TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

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

ВЫПУСКНАЯ КВАЛИФИКАЦИОННАЯ РАБОТА МАГИСТРАНТА

Тема работы
Исследование соотношений $^{90}Sr/^{137}Cs$ в поверхностном слое почвы на территории Карагандинской области в пределах Семипалатинского испытательного полигона

УДК: 621.039.76(574.31)

Обучающийся

Группа	ФИО	Подпись	Дата
0АМ13	Бакланова Юлия Валерьевна		

Руководитель ВКР

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

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОСГН ШБИП	Спицына Л.Ю.	к.э.н.		

По разделу «Социальная ответственность»

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

ДОПУСТИТЬ К ЗАЩИТЕ:

Руководитель ООП	ФИО	Ученая степень, звание	Подпись	Дата
Ст. преподаватель ОЯТЦ ИЯТШ	Семенов А.О.	к.т.н.		

Томск – 2023

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

School of Nuclear Science & Engineering
Education program: 14.04.02 Nuclear physics and technology
Specialization: Nuclear and Radiation Safety
Division Department of Nuclear Fuel Cycle

MASTER THESIS

Topic of study work
Study of $^{90}Sr/^{137}Cs$ ratios in the topsoil of the Karaganda region within the Semipalatinsk test site

UDC: 621.039.76(574.31)

Student

Group	Full name	Signature	Date
0AM13	Baklanova Yuliya Valerievna		

Scientific supervisor

Position	Full name	Academic degree, title	Signature	Date
Professor	Yakovleva V.S.	Ph.D.		

CONSULTANTS FOR SECTIONS:

According to the section "Financial management, resource efficiency and resource saving"

Job title	Full name	Academic degree, title	Signature	Date
Associate Professor	Spitsyna L.Yu.	Ph.D.		

Under the section "Social responsibility"

Job title	Full name	Academic degree, title	Signature	Date
Associate Professor	Perederin Yu.V.	Ph.D.		

ADMISSION TO DEFEND:

Head of the PLO	Full name	Academic degree, title	Signature	Date
Nuclear physics and technology	Semenov A.O.	Ph.D.		

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

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

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

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

Обучающийся:

Группа	ФИО
0АМ13	Бакланова Юлия Валерьевна

Тема работы:

Исследование соотношений $^{90}Sr/^{137}Cs$ в поверхностном слое почвы на территории Карагандинской области в пределах Семипалатинского испытательного полигона	
Утверждена приказом директора (дата, номер)	*№ 33-46 от 02.02.2023 г.*

Срок сдачи обучающимся выполненной работы:	26.05.2023 г.

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе *(наименование объекта исследования или проектирования; производительность или нагрузка; режим работы (непрерывный, периодический, циклический и т. д.); вид сырья или материал изделия; требования к продукту, изделию или процессу; особые требования к функционированию (эксплуатации) объекта или изделия в плане безопасности эксплуатации, влияния на окружающую среду, энергозатратам; экономический анализ и т. д.)*	– Материалы научно-исследовательской работы, материалы комплексного экологического обследования территории Семипалатинского испытательного полигона за период 2008-2021 гг. (удельная активность ^{137}Cs, ^{90}Sr, в почве); – литературные источники.
Перечень разделов пояснительной записки, подлежащих исследованию, проектированию и разработке *(аналитический обзор литературных источников с целью выяснения достижений мировой науки техники в рассматриваемой области; постановка задачи исследования, проектирования, конструирования; содержание процедуры исследования, проектирования, конструирования; обсуждение результатов выполненной работы; наименование дополнительных разделов, подлежащих разработке; заключение по работе)*	– обзор литературных источников по теме исследования; – формирование радиоактивного загрязнения почвы при ядерных испытаниях; – теоретическая оценка величины соотношения в зависимости от делящегося материала ядерного заряда (^{235}U и ^{239}Pu); – обзор имеющихся экспериментальных данных (результатов измерения активности ^{90}Sr и ^{137}Cs) и рассчитать на их

	основе соотношение исследуемых продуктов деления; – статистическая обработка экспериментальных данных (рассчитанных соотношений $^{90}Sr/^{137}Cs$); – сравнение результатов теоретической оценки соотношений $^{90}Sr/^{137}Cs$ и соотношений, рассчитанных на основе экспериментальных данных.
Перечень графического материала *(с точным указанием обязательных чертежей)*	– карта-схема расположения точек отбора проб почвы; – карта-схема распределения удельной активности ^{137}Cs в почвах исследуемой территории; – карта-схема распределения соотношений $^{90}Sr/^{137}Cs$ на исследуемой территории; – графический материал распределения соотношений исследуемых продуктов деления; – карты-схемы распределения удельной активности ^{90}Sr в почвах исследуемой территории; – презентация доклада.

Консультанты по разделам выпускной квалификационной работы

Раздел	Консультант
Оценка соотношений $^{90}Sr/^{137}Cs$ по экспериментальным данным с последующей статистической обработкой. Сравнение результатов теоретической оценки соотношений $^{90}Sr/^{137}Cs$ и соотношений $^{90}Sr/^{137}Cs$, рассчитанных на основе экспериментальных данных.	Профессор ОЯТЦ, д.т.н., Яковлева В.С. директор филиала ИРБЭ РГП НЯЦ РК, к.б.н., PhD Айдарханов А.О.
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	доцент ОСГН ШБИП, к.э.н. Спицына Л.Ю.
Социальная ответственность	доцент ОЯТЦ ИЯТШ, к.т.н. Передерин Ю.В.
Иностранный язык	Профессор ОЯТЦ, д.т.н., Яковлева В.С.

Названия разделов, которые должны быть написаны на иностранном языке:

1 Литературный обзор по теме исследования

2 Формирование радиоактивного загрязнения почвы при ядерных испытаниях

3 Объект исследования

4 Теоретическая оценка соотношений $^{90}Sr/^{137}Cs$ в зависимости от делящегося материала ядерного заряда

5 Оценка соотношений $^{90}Sr/^{137}Cs$ по экспериментальным данным

6 Финансовый менеджмент, ресурсоэффективность и ресурсосбережение

7 Социальная ