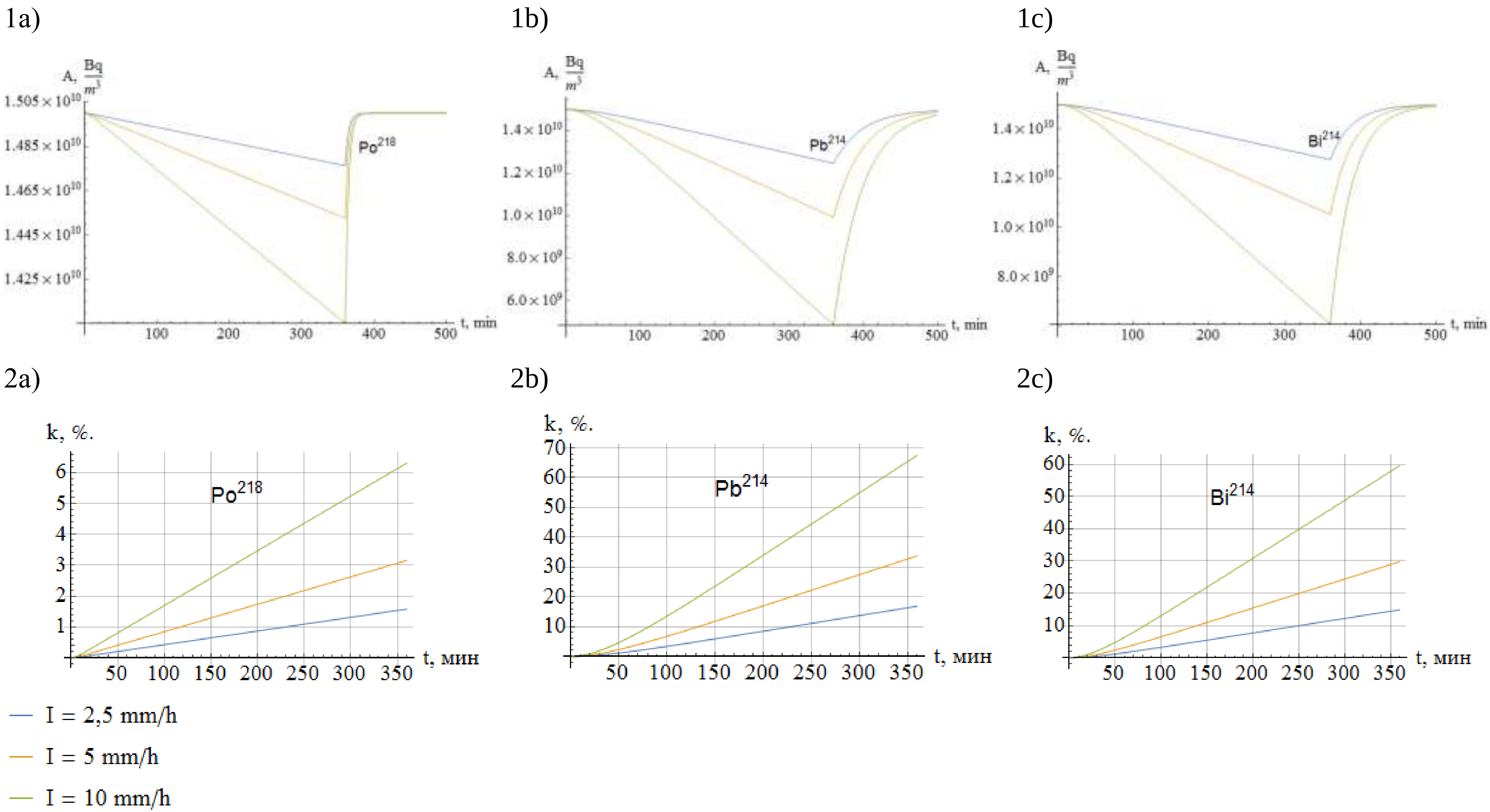


Figure 4.8 - Dynamics of temporal activity of ^{222}Rn daughter decay products in the atmosphere, at different rain intensities, precipitation time - 6 h (1a, 1b, 1c) with corresponding degrees of decrease in volumetric activity ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

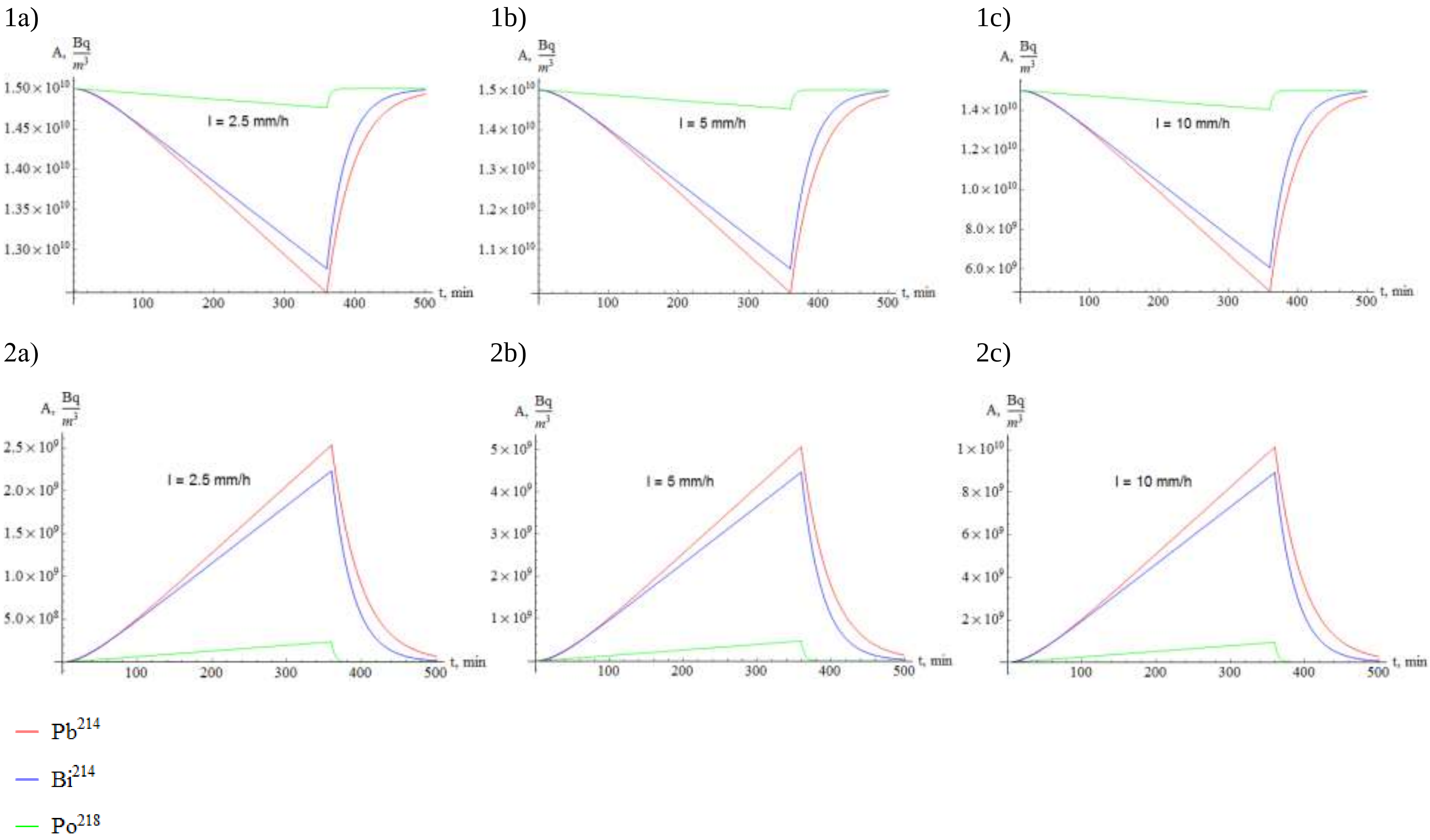


Figure 4.9 - Dynamics of temporal activity of 222Rn daughter decay products in the atmosphere (1a, 1b, 1c) and on the Earth surface (2a, 2b, 2c), at different rain intensities, precipitation time - 6 h

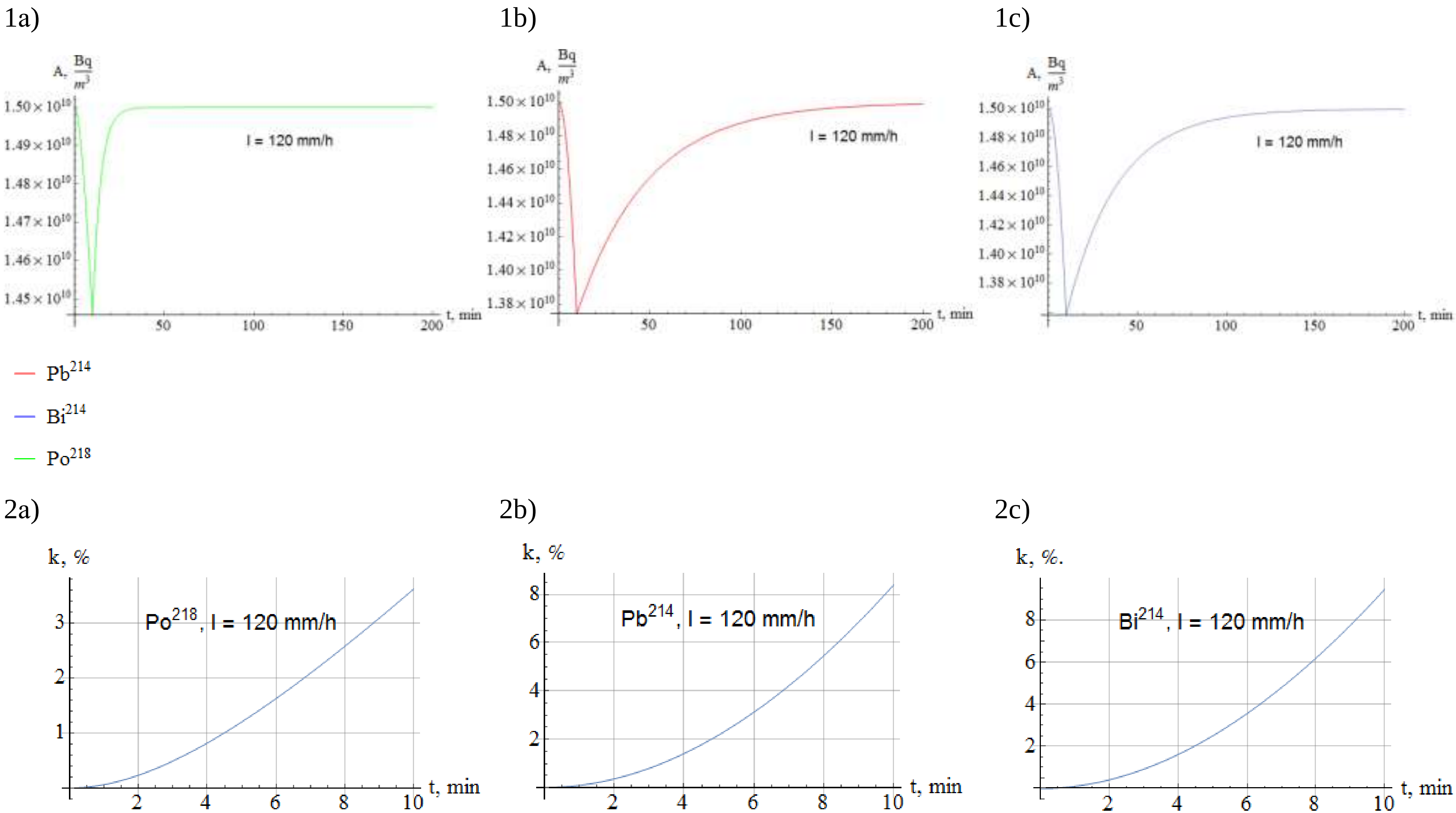


Figure 4.10 - Dynamics of temporal activity of ^{222}Rn daughter decay products in the atmosphere at downpour intensity of 120 mm/h, precipitation time - 10 min (1a, 1b, 1c) with corresponding degrees of decrease in volume activity of ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

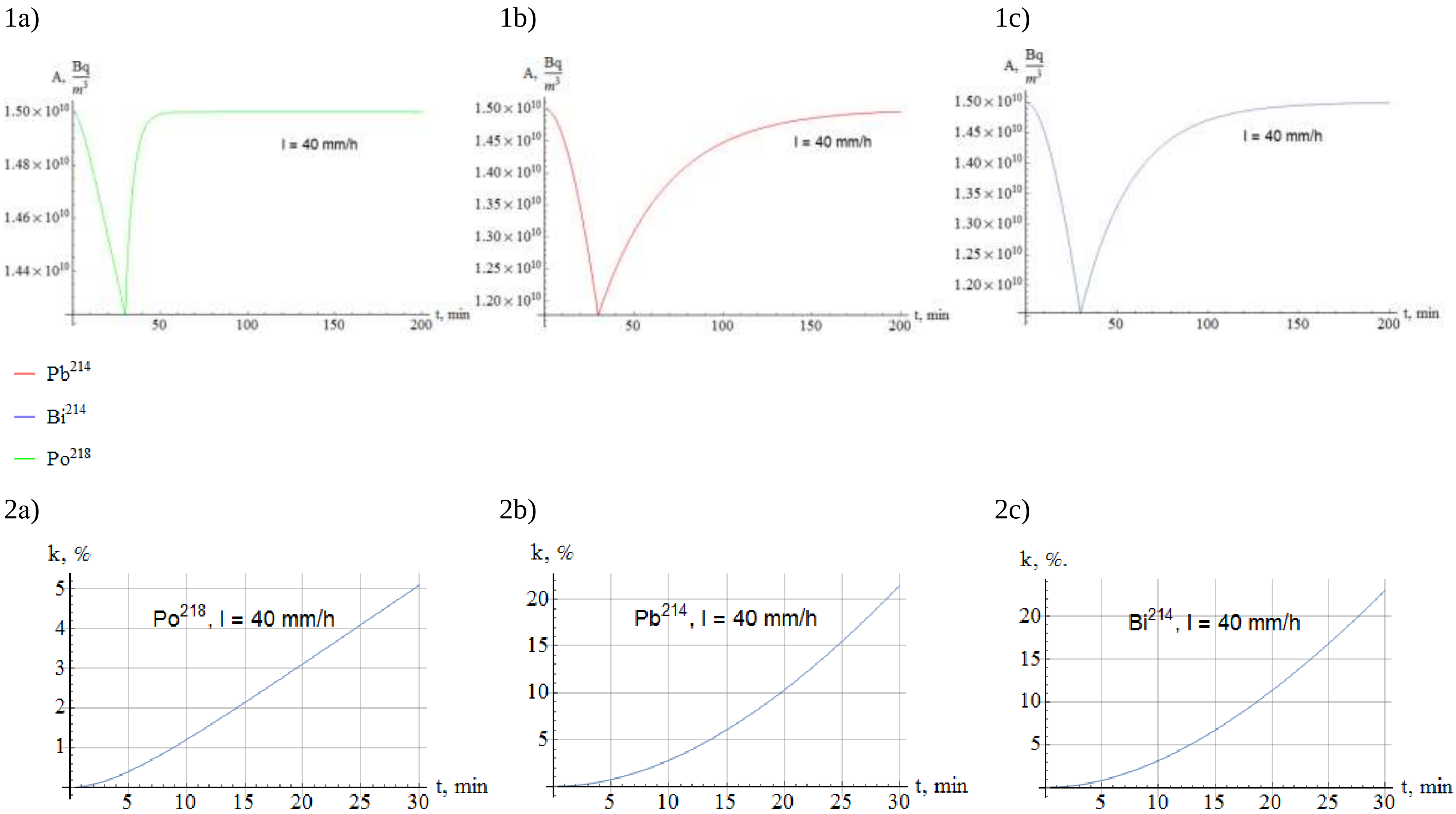


Figure 4.11 - Dynamics of temporal activity of ^{222}Rn daughter decay products in the atmosphere at intensity of a downpour of 40 mm/h, precipitation time - 30 min (1a, 1b, 1c) with corresponding degrees of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

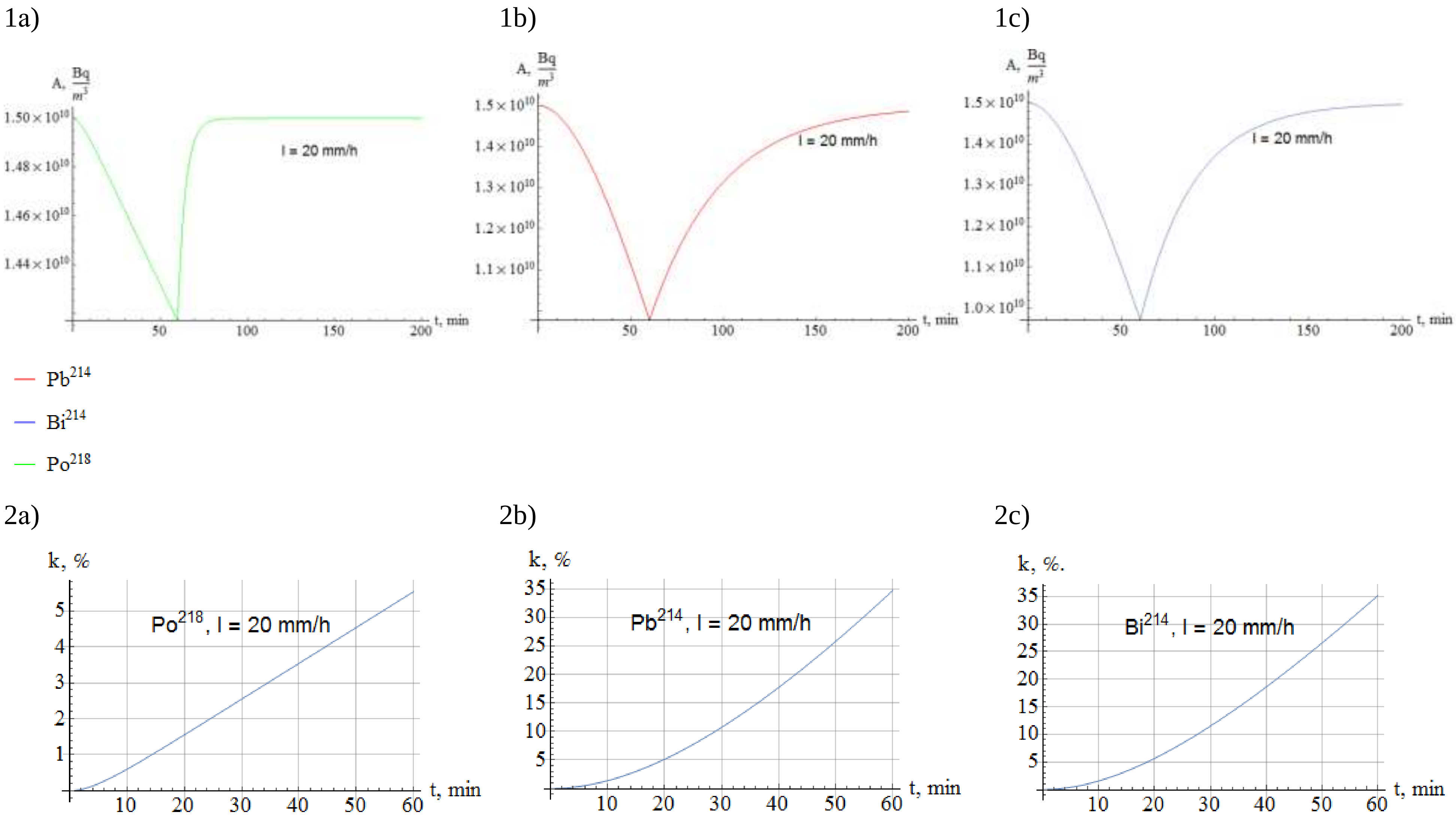


Figure 4.12 - Dynamics of the temporal activity of ^{222}Rn daughter decay products in the atmosphere at the downpour intensity of 20 mm/h, precipitation time - 60 min (1a, 1b, 1c) with corresponding degrees of decrease in the volume activity of ^{218}Po, ^{214}Pb, ^{214}Bi (2a, 2b, 2c)

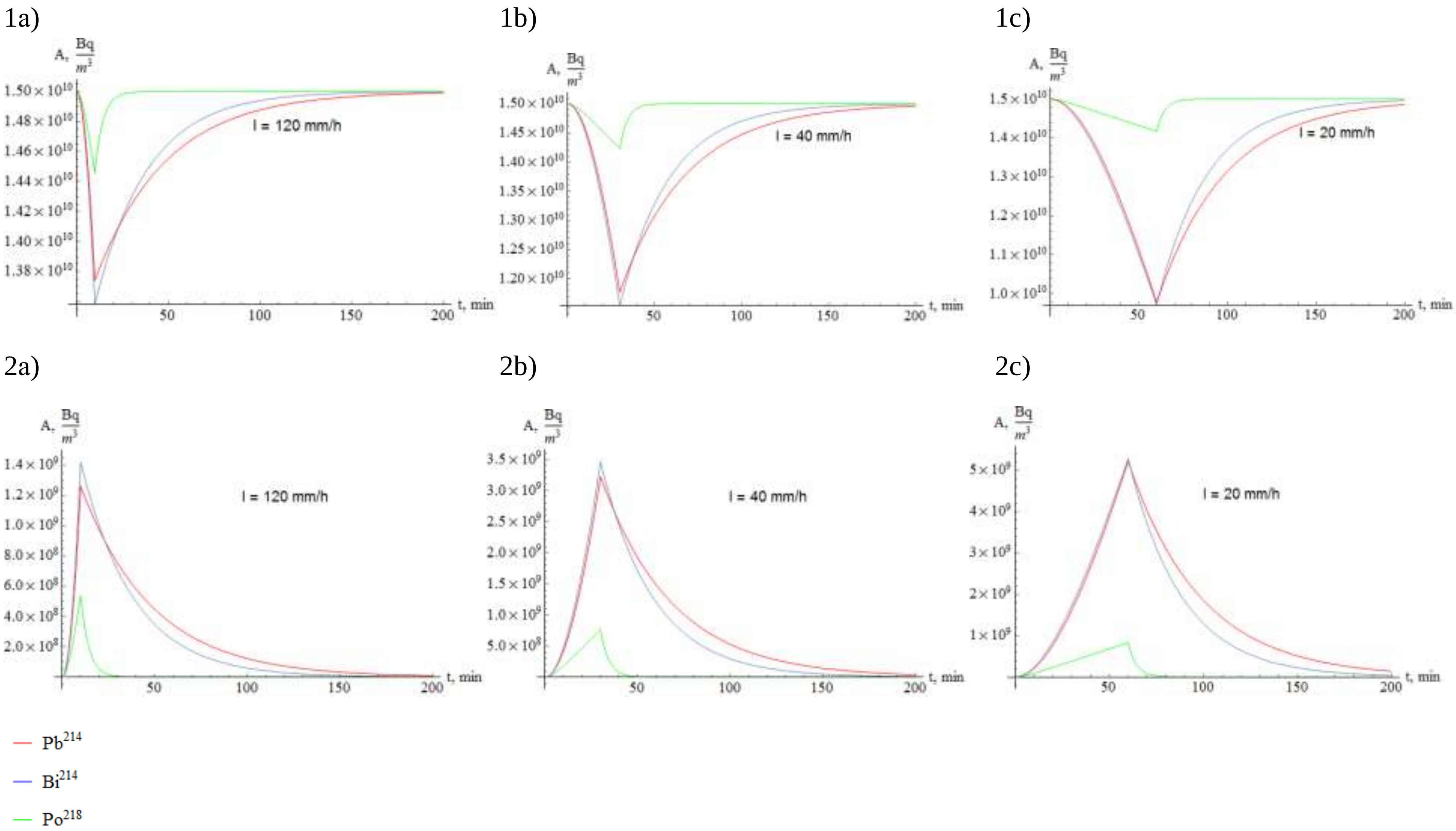


Figure 4.13 - Dynamics of temporal activity of ^{222}Rn daughter decay products, in the atmosphere (1a, 1b, 1c) and on the Earth surface (2a, 2b, 2c), at different storm intensities and precipitation time (1a, 2a - 10 min, 1b, 2b - 30 min, 1c, 2c - 60 min)

Table 4.3 - Summary table of the obtained results on determining the degrees of reduction of volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi depending on the type of liquid precipitation, its duration and intensity

Precipitation time, min	Radon DPR	Precipitation intensity, mm/h							
		frost		rain			downpour		
		0.1	0.25	2.5	5	10	20	40	120
10	^{218}Po								3.6
	^{214}Pb								8.5
	^{214}Bi								7.5
30	^{218}Po							5.1	
	^{214}Pb							22	
	^{214}Bi							23	
60	^{218}Po			0.25	0.5	1	5.6		
	^{214}Pb			1.6	3	6.2	35		
	^{214}Bi			1.5	3.2	6.3	35		
180	^{218}Po	0.14	0.35	0.8	1.6	3.2			
	^{214}Pb	1.3	3.4	8	15	30			
	^{214}Bi	1.3	3.1	7	14	28			
360	^{218}Po	0.28	0.7	1.6	3.2	6.3			
	^{214}Pb	3	7.5	16	34	68			
	^{214}Bi	2.6	6.6	15	30	60			

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

Группа	ФИО
0АМ13	Чуприна Анастасии Владимировне

Школа	ИШЯТ	**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»:	
Стоимость ресурсов научного исследования (НИ): материально-технических, энергетических, финансовых, информационных и человеческих	Бюджет проекта – не более 426220,4 руб., в т.ч. затраты по оплате труда – не более 198933,5 руб.
Нормы и нормативы расходования ресурсов	Значение показателя интегральной ресурсоэффективности – не менее 4,25 баллов из 5
Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования	Отчисления во внебюджетные фонды составляют 30%
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
Оценка коммерческого и инновационного потенциала НТИ	Технико-экономическое обоснование проекта, определение потенциальных потребителей результатов
Планирование процесса управления НТИ: структура и график проведения, бюджет.	Планирование работ по проекту. Расчет бюджета затрат, в том числе материальных затрат, затрат на оборудование и заработную плату сотрудников
Определение ресурсной, финансовой, экономической эффективности	Определение ресурсной, финансовой и экономической эффективности исследования
Перечень графического материала:	
Сегментирование рынка Оценка конкурентоспособности технических решений Матрица SWOT Диаграмма Ганта Сетевой план-график График проведения и бюджет НТИ Оценка ресурсной, финансовой и экономической эффективности НТИ	

Дата выдачи задания для раздела по линейному графику	13.03.2023

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	Чуприна Анастасия Владимировна		13.03.2023

ASSIGNMENT FOR THE SECTION
"FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING"

To the Student:

Group	FULL NAME
0AM13	Chuprina Anastasia Vladimirovna

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

Input data for the section "Financial Management, Resource Efficiency and Resource Saving":	
1. The cost of scientific research (SR) resources: material and technical, energy, financial, information and human	Project budget - not more than 426220 rubles, including labor costs - not more than 198934 rubles.
2. Norms and standards of resource consumption	The value of the integral resource efficiency indicator - at least 4.25 points out of 5
3. the taxation system used, tax rates, deductions, discounting and lending	Contributions to non-budgetary funds are 30%
List of issues to be researched, designed and developed:	
1. Assessment of the commercial and innovative potential of STI	Feasibility study of the project, identifying potential consumers of the results
2. Planning the STI management process: structure and schedule, budget.	Planning work on the project. Calculation of the cost budget, including material costs, equipment costs, and employee salaries
3. Determination of resource, financial, and economic efficiency	Determination of resource, financial and economic efficiency of the study
A list of graphic material:	
Market segmentation Assessing the competitiveness of technical solutions SWOT matrix Gantt chart Network plan schedule STI timeline and budget Assessment of resource, financial and economic efficiency of STI	

Assignment date for the line graph section	13.03.2023

The assignment was given by a consultant:

Position	FULL NAME	Academic degree, rank	Signature	Date
Assistant professor of SSHD of SCEE	Lyubov Yuryevna Spitsyna	PhD in Economics		

The assignment was accepted for execution by the student:

Group	FULL NAME	Signature	Date
0AM13	Chuprina Anastasia Vladimirovna		13.03.2023

5. Financial Management, Resource Efficiency and Resource Saving

Introduction

The purpose of this section is to assess the prospects of scientific research, planning the financial and commercial value of the research project, the development of a management mechanism. Commercial attractiveness of scientific research is determined by how quickly and successfully the developer will answer the following questions: whether the product will be in demand in the market, what will be its price, what is the budget of the scientific project, what time will be required to promote the product in the market, etc.

Achievement of the goal is ensured by solving the following tasks:

- assessment of commercial potential and prospects for research;
- planning of research work;
- calculation of the budget of research work;
- Determination of resource, financial, social efficiency of research.

5.1 Assessment of commercial potential and prospects of scientific research in terms of resource efficiency and resource conservation

5.1.1 Potential consumers of the research results

This master's thesis examines the relationship between gamma ray bursts and the characteristics of rains and showers.

Increased radiation gamma background in the form of bursts of various shapes and durations observed during periods of liquid precipitation, this is confirmed by the data obtained during the study.

The data on gamma-background obtained at the experimental site of the geophysical observatory IMKES SB RAS through the use of gamma-radiation detectors BDKG-03 were used for the study.

Conducting instrumental measurements of radionuclide activity, □-background by air column height is difficult due to the complexity of using devices at height, their inaccuracy, difficulty in fixing by points the measured values, impossibility to perform measurements promptly. In this case, it is realistic to use exactly the results of modeling. The considered topic, concerning the degree of atmospheric purification, is of interest, first of all, for radiation monitoring.

The main task of radiation monitoring is to identify as accurately as possible the causes, the nature of the registered gamma background bursts.

Various research institutes and operational radiological services may be interested in this research.

Based on all of the above, a map of service market segmentation is constructed.

Table 5.1 - Service market segmentation map

		Organization	
		Scientific research institutes	Operational radiological services
Area of application	Results of research work		
	Ability to assess and predict the degree of purification of the atmosphere from radionuclides		

In this paragraph, the main potential consumers of the study under consideration were analyzed, these are research institutes and operational radiological services.

5.1.2 Analysis of competitive technical solutions

The analysis of competitive technical solutions from the position of resource efficiency and resource conservation allows us to evaluate the comparative effectiveness of scientific development.

For the analysis of competitive technical solutions, the data on experimental measurements by detectors are used. The position of the development and competitive method is evaluated for each indicator by expert way on a five-point scale, with 1 point denoting the weakest position, 5 points - respectively, the strongest position. The weights of the indicators, determined by the expert way, in the sum should be unity [19].

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

$$K = \sum B_i \cdot Б_i, \ (3.1)$$

where K - competitiveness of the scientific development or competitor; B_i - weight of the indicator (share); $Б_i$ - weighted average value of the i-th indicator; B_{k1} - measurements by detectors.

It is reasonable to carry out this analysis with the help of the scorecard below.

Table 5.2 - Scorecard for comparison of competitive technical solutions (developments)

Evaluation Criteria	**Weight of the criterion**	**Points**		**Competitiveness**	
		Б_ф	***Б_{к1}***	***К_ф***	***К_{к1}***
1	**2**	**3**	**4**	**5**	**6**
Technical criteria for evaluating resource efficiency					
1. Reliability of the data obtained	0.30	4	4	1.20	1.20
2. No influence of atmospheric conditions on the eusperiment	0.15	4	3	0.60	0.45
3. Ease of experimentation	0.12	5	4	0.60	0.48
4. Safety of the experiment	0.10	4	3	0.40	0.30
5. Data runtime	0.10	3	3	0.30	0.30
6. Availability of expensive equipment	0.05	5	3	0.25	0.15
Economic criteria for evaluating efficiency					
1. The cost of materials	0.10	5	2	0.50	0.20
2. Financing of scientific development	0.05	5	2	0.25	0.10
3. Competitiveness	0.03	4	4	0.12	0.12
Total	**1**			**4.22**	**3.30**

Note: in Table 5.2 the indicators with index "ф" characterize the development under consideration, and index "к1" corresponds to the method of monitoring the surface atmosphere by alpha- and beta-detectors.

The results of the table show that the considered scientific development is able to interest partners and investors due to its resource efficiency, different from experimental measurements with detectors.

5.1.3 SWOT Analysis

The SWOT analysis (Strengths; Weaknesses; Opportunities; Threats) is a comprehensive analysis of a research project. This type of analysis is used to study the external and internal environment of the project as a whole.

SWOT-analysis is to describe the strengths and weaknesses of the project, to identify opportunities and threats to the project that have appeared or may appear in its external environment [19].

Strengths are factors that characterize the competitiveness of the research project. Strengths indicate that the project has a certain advantage or resources that are special in terms of competition. Thus, strengths are resources or opportunities that are available to the project management and can be effectively used to achieve the goals.

Weaknesses are shortcomings, omissions, limitations of the research project that prevent the achievement of the goals.

Opportunities include some preferable present or future situations arising in the environment of the project, for example, trends, changes, needs that can support the demand for the project results and help the project management to improve its competitive position.

Threats are any undesirable situations, trends, changes in environmental conditions that are destructive or threatening to the competitiveness of the project in the present or future. A threat can be a barrier, constraint, or anything else that can cause problems, destruction, harm, or damage to the project.

Table 5.3 presents the SWOT analysis of the research work.

Table 5.3 - SWOT Analysis

	Strengths of the research project: C1. Reliability of the data obtained; C2. Novelty of scientific research; C3. Extension of the boundaries of applicability; C4. Safety of the research; C5. Qualified personnel.	Weaknesses of the research project: Sl1. Lack of funding; Sl2. Significant time for processing the results; Sl3. Lack of information about the results of this type of research.
Capabilities: B1. Use of TPU's innovative infrastructure; B2. Novelty of the research will lead to the emergence of stakeholders.	The results of the analysis of the interactive matrix of the draft fields "Strengths and Opportunities": 1) increase in demand for such research due to distribution among various organizations and universities; 2) the priority of research in comparison with competitors due to proper reliability and security.	The results of the analysis of the interactive matrix of the field project "Weaknesses and Opportunities": 1) lack of a large number of research orders; 2) improvement of gamma detectors in the future will reduce their measurement error.
Threats: У1. High competition due to modernization of other devices; У2. Lack of funding or untimely funding from the university and the state.	1) high reliability and low cost of data increases competitiveness; 2) the novelty of the idea gives an advantage over competitors.	1) stagnation of research due to lack of funding; 2) a decrease in the cost of gamma detectors will make it possible to purchase an additional number of them to expand the field of dose rate measurement, which in turn will lead to an increase in demand for the methodology

In order to identify the extent of the need for strategic change, an interactive matrix is built, as shown below. Its use helps to understand the various combinations of interrelationships of the SWOT matrix areas.

Table 5.4 - Interactive project matrix

Strengths of the research project						
Features		C1	C2	C3	C4	C5
	B1	+	+	0	+	+
	B2	-	+	+	-	+

Note: "+" - significant compliance of the strengths with the opportunities; "-" - insignificant compliance; "0" - doubt in the choice.

Based on the data of the interactive matrix, we can conclude that the strengths of the project are related to the opportunities of the external environment, due to them the project with a high probability can be implemented and be in demand in the market.

5.2 Project initiation

5.2.1 Project Goals and Outcome

This section provides information about the project stakeholders, the hierarchy of project goals, and the criteria for achieving the goals.

Project stakeholders are defined as individuals or organizations that are actively involved in the project or whose interests may be affected either positively or negatively in the course of implementation or as a result of project completion. Information on project stakeholders is presented in Table 5.5.

Table 5.5 - Project Stakeholders

Project stakeholders	Stakeholder expectations
Engineer	Adequate interpretation of gamma-background bursts, identification of the reasons that caused them. Determination and prediction of the degree of purification of the atmosphere from radionuclides by rainfall through mathematical modeling
Scientific research institutes	Development of a method for determining and predicting the degree of atmospheric radionuclide clearance from rainfall through mathematical modeling
Operational radiological services	Using a reliable method of determining the degree of purification of the atmosphere from radionuclides by rainfall, prompt and adequate response to gamma background bursts, and identifying the causes of gamma background fluctuations

Table 5.6 provides information about the hierarchy of project goals and criteria for achieving the goals.

Table 5.6 - Project goals and results

Project Objectives:	Conduct experimental studies of changes in gamma-radiation dose rate at the experimental site
	Identify the relationship between gamma-radiation power bursts and the characteristics of liquid precipitation
	Determine the degree of purification of the atmosphere from radionuclides depending on the characteristics of liquid atmospheric precipitation
Requirements for the result of the project	Reliable results of experimental studies of changes in gamma radiation dose rate at the experimental site
	The adequacy of the identified relationship between gamma-radiation power bursts and the characteristics of liquid atmospheric
	Comparison of the effect on the gamma background of rainfall with different characteristics
	Obtaining adequate values of the degree of purification of the atmosphere from radionuclides depending on the characteristics of liquid atmospheric precipitation

5.2.2 Project Organizational Structure

The following questions must be solved: who will be in the working group of this project, define the role of each participant in this project, as well as describe the functions performed by each of the participants and their labor costs. The data is summarized in Table 5.7.

Table 5.7 - Project Working Group

No	Full name, main place of work, position	Role in the project	Functions	Labor costs, days.
1	Valentina Stanislavovna Yakovleva, Professor of NFCD of SNSE, Doctor of technical sciences	Project Manager	Development of terms of reference, selection of research direction, coordination of developer's activities, evaluation of obtained results	27
2.	Chuprina Anastasia Vladimirovna, student of 0AM13	Engineer	Theoretical and experimental research, mathematical modeling as part of the project objectives	78
			Total:	105

5.3 Planning the research work

5.3.1 Structure of research work

Planning of a set of research work is carried out in the following order:

- determination of the structure of works within the framework of scientific research;
- defining the number of performers for each activity;
- definition of duration of works;
- construction of the schedule of scientific research.

To optimize the process it is convenient to use the classical method of linear planning and control. The result of such planning is a linear schedule of all types of work.

To carry out scientific research, a work group is formed, consisting, if necessary, of scientific staff and teachers, engineers, technicians and laboratory assistants, the number of groups can vary. For each type of planned work, an appropriate position of performers is established. In this study, a working group was formed, consisting of a manager and an engineer.

The order of stages and types of work in the performance of the EWC, as well as the distribution of performers by type of work is shown in the table below.

Table 5.8 - List of stages, works and distribution of performers

The main stages	Job number	Content of work	Position of the Performer
Development of terms of reference for research work	1	Drawing up, approval of the terms of reference	Manager
Choosing the direction of the study	2	Choosing the direction of the study	Manager
	3	Development of research methodology	Manager
	4	Planning work schedules	Manager Engineer
Theoretical and experimental research	5	Literature analysis	Engineer
	6	Conducting a practical calculation	Engineer
Summary and evaluation of results	7	Evaluating the effectiveness of the results	Manager Engineer
	8	Settlement processing	Engineer
	9	Writing an explanatory note	Engineer
	10	Preparing to defend your work	Engineer

5.3.2 Determination of labor input of research

The labor costs in most cases form the main part of the development cost, therefore, the important point is to determine the labor intensity of the work of each of the participants of scientific research.

The labor intensity of scientific research is estimated by expert way, it has a probabilistic character. For calculation we use the formula:

$$t_{ожi} = \frac{3 \cdot t_{\min i} + 2 \cdot t_{\max i}}{5}, \quad (5.1)$$

where $t_{ожi}$ - expected labor intensity of the implementation of the *i*-th work, man-days; $t_{\min i}$ - minimum possible labor intensity of the implementation of the given *i*-th work (optimistic estimate assuming the most favorable set of circumstances), man-days; $t_{\max i}$ - maximum possible labor intensity of the implementation of the given *i*-th work (pessimistic estimate assuming the most unfavorable set of circumstances), man-days.

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

$$T_{pi} = \frac{t_{ожі}}{Ч_i}, \quad (5.2)$$

where T_{pi} - the duration of the *i*-th job, working days; $t_{ожі}$ - expected labor intensity of the *i*-th job, man-days; $Ч_i$ - the number of performers performing simultaneous *i*-th job at this stage, man.

5.3.3 Development of the schedule of scientific research

The calendar plan of research work execution is developed with the construction of the schedule of research work execution in the form of Gantt diagrams. The Gantt chart is a horizontal ribbon diagram, on which the works are represented by stretched in time segments, characterized by the dates of the beginning and end of the works.

To build a Gantt chart, the duration of work in working days should be converted into calendar days:

$$T_{ki} = T_{pi} \cdot k, \quad (5.3)$$

where T_{ki} - duration of the *i*-th job, calendar days; T_{pi} - duration of the *i*-th job, working days; k - calendar coefficient to convert working time into calendar time.

$$k = \frac{T_{кг}}{T_{кг} - T_{вд} - T_{пд}}, \quad (5.4)$$

where $T_{кг}$ - number of calendar days per year (in 2022 and 2023 is 365 days); $T_{вд}$ - number of days off per year; $T_{пд}$ - number of holidays per year (in 2022 and 2023 the number of non-working days, that is, days off and holidays, is 118 days).

Based on the 2022 and 2023 data, the calendar factor is:

$$k = \frac{365}{365-118} = 1{,}48.$$

Based on all of the above, the table reflecting the temporal indicators is filled out.

Table 5.9 - Temporal indicators of scientific research

Performer	i	$t_{\min i}$, man-days	$t_{\max i}$, man-days	$t_{ожi}$ man-days	$Ч_i$, man	T_{pi}, working day.	T_{ki}, day.	
							calculation	rounded
Manager	1	1	2	1.4	1	1.4	2.07	2
Manager	2	1	2	1.4	1	1.4	2.07	2
Manager	3	2	4	2.8	1	2.8	4.14	4
Manager	4	2	4	2.8	1	2.8	4.14	4
Engineer	5	4	6	4.8	1	4.8	7.10	7
Engineer	6	14	30	26.4	1	26.4	39.07	39
Engineer	7	4	6	4.8	1	4.8	7.10	7
Manager	8	7	14	9.8	1	9.8	14.50	15
Engineer	9	4	6	4.8	1	4.8	7.10	7
Engineer	10	4	6	4.8	1	4.8	7.10	7
Engineer	11	4	6	4.8	1	4.8	7.10	7
Engineer	12	2	4	2.8	1	2.8	4.14	4
Total	-	49	90	71.4	-	71.4	-	105

5.3.4 Developing a schedule for the research project

As part of the planning of the research project it is necessary to build a calendar and a network schedule of the project.

The calendar schedule is presented in the form of a table with a breakdown by months and decades, the so-called Gantt chart. The activities on the schedule are highlighted with different shading to indicate the responsible performer.

Parameters of the network schedule are calculated graphically.

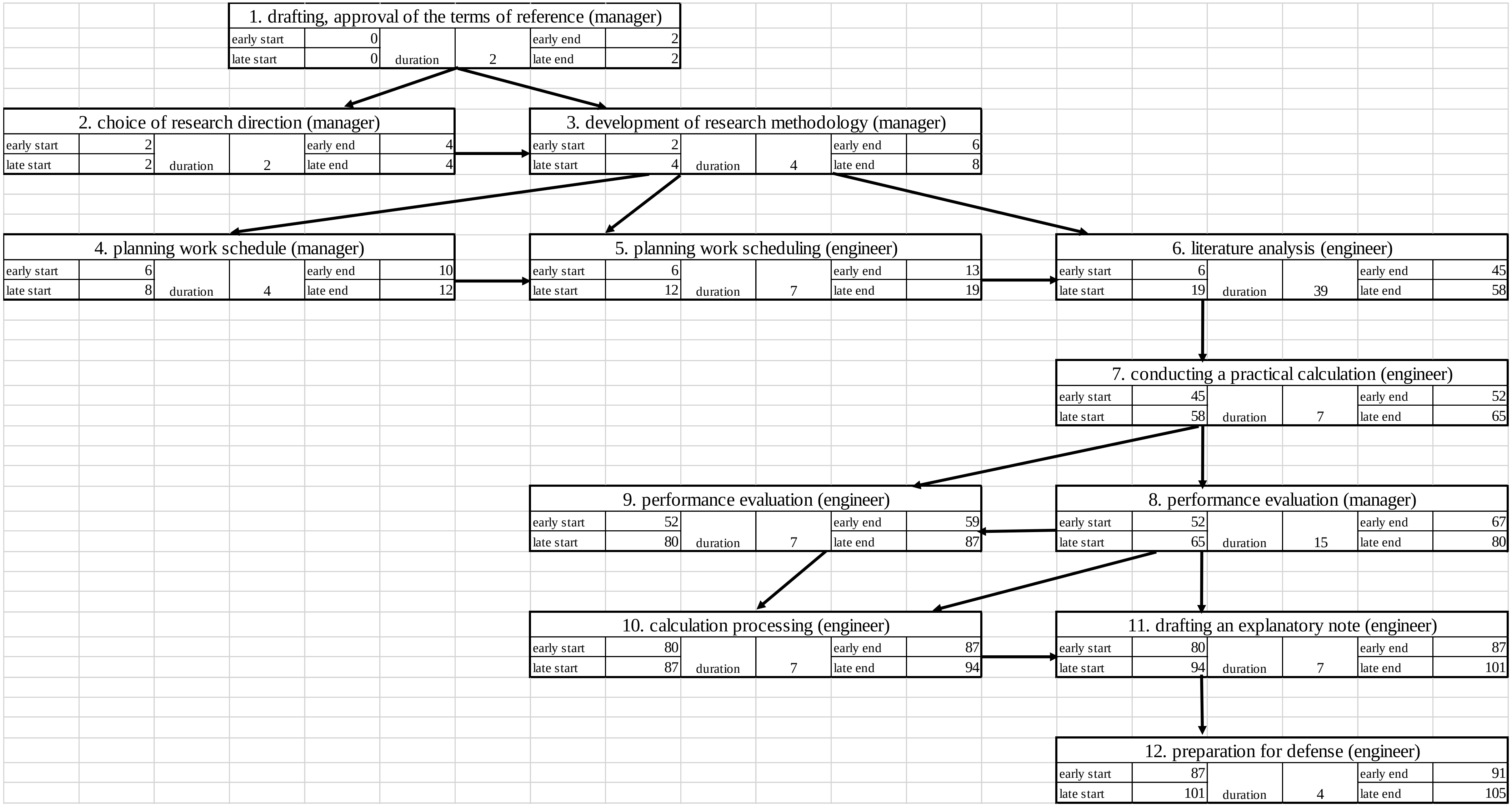
Table 5.10 - Schedule of scientific research

i	Type of work	Performer	T_{ki}, calendar days	The duration of the work											
				March			April			May			June		
				1	2	3	1	2	3	1	2	3	1	2	3
1	drafting, approval of the terms of reference	Manager	2												
2	choice of research area	Manager	2												
3	development of a methodology for conducting research	Manager	4												
4	time scheduling	Manager	4												
5		Engineer	7												
6	literature analysis	Engineer	39												
7	practical calculation	Engineer	7												
8	performance measurement	Manager	15												
9		Engineer	7												
10	payment processing	Engineer	7												
11	notes drafting	Engineer	7												
12	paper preparation	Engineer	4												
			105												

- Manager

- Engineer

Figure 5.1 - Network plan-schedule of scientific research



5.3.5 The budget of scientific research

When planning the budget of scientific and technical research, it is necessary to fully and accurately reflect all types of costs associated with its implementation.

Costs by item:

- material costs;
- costs of special equipment;
- basic salaries of employees;
- additional wages and salaries of employees;
- contributions to non-budgetary funds;
- overhead costs.

5.3.5.1 Calculation of material costs

Data on this type of costs are summarized in the table below.

Table 5.11 - Material costs

Name of materials	Price per unit, rubles.	Number of units.	Amount, rubles.
A4 office paper	300	2	600
Printer cartridge for HP laser printer	1000	1	1000
Office supplies set	350	2	700
		Total	2300

5.3.5.2 Calculation of costs for special equipment

Calculation in our case comes down to determining the depreciation charges, since the equipment was purchased before the start of work on the topic and used before, so when calculating the cost of equipment, we consider only the working days on which the work was carried out.

The rate of depreciation is calculated by the formula:

$$H_A = \frac{1}{n}, \ (5.5)$$

where n - useful life, years.

A PC Asus was used during the project. Useful life of the laptop according to the technical certificate is 3 years. The cost of the laptop is 64000 rubles.

$$H_A = \frac{1}{3} = 0{,}33.$$

Depreciation is determined as follows:

$$A = \frac{H_A \cdot И}{12} \cdot m, \ (5.6)$$

where И - total amount, rubles; m - time of use, months.

$$A = \frac{0{,}33 \cdot 64000}{12} \cdot 3{,}5 = 6160 \text{ rubles.}$$

5.3.5.3 Basic salaries

This expense item includes the basic salary of scientific and engineering employees directly engaged in the execution of work on the subject. The amount of salary expenses is determined on the basis of labor intensity of the work performed and the existing system of labor remuneration. The basic salary includes a bonus paid monthly from the wage fund.

The item includes the basic salary of employees (including bonuses, additional payments) $З_{осн}$ and additional salary $З_{доп}$:

$$C_{зп} = З_{осн} + З_{доп}. \ (5.7)$$

The employee's basic salary is calculated according to the formula:

$$З_{осн} = З_{дн} \cdot T_p, \ (5.8)$$

where $З_{дн}$ - average daily salary of the employee, rubles; T_p - duration of the work performed by the scientific and technical employee, working days.

The average daily wage is determined by the formul:

$$З_{дн} = \frac{З_м \cdot M}{F_д}, (5.9)$$

where $З_м$ - monthly official salary of the employee, rubles; M - number of months of work without leave during the year (at the leave of 24 working days, 5-day week of the $M = 11{,}2$ month); $F_д$ - actual annual fund of working time of the scientific and technical employee, working days.

Table 5.12 - Balance of working time

Working time indicators	Manager	Engineer
Calendar number of days	365	365
Number of days off		
Weekends	92	92
Holidays	26	26
Loss of working time		
Vacation	24	24
Absences due to illness	12	12
Actual annual working time fund	211	211

Monthly salary of the employee:

$$З_м = З_б \cdot (k_{пр} + k_д) \cdot k_р, \ (5.10)$$

where $З_б$ - base salary of an employee (in the calculation we take equal for a manager and an engineer 30,000 and 15,000 respectively), rubles; $k_{пр}$ - bonus coefficient, defined by the Payroll Regulations (in the calculation we take equal to 0.65); $k_д$ - coefficient of additional payments and bonuses, defined by the Payroll Regulations (in the calculation we take equal to 0.65); $k_р$ - regional coefficient (for Tomsk it is 1.3).

Basic pay is calculated on the basis of industry pay. The branch payroll system in TPU assumes the composition of wages: 1) salary, which is determined by the enterprise, in TPU the salaries are distributed in accordance with the positions occupied; 2) incentive payments, which are set by the head of the unit for effective work, performance of additional duties, etc.; 3) other payments, district coefficient.

The results of calculations are summarized in the table below.

Table 5.13 - Calculation of basic salary

Performer	$З_б$, rubles.	$k_{пр}$	$k_д$	$k_р$	$З_м$, rubles.	$З_{дн}$, rubles.	$T_р$, working day.	$З_{осн}$, rubles.
Manager	30000	0.65	0.65	1.3	50700	2691.2	27	72662.4
Engineer	15000	0.65	0.65	1.3	25350	1345.6	78	104956.8
							Total $З_{осн}$	177619.2

5.3.5.4 Additional wages of research and production personnel

The item includes the amount of payments stipulated by labor legislation, such as payment for regular and additional vacations; payment for the time of performance of state and public duties; payment of compensation for length of service, etc. As a rule, the average value of these payments is 12% of the basic salary.

Additional wages are calculated according to the formula:

$$З_{доп} = k_{доп} \cdot З_{осн}, \quad (5.11)$$

where $k_{доп}$ - coefficient of additional wages (in the calculation we take 0.12); $З_{осн}$ - basic salary, rubles.

The results of the calculations are summarized in the table.

Table 5.14 - Salaries of scientific and technical research executors

Wages	Manager	Engineer	Total
Basic salary	72662.4	104956.8	177619.2
Extra pay	8719.5	12594.8	21314.3
Employee Salary	81381.9	117551.6	198933.5

5.3.5.5 Social contributions

This item includes contributions to non-budgetary funds (pension fund, compulsory health insurance fund, etc.).

$$C_{внеб} = k_{внеб} \cdot (З_{осн} + З_{доп}), \quad (5.12)$$

where $k_{внеб}$ - the coefficient of deductions for payments to non-budgetary funds.

Contributions to non-budgetary funds are 30%, including: 22% to the Russian Federation Pension Fund, 2.9% to the Federal Social Insurance Fund, and 5.1% to the Federal Compulsory Medical Insurance Fund.

Table 5.15 - Contributions to non-budgetary funds

Employee	Value of deductions, rubles.
Manager	24414.6
Engineer	35265.5
Total	59680.1

5.3.5.6 Overhead costs

This item includes the costs of management and housekeeping services attributed to the study in question. In addition, they include the cost of maintenance, operation and repair of equipment, buildings, structures, etc. As a rule in calculations these expenses are accepted at a rate of 70-90% of the sum of the basic salary or 80-100% of the sum of the basic and additional salaries of employees participating in work.

$$C_{накл} = k_{накл}(З_{осн} + З_{доп}), \quad (5.13)$$

where $k_{накл}$ - the coefficient of overhead costs (in the calculation we take 0.8).

$$C_{накл} = k_{накл}(З_{осн} + З_{доп}) = 0{,}8 \cdot 198933{,}5 = 159146{,}8 \text{ rubles.}$$

On the basis of the obtained data on the individual cost items a calculation of the planned cost of scientific research is made.

Table 5.16 - Calculation of costs

Article name	Amount, rubles.
Material costs	2300
Costs of special equipment	6160
Basic salary of employees	177619
Additional employee salaries	21314
Contributions to non-budgetary funds	59680
Overhead costs	159147
	426220

5.4 Determination of Project Efficiency

The effectiveness of a scientific project includes social, economic and budgetary efficiency. In addition, it is possible to distinguish the resource effect, scientific and technical, etc.

As part of the work under consideration, we will determine the effectiveness by calculating the integral indicator of scientific research efficiency. Its value is the sum of financial efficiency and resource efficiency coefficients.

The integral index of financial effectiveness of scientific research, as a rule, is obtained in the course of evaluation of the cost budget of several options of scientific research implementation. Thus the greatest integral indicator of realization of a technical problem is accepted as a base of calculation (denominator) with which financial values on all variants of execution are correlated.

The formula for determining the integral financial indicator of development:

$$I_{\phi}^{p} = \frac{\Phi_{pi}}{\Phi_{\max}}, \ (5.14)$$

where Φ_{pi} - the cost of the *i*-th execution variant; $\Phi_{\max}$ - the maximum cost of execution of the research project.

The resulting value of the integral financial indicator of development reflects the corresponding numerical increase in the budget of development costs in times (in the case of a value greater than unity), or the corresponding numerical decrease in the cost of development in times (in the case of a value less than unity, but greater than zero).

The development has one execution, so $I_{\phi}^{p} = 1$.

The integral index of resource efficiency (for the *i*-th version) is determined by the formula:

$$I_{m}^{p} = \sum_{i=1}^{n} a_i \cdot b_i, \ (5.15)$$

where a_i - weight coefficient of the *i*-th development option; b_i - point estimate of the *i*-th development option, which is set by expert method according to the selected evaluation scale.

Table 5.17 - Assessment of the characteristics of project implementation

Criteria	Parameter weighting factor	Evaluation
1. Promotes productivity	0.10	5
2. Ease of use	0.15	4
3. Interference resistance	0.15	5
4. Energy Conservation	0.20	4
5. Reliability	0.25	4
6. Material capacity	0.15	4
Total	1.00	

The integral index of resource efficiency in our case is:

$$I_m^p = 0{,}10 \cdot 5 + 0{,}15 \cdot 4 + 0{,}15 \cdot 5 + 0{,}20 \cdot 4 + 0{,}25 \cdot 4 + 0{,}15 \cdot 4 = 4{,}25.$$

Integral performance indicator:

$$I_{финр}^p = \frac{I_m^p}{I_ф^p}. \quad (5.16)$$

$$I_{финр}^p = \frac{4{,}25}{1} = 4{,}25.$$

Comparison of integral indicators of project efficiency and analogues allows you to choose a more effective option to solve the technical problem from the position of financial and resource efficiency. In our case, there is only one variant of the project, so it is assumed that it is the most effective.

Table 5.18 - Efficiency of development

	Indicators	Evaluation
1	Integral financial indicator	1
2	Integral resource efficiency indicator	4.25
3	Integral performance indicator	4.25

In the course of this section, the financial development indicator, the resource efficiency indicator, and the integral efficiency indicator were determined.

5.5 Chapter Conclusion

As a result, the following conclusions can be drawn:

- the result of the analysis of competitive technical research is to choose the most appropriate and optimal in comparison with others;
- this paper considers the only option for the implementation of scientific research, and we consider it to be the most appropriate and optimal;
- in the course of planning, schedules were developed for the manager and the engineer to implement the stages of work, which made it possible to evaluate and plan the working time of the employees;
- the expenses for the project realization were estimated; the budget of the project was 426220 rubles;
- as a result of the efficiency evaluation the following indicators were determined:

1) the value of the integral financial indicator 1, the advantages or disadvantages of the considered option of execution are not identified, as the effectiveness of the only option is considered;

2) the value of the integral index of resource efficiency is 4.25, which is a good indicator, the considered option of execution is resource-efficient;

3) the value of the integral efficiency indicator is 4.25, the considered execution variant is effective.

ЗАДАНИЕ К РАЗДЕЛУ
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Обучающемуся:

Группа	ФИО
0АМ13	Чуприна Анастасии Владимировне

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

Исходные данные к разделу «Социальная ответственность»:	
1. Описание организационных условий реализации социальной ответственности	Объектом исследования является степень очищения атмосферы от радионуклидов дождевыми осадками. Рабочая зона – лаборатория, расположенная в 118 аудитории 10 корпуса ТПУ Область применения - научно-исследовательские институты, оперативные радиологические службы
2. Законодательные и нормативные документы	При выполнении научно-исследовательской работы необходимо следовать требованиям: Трудовой кодекс Российской Федерации от 30.12.2011 №197-ФЗ (ред. от 19.12.2022, с изм. от 11.04.2023); ГОСТ 12.2.032-78 Система стандартов безопасности труда. Рабочее место при выполнении работ сидя. Общие эргономические требования; ГОСТ Р 50923-96 Дисплеи. Общие эргономические требования и требования к производственной среде. Методы измерения; ГОСТ 21889-76 Система «человек-машина». Кресло человека-оператора. Общие эргономические требования; ГОСТ 12.1.005-88 Система стандартов безопасности труда. Общие санитарно-гигиенические требования к воздуху рабочей зоны; ГОСТ 12.1.003-83 Система стандартов безопасности труда. Шум. Общие требования безопасности; СНиП 23-05-95* Естественное и искусственное освещение; СанПиН 2.2.2/2.4.1340-03. Санитарно-эпидемиологические правила и нормативы «Гигиенические требования к ПЭВМ и организации работы»; СНиП 21-01-97* Пожарная безопасность зданий и сооружений; СП 12.13130.2009 Определение категорий помещений, зданий и наружных установок по взрывопожарной и пожарной опасности; Пожаро-взрывобезопасность промышленных объектов. ГОСТ Р12.1.004-85 ССБТ Пожарная безопасность; СанПиН 2.2.1/2.1.1.1278–03. Гигиенические требования к естественному, искусственному и совмещённому освещению жилых и общественных зданий; ГОСТ 12.1.038-82. ССБТ. Электробезопасность; СанПиН 2.6.1.2523-09 Нормы радиационной безопасности (НРБ-99/2009).

Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. Производственная безопасность при проведении исследования:	Вредные и опасные производственные факторы: - повышенный уровень шума; - параметры микроклимата; - освящение рабочего места; - психофизические факторы; - ионизирующее излучение; - электрический ток; - электробезопасность; - пожаро- и взрывоопасность рабочей зоны.
2. Безопасность в аварийных и чрезвычайных ситуациях (АС и ЧС) при проведении исследования:	Возможные аварийные и чрезвычайные ситуации: повреждения / перелом при падении с высоты собственного роста, поражение электрическим током, пожар. Наиболее вероятной АС и ЧС является возникновение пожара на рабочем месте вследствие возгорания оборудования.
Дата выдачи задания к разделу в соответствии с календарным учебным графиком	13.03.2023

Задание выдал консультант:

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0АМ13	Чуприна Алнастасия Владимировна		

ASSIGNMENT FOR THE SECTION "SOCIAL RESPONSIBILITY"

To the Student:

Group	FULL NAME
0AM13	Chuprina Anastasia Vladimirovna

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

Input data for the "Social Responsibility" section:	
1. Description of organizational conditions for implementing social responsibility	The object of the study is the degree of purification of the atmosphere from radionuclides by rainfall. Working area - laboratory, located in classroom 118 of TPU building 10 Scope - research institutes, operational radiological services
2. Legislative and regulatory documents	When performing research work it is necessary to follow the requirements: Labor Code of the Russian Federation from 30.12.2011 №197-FZ (ed. from 19.12.2022, amended from 11.04.2023); GOST 12.2.032-78 Occupational Safety Standards System. Workplace for working while sitting. General ergonomic requirements; GOST R 50923-96 Displays. General ergonomic requirements and requirements for working environment. Methods of measurement; GOST 21889-76 Human-machine system. Human operator's armchair. General ergonomic requirements; GOST 12.1.005-88 Occupational safety standards system. General sanitary and hygienic requirements for the air in the working area; GOST 12.1.003-83 System of Standards on Occupational Safety. Noise. General safety requirements; SNiP 23-05-95* Natural and artificial lighting; SanPiN 2.2.2/2.4.1340-03. Sanitary and Epidemiological Rules and Norms "Hygienic Requirements to Personal Computer and Work Organisation"; SNiP 21-01-97* Fire safety of buildings and constructions; SP 12.13130.2009 Determination of explosion and fire hazard categories of buildings and outdoor installation; Fire and explosion safety of industrial facilities. GOST R12.1.004-85 SSBT Fire safety; SanPiN 2.2.1/2.1.1.1278-03. Hygienic requirements for natural, artificial and combined lighting of residential and public buildings; GOST 12.1.038-82. SSBT electrical safety; SanPiN 2.6.1.2523-09 Radiation Safety Standards (NRB-99/2009).
List of issues to be researched, designed and developed:	
1. Occupational safety when conducting research:	Harmful and hazardous production factors: - increased noise level; - microclimate parameters; - lighting of the workplace; - psychophysical factors; - ionising radiation; - electric current;

	- electrical safety; - fire and explosion hazards of the work area.
Safety in emergencies and emergency situations (AS & ES) when research:	Possible accidents and emergencies: injuries/fractures from falling from one's own height, electric shock, fire. The most probable accident and emergency is a fire at the workplace due to equipment fire.
Date of assignment to the section in accordance with the academic calendar	13.03.2023

The assignment was given by a consultant:

Position	FULL NAME	Academic degree, rank	Signature	Date
Assistant professor of NFCD of SNSE	Y. V. Perederin	PhD		

The assignment was accepted for execution by the student:

Group	FULL NAME	Signature	Date
0AM13	Chuprina Anastasia Vladimirovna		13.03.2023

6 Social Responsibility

The widespread introduction of an integrated occupational safety management system, combining various measures into a single system of purposeful actions at all stages of the production process is one of the key directions of improving the work to reduce the occupational injuries and occupational disease rate.

A hazardous production factor is such a production factor, the effect of which on an employee under certain conditions leads either to a disease or to a decrease in the employee's ability to work.

A hazardous production factor is a production factor, the impact of which in some conditions can lead to injury of an employee or other sudden deterioration of health.

When working at a PC, the employee is exposed to harmful factors:

- physical - temperature and humidity of the ambient air, workplace illumination, noise, static electricity, presence of radiation, low frequency electromagnetic field;
- psychophysical - physical static and dynamic overload, nervous and mental overload (mental overload, emotional overload, monotony of work).

When working on a computer one can single out a hazardous production factor - electric shock.

When working with a computer, it is also necessary to observe a rational regime of work and rest, because otherwise employees have significant visual strain, headaches, pain in the lower back, neck and arms, sleep disorders, fatigue, in turn, it leads to dissatisfaction at work and reduced efficiency.

The section deals with hazardous and harmful factors affecting the employee in the 118 classroom of TPU building 10, factors affecting the research process, legal and organizational issues, as well as activities in emergency and extraordinary situations.

6.1 Legal and organizational issues of safety

The key provisions on labor protection are presented in the Labor Code of the Russian Federation [20]. Protecting workers' health, ensuring safe working conditions, preventing occupational diseases and injuries at work are priority tasks of the state.

According to the Labor Code of the Russian Federation [20], every worker has the right to:

- a workplace that meets the labour safety requirements;
- mandatory social insurance against occupational diseases and accidents at work;
- reliable information about the conditions and labor protection at the workplace, health risks, measures of protection against harmful and hazardous production factors, this information must be provided in full by the employer, relevant state authorities and public organizations;
- refusal to perform work that poses a risk to his or her life and health, including as a result of violations of occupational health and safety requirements;
- provision, at the employer's expense, of personal and collective protective equipment in accordance with the requirements of occupational safety and health
- training in safe working methods and techniques at the employer's expense;
- personal participation or participation through representatives in reviews of safe working conditions at the workplace and in the investigation of industrial accidents or occupational diseases
- unscheduled medical examinations for medical reasons, while retaining his/her job and average earnings during the medical examination;
- guarantees and compensations established in accordance with the Labor Code of the Russian Federation, collective agreement, employment contract, if the work performed has harmful and hazardous working conditions.

According to the Labor Code of the Russian Federation [1], the normal working hours must not exceed 40 hours per week, and the employer is obliged to keep records of working hours for each employee.

All employees must know and strictly comply with safety and sanitary regulations, the training for which consists of introductory and on-the-job briefings by a responsible person.

The knowledge of an employee on safety rules is checked by a commission after the training at the workplace, and the inspected person, upon positive outcome of the check, is assigned a qualification group on safety engineering corresponding to his knowledge and work experience and is issued a special certificate.

Persons operating electrical installations must not have any diseases that interfere with production work.

Their state of health is determined by a medical examination.

6.2 Ergonomic requirements for the workplace

The workplace, as well as the mutual arrangement of workplace elements, must comply with anthropometric and physical as well as psychological requirements.

The workplace must be rationally planned, this implies an order and consistency in the placement of documentation, tools, objects. Frequently used in the performance of work should be placed, if possible, in the area of the so-called easy reach of the workspace, the scheme is shown in Figure 6.1.

The ergonomic aspects of workplace organization include the height of the work surface, the size of the free legroom, the location of documents at the workplace (distance from the employee's eyes to the screen, keyboard, document, document stand size, etc.), and the surface of the desk, adjustability of workplace elements, and characteristics of the work chair.

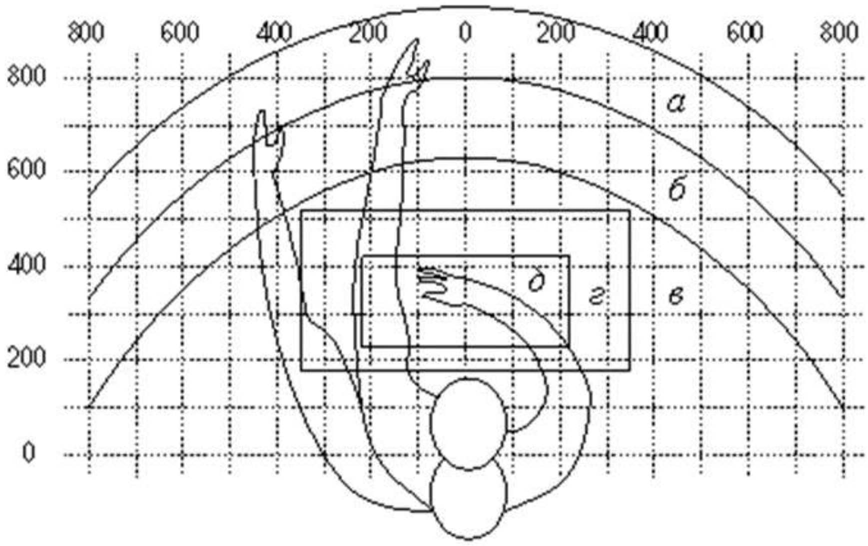


Figure 6.1 - Hand reach zones in the horizontal plane
а - maximum hand reach zone; б - finger reach zone with outstretched hand; в - light palm reach zone; г - optimal space for coarse manual work; д - optimal space for fine manual work

Figure 6.2 shows an example of the basic and peripheral components of a PC on an employee's desk.

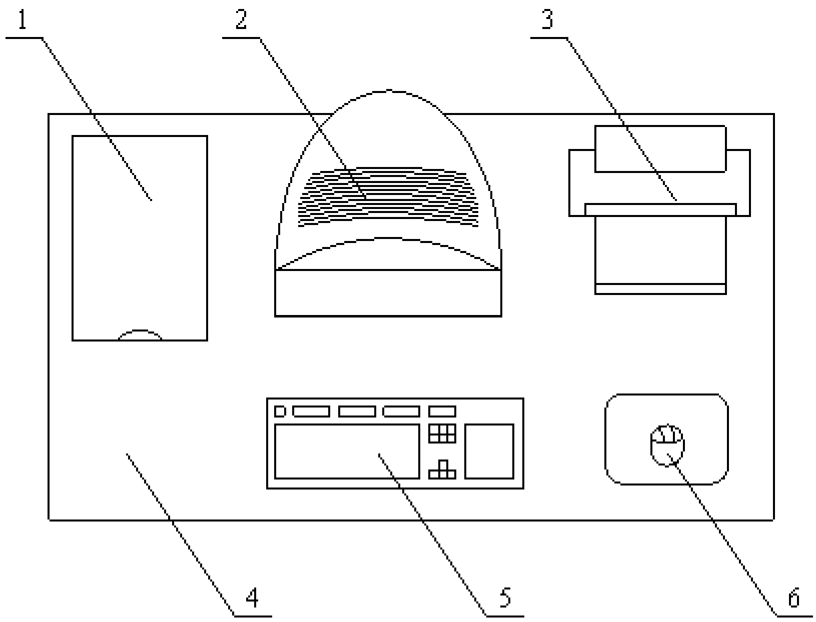


Figure 6.2 - Example of arrangement of the main and peripheral components of the PC
1 - scanner (or system unit); 2 - monitor; 3 - printer (or printer-scanner); 4 - table top; 5 - keyboard; 6 - manipulator "mouse

Accordingly: the display is in zone а (center); the keyboard is in zone г or д; the system unit (or scanner) is in zone б (left); the printer or multifunction printer/scanner is in zone a (right); the mouse is in zone в (right); the documentation needed in work) is in easy reach of the palm, and the documentation not used constantly is in the drawers of the desk.

According to [22] the adjustable height of the working surface of the table should vary between 680-800 mm, and in the absence of regulation the height of the working surface of the table should be 725 mm. The dimensions of the working surface of the table should be: depth - not less than 600 mm, width - not less than 1200 mm; and the preferred dimensions are 800 mm and 1600 mm respectively. In addition, the work table should have a leg space of at least 600 mm high, at least 500 mm wide, at least 450 mm deep at knee level and at least 650 mm deep at foot level.

The same document regulates the requirements for a work chair. Basic provisions: the working chair must be adjustable in height and angles of inclination of the seat and back as well as the distance of the backrest from the front edge of the seat; the seat surface must have a width and depth of at least 400 mm and the height of the seat surface must be adjustable within the range of 400 to 550 mm.

The monitor shall be positioned at eye level of the operator at a distance of 500-600 mm. The display should be positioned so that the image in any part of it can be seen without having to raise or lower the head.

The keyboard should be positioned 100-300 mm from the edge of the table, and it should be possible to move it freely.

With monotonous mental work, requiring considerable nervous and visual tension, concentration, it is recommended to choose dim shades of low-contrast, not scattering the attention. Shades of warm tones that excite human activity are recommended.

Classroom 118 of TPU 10 meets all the necessary requirements [21,22,23].

6.3 Occupational safety

A hazardous industrial factor is an industrial factor, the effect of which on the employee under certain conditions leads to illness or reduced ability to 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 of health.

When working at a PC, the employee is exposed to hazardous factors:

- physical - temperature and humidity of the ambient air, workplace illumination, noise, static electricity, presence of radiation, low frequency electromagnetic field;
- psychophysical - physical static and dynamic overload, nervous and mental overload (mental overload, emotional overload, monotony of work).

When working at a PC, one may single out a hazardous production factor - electric shock.

Below are the identified harmful and hazardous factors are presented hazardous and harmful factors occurring while working with a PC in the TPU building's room 118, as well as measures to protect employees from their effects.

6.3.1 Microclimate

The parameters of the microclimate can vary widely, while a necessary condition for human activity is to maintain a constant body temperature through thermoregulation, i.e. the body's ability to regulate the release of heat into the environment. The principle of microclimate regulation is the creation of optimal conditions for the heat exchange of the human body with the environment.

Indicators which characterize the microclimate are: air temperature, relative humidity, air speed, the intensity of thermal radiation.

Computer equipment is the source of considerable heat emission, which may lead to increased temperature and decreased relative humidity in the room.

The optimum and permissible values of air temperature, humidity and air velocity for work category 1a, which is the work of an operator, an employee conducting research using a PC, are given below in Table 6.1 [Table 1, 24].

Table 6.1 Optimal and permissible norms of temperature, relative humidity and air velocity in the working zone of industrial premises

Period of the year	Job category	Temperature, °C					Relative humidity, %		Air speed, m/s	
		optimal	admissible				optimal	Permissible at workplaces of permanent and non-permanent, not more	Optimal, not more	Allowable at workplaces of permanent and non-permanent
			Upper limit		Lower limit					
			In the workplace							
			permanent	non-permanent	permanent	non-permanent				
cold	Easy – 1a	22-24	25	26	21	18	40-60	75	0.1	Not more than 0.1
warm	Easy – 1a	23-25	28	30	22	20	40-60	55 (at 28°C)	0.1	0.1-0.2

Measures to improve the air environment in the production area include: the organization of ventilation and air conditioning, heating. Ventilation can be carried out both naturally and mechanically. The room shall receive the following volumes of air: when the volume of space up to 20 m^3 per person - at least 30 m^3/h per person; when the volume of space over 40 m^3 per person and the absence of allocation of harmful substances allowed to use only natural ventilation.

The heating system must provide sufficient, constant and even heating of the air. In rooms with increased requirements for clean air, water heating should be used.

The microclimate parameters in the room in question are regulated by the central heating system as well as the air humidifier and have the following values: humidity - 50%, summer temperature - 20-28°C, winter temperature - 18-26°C. Natural ventilation is used in the room, the air comes in through the windows, doors, window slits. The main disadvantage of this type of ventilation is that the air enters the room without pre-cleaning and heating.

Auditorium 118 of the 10 building of TPU meets the requirements [24].

6.3.2 Noise level

Noise worsens working conditions by having a harmful effect on the human body. Employees under prolonged noise exposure experience irritability, headaches, dizziness, memory loss, increased fatigue, decreased appetite, tinnitus, etc. Such disorders in a number of human organs and systems can cause negative changes in a person's emotional state, up to and including stress. All this reduces human performance and productivity, quality and safety of work. Prolonged exposure to intense noise (more than 80 dBA) on human hearing leads to its partial or complete loss. [25]

The noise level at the workplace of programmers and operators should not exceed 50dBA, and in the information processing rooms of computing machines - 65dBA. To reduce the noise level, the walls and ceiling of the rooms where computers are installed can be lined with sound-absorbing materials. The vibration level in the computing rooms can be reduced by installing the equipment on special vibration isolators.

Noise levels do not exceed the limit values in Room 10 of the building [25].

6.3.3 Lighting

Properly designed and executed industrial lighting improves the conditions of visual work, reduces fatigue, contributes to increased productivity, has a positive effect on the working environment, has a positive psychological impact on the employee, increases work safety and reduces injuries.

Insufficient lighting leads to visual strain, weakens attention, leads to the onset of premature fatigue. Excessively bright lighting causes dazzle, irritation, and eye irritation. Incorrect light direction in the workplace can create harsh shadows, glare, and disorient the employee. All of these causes can lead to accidents or occupational diseases, which is why proper lighting calculations are so important.

There are three types of lighting - natural, artificial and combined.

Natural lighting is lighting of premises with daylight penetrating through openings in the external envelope of premises. This type of lighting is characterized by the fact that it varies widely depending on the time of day, time of year, the nature of the area and a number of other factors.

Artificial lighting is used when working at night and during the day if the normal values of the coefficient of natural light cannot be provided. Lighting, in which inadequate by the standards of natural light is supplemented by artificial lighting, called combined coverage.

Artificial lighting is divided into working, emergency, evacuation, security. Working lighting, in turn, may be general or combined. General lighting is lighting, in which lighting fixtures are located in the upper zone of the room evenly or in relation to the location of the equipment. Combined lighting is lighting, in which the general lighting is added to the local lighting.

According to [26] in the premises of computer centers it is necessary to use a system of combined lighting. When performing the category of high visual accuracy work the value of the coefficient of natural light (DO) must be at least 1.5%, and the visual work of medium accuracy DO should not be less than 1.0%. The sources of artificial lighting are fluorescent lamps such as LB or DRL, which are combined in pairs in the lighting fixtures located above the working surfaces evenly.

In addition, the entire field of view should be illuminated fairly evenly - this is a basic hygiene requirement. In other words, the degree of room lighting and the brightness of the computer screen should be approximately the same, because bright light in the peripheral vision area significantly increases eye strain and, as a consequence, leads to their rapid fatigue.

According to the regulations [32], the illumination on the surface of the table in the area of placement of the working document should be 300-500 lux. Lighting should not create glare on the screen surface. Illumination of the screen surface should not be more than 300 lux.

The brightness of the general lighting fixtures in the area of the radiation angles from 50 to 90° with vertical in longitudinal and transverse planes should not be more than 200 cd/m, the protective angle of the fixtures should be at least 40°. The safety factor (Kz) for general lighting installations shall be 1.4. The coefficient of pulsation should not exceed 5%.

Artificial lighting in the rooms for the operation of PCs shall be provided by a system of general uniform lighting. In production and administrative and public spaces, in cases of predominant work with documents, the following systems should be used: combined lighting (general lighting is installed in addition to general lighting fixtures; local lighting designed to illuminate the area where documents are located).

The main way to protect against insufficient lighting is to comply with lighting standards. In the room with Grade III visual work with high accuracy should be 200 lux, and a ripple factor of 15%. Pulsation of the illumination is due to the low inertia of the emission of discharge lamps, the luminous flux from which pulsates with alternating current of industrial frequency.

The number of luminaires (n) for the room is calculated:

$$n = \frac{E \cdot S \cdot Z \cdot K}{F \cdot U \cdot m}, \quad (6.1)$$

where E - the standard illumination, E = 300 lux;

S - area of the room, S = 22 m^2;

Z - correction factor of the luminaire, Z = 1.2;

K - safety factor, taking into account decrease of illumination during operation, K=1.4;

F - luminous flux of one lamp, F=1300 lm;

U - utilization factor, U=0.6;

m - number of lamps in the luminaire, m=4.

We obtain:

$$n = \frac{300 \cdot 22 \cdot 1{,}2 \cdot 1{,}4}{1300 \cdot 0{,}6 \cdot 4} = 3{,}6 \approx 4.$$

Thus, the minimum number of lighting fixtures for classroom 118 in Building 10 is 4.

There are 10 lights in classroom 118, which fully meets the requirements of lighting standards [27].

6.3.4 Electromagnetic and ionizing radiation

It is believed that short-term as well as long-term exposure to all kinds of radiation from the monitor screen is not harmful to the health of the personnel working with the computer. However, there are no comprehensive data regarding the danger of exposure to radiation from monitors, and research in this direction is ongoing.

The permissible values of parameters of non-ionizing electromagnetic radiation from computer monitors are presented below in Table 6.2. [27]

Table 6.2 - Temporary permissible levels of electromagnetic fields generated by PCs in workplaces

<table>
<tr><td colspan="2">Parameter Name</td><td>Temporary permissible levels</td></tr>
<tr><td rowspan="2">Electric field strength</td><td>in the frequency range 5 Hz - 2 kHz</td><td>25 V/m</td></tr>
<tr><td>in the frequency range 2 kHz - 400 kHz</td><td>2.5 V/m</td></tr>
<tr><td rowspan="2">Magnetic flux density</td><td>in the frequency range 5 Hz - 2 kHz</td><td>250 nTl</td></tr>
<tr><td>in the frequency range 2 kHz - 400 kHz</td><td>25 nTl</td></tr>
<tr><td colspan="2">Electrostatic field strength</td><td>15 kV/m</td></tr>
</table>

To protect against electromagnetic fields, increase the distance from the source, i.e., the screen should be at least 50 cm from the user. Filters and other personal protective equipment should also be used.

You can select the following types of filters from electromagnetic fields: glass filters full protection, providing lowering power of electromagnetic radiation, such as filters produced in Russia by "Russian Shield" and "CINCO"; spectral computer glasses, special headband for partial shielding of negative energy-information interaction of computer radiation in the frequency range of 5 Hz - 400 kHz.

When working with a computer, the source of ionizing radiation is the display. Under the influence of ionizing radiation in the body may occur disturbance of normal blood clotting, increased fragility of blood vessels, decreased immunity, etc.

The radiation dose at a distance of 20 cm to the display is 50 μR/h. In accordance with the norms the design of PCs shall ensure that the exposure dose at a distance of 50 cm from the screen is not more than 100 μR/h.

To reduce exposure to radiation it is recommended to use monitors with reduced radiation levels, install protective screens, as well as follow the regulated modes of work and rest.

All rules and norms of radiation safety are observed in the process of research [34].

6.3.5 Psychophysical factors

Psychophysiological hazardous and harmful factors of production are divided into: physical overload (static, dynamic) and neuropsychiatric overload (mental overload, monotony of work, emotional overload).

Labor activity of employees in the non-productive sphere refers to the category of work associated with the use of large amounts of information, with the use of computerized jobs, with the frequent adoption of critical decisions in conditions of lack of time, direct contact with people of different types of temperament, etc. This causes a high level of neuro-psychological overload, reduces the functional on the activity of the central nervous system, leads to disorders in its activity, the development of fatigue, overwork, stress.

The most effective means of preventing fatigue at work are means of normalizing the active work activity of the person. Against the background of the normal course of production processes, one of the important physiological measures against fatigue is a proper mode of work and rest [27].

In the course of work the correct regime of work and rest is observed and overfatigue and stress do not occur.

6.3.6 Electrical Safety

The workplace according to the danger of electric shock is class 1, i.e. it is a room without an increased risk due to the possibility of simultaneous human contact with the metal structures of buildings, technological devices, mechanisms, etc. having a connection with the ground, on the one hand, and with the metal housings of electrical equipment, on the other hand [33].

There is a danger of electrocution in the following cases:

- by direct contact with live parts during repairs;
- by touching live, non-current carrying parts that have been energized (in the event of a fault in the insulation of live parts)
- by touching the floor or walls with live parts;
- in case of a short circuit in the high-voltage blocks: power supply unit and the display unit.

The degree of hazardous effects of electric current on the human body depends on:

- the type and magnitude of the voltage and current;
- the frequency of the electric current;
- the path of current through the human body;
- the duration of exposure to the human body;
- environmental conditions.

Electric current has thermal, electrolytic, mechanical and biological effects on humans.

Thermal effects of current is manifested in burns, heating blood vessels and other organs, as a result of which they arise functional disorders.

Electrolytic effect of current is characterized by decomposition of blood and other organic fluids, which causes violations of their physicochemical composition.

The mechanical effect of current is manifested in damage (tearing, splitting, etc.) of various body tissues as a result of the electrodynamic effect.

Biological effect of current on living tissue is expressed in a dangerous excitation of cells and tissues of the body, accompanied by involuntary convulsive muscle contractions. As a result of such excitation there can be a disturbance and even complete cessation of respiratory and circulatory organs activity [33].

The main measures to protect against electric shock are:

- ensuring inaccessibility of live parts by using insulation in equipment enclosures;
- application of means of collective protection against electric shock;
- use of protective earthing, protective disconnection
- use of uninterruptible power supply devices.

Technical methods and means are used separately or in combination with each other so as to ensure optimal protection.

Organizational measures for electrical safety are periodic and unscheduled briefings. Periodic briefings are held for all non-electrotechnical personnel performing the following work: switching on and off electrical appliances, cleaning rooms near electric boards, sockets and switches, etc. All non-electrotechnical personnel must be certified to the first qualification group for electrical safety. Periodic briefings shall be conducted at least once a year.

Unscheduled briefing shall be carried out by the head of the subdivision when new technical electrical equipment is put into operation [33].

6.4 Fire and explosion safety

According to fire and explosion hazard the buildings are divided into А, Б, В1 - В4, Г and Д categories and the buildings are divided into А, Б, В, Г and Д categories [28]. The categories of rooms and buildings are determined on the basis of the type of combustible substances and materials present in the rooms, their quantity and fire hazardous properties as well as on the basis of the space planning solutions of the rooms and the characteristics of the technological processes carried out in them.

The room in which this work is carried out, according to the degree of explosion and fire hazard is a category B (moderate fire hazard) [29].

Possible causes of fire:

- short circuits in the power supply;
- working with open electrical equipment;
- faulty current-carrying parts of the units;
- failure to comply with fire safety rules;
- presence of combustible components including doors, tables, cable insulation, etc.

Measures for fire prevention are divided into technical, operational, organizational, and regime.

The technical measures include: compliance with fire regulations, standards in the design of buildings, construction of electrical wiring and equipment, heating, ventilation, lighting, proper placement of equipment, etc.

Operational measures include timely preventive inspections, repairs and testing of process equipment, etc.

Organizational measures include proper operation of equipment, proper maintenance of buildings and territories, fire instruction of workers and employees, training of production personnel in fire safety rules, publication of instructions, posters, availability of an evacuation plan, etc.

Regulated activities include establishing work organization rules and compliance with fire safety measures.

In the event of an emergency situation it is necessary to:

- notify the management (duty officer);
- Call the respective emergency service or the emergency ministry - tel. 112;
- take measures to eliminate the accident in accordance with the instructions [30].

6.5 Emergency and Disaster Situations (AS and ES)

An emergency situation is a situation in a certain area resulting from an accident, natural hazard, catastrophe, the spread of a disease that is dangerous to others, natural or other disasters, which may cause or have caused human casualties, damage to human health or the environment, significant material losses and disruption of people's livelihoods. There are two types of emergencies: man-made and natural.

Fires, explosions, sabotage, releases of toxic substances can be attributed to man-made emergencies. Natural emergencies include natural disasters. Fires are the most probable man-made ES.

Accident hazards include a sudden and uncontrollable source of energy: a moving object, uncontrollable movement or energy [31].

Consider possible accidents and emergencies in the laboratory, viz:

- falling from one's own height;
- electric shock;
- fire.

The accidents and emergencies are presented in Table 6.3.

Table 6.3 - AS and ES

№	AS and ES	Measures to prevent AS and ES	Measures to eliminate the consequences of the AS and ES
1	Damage / fracture of a limb in a fall from a height own height	1.Timely briefing. 2.Keeping the room in proper order. 3.Restriction of working space.	1. examine or question the victim; 2. If necessary, call an ambulance (112); 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 complete rest in the supine position until qualified medical assistance is provided.
2	Electric shock	1. Timely briefing. 2. Grounding all electrical installations. 3.Restriction of work area 4.Ensuring that live parts of the equipment are not accessible.	1. quickly free the victim from the action of the electric current; 2. Call an ambulance (112); If the victim has lost consciousness but is still breathing, lie him/her down comfortably, undo any restrictive clothing, get fresh air and ensure complete rest; 4. 4. The victim should be given smelling ammonia, splashing his face with water, rubbing and warming the body;
3	Fire	1.Timely briefing. 2.Installation of automatic fire extinguishing equipment in the premises. 3.Installation of smoke and fire detectors. 4.Providing evacuation routes and keeping them in proper condition. 5. Monitoring the operation of electrical appliances.	1. de-energize the room, cut off the air supply; 2. Immediately report the fire to the person on duty or to the guard post (112); 3. If possible, take measures to evacuate people, extinguish the fire and save material assets.

6.6 Conclusions of the section

In this chapter, harmful and hazardous factors formed during the analysis of gamma-background measurement data on the PC were identified, among which we can single out

- noise [25];
- microclimate [21,22,23,24];
- electrical safety [33];
- ionizing radiation [34];
- illumination [27];
- fire and explosion hazards [30].

It was found that the laboratory in question:

- belongs to electrical safety class 1 (up to 1000 V) [33];
- belongs to the class B "moderately flammable" on fire and explosion safety [29].

The methods of reducing the impact of harmful and hazardous factors on the researcher are described. The last subsection analyzes possible accidents and emergencies. The measures to prevent them and measures to eliminate the consequences of the AS and ES are also considered. The most probable AS and ES is the occurrence of fire in the workplace due to equipment fire.

Conclusion

1. The drizzle, which has the highest relative leaching capacity as compared to other types of precipitation under consideration, liberates the atmosphere from the daughter products of radon decay to a lesser extent, which is confirmed by certain degrees of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi, because of low intensity of this type of precipitation. For the West Siberian region the maximum intensity of drizzle is 0.25 mm/h.

When the duration of drizzle or its intensity increases, the degree of decrease in volumetric activity of ^{218}Po, ^{214}Pb, and ^{214}Bi increases multiply.

2. Degree of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi grows at transition from weak rain (intensity of 2.5 mm/h) to moderate rain (intensity of 5 mm/h) and further to strong rain (intensity of 10 mm/h). At the same time when precipitation time remains the same, a 2-fold increase in intensity leads to a 2-fold increase in degree of decrease in the volumetric activity of radon daughter decay products.

A 3-fold increase in rain duration (from 1 to 3 hours) at constant precipitation intensity leads to a 5-fold average decrease in volumetric activity of ^{214}Pb, ^{214}Bi, and a 3-fold increase for ^{218}Po.

When rain duration increases by a factor of 2 (from 3 to 6 hours) with constant intensity of precipitation, the degree of decrease in volumetric activity of ^{218}Po, ^{214}Pb, ^{214}Bi grows on average by a factor of 2.

3. A shower of moderate intensity (20 mm/h) with a duration of rainfall close to the maximum possible for showers in the West Siberian region (1 h) causes the greatest values of the degrees of reduction of volumetric activity ^{218}Po, ^{214}Pb, ^{214}Bi compared to showers of more intensity (40 mm/h), but less long (30 min.), i.e. during 2 times more intensive downpour and 2 times less long duration, the degree of ^{214}Pb, ^{214}Bi volumetric activity decrease is 1.5 times lower on the average, while the degree of ^{218}Po volumetric activity decrease practically does not change.

In comparison with downpours of very high intensity (120 mm/h) but very short duration (10 min), a moderate intensity downpour (20 mm/h) with precipitation duration close to maximum possible for downpours in West Siberian region (1 h) causes greater degrees of ^{218}Po, ^{214}Pb, ^{214}Bi volumetric activity decrease 1.5 times, 4 times and 4.5 times respectively.

4. Strong long rains and showers of moderate intensity with a duration close to the maximum value for showers for the West Siberian region (1 h) most effectively clean the atmosphere from the daughter products of radon decay.

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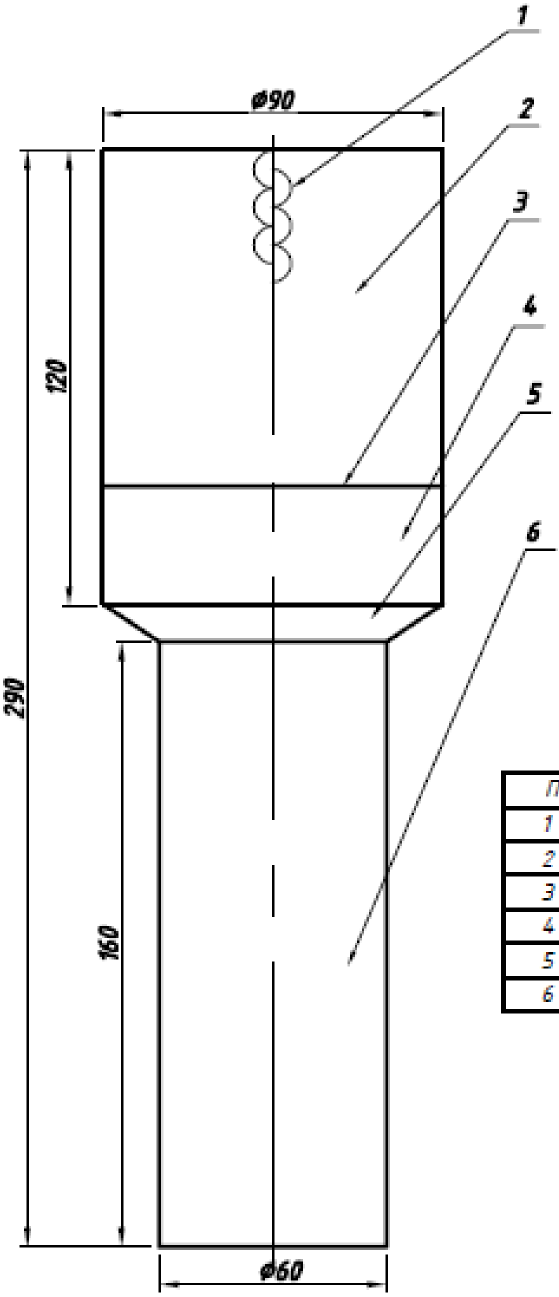

Поз.	Наименование
1	Система динодов
2	Фотоумножитель
3	Фотокатод
4	Световод
5	Свет
6	Сцинтиллятор

ФЮРА 14.04.02.013. СЧ

Изм	Лист	№ докум.	Подп.	Дата
Разраб.		Чуприна А.В.		
Пров.		Яковлева В.С.		

Приложение А. Сцинтилляционный детектор

Лит.	Масса	Масштаб
у		1:2
Лист	Листов	

ТПУ, ИЯТШ
гр. 0АМ13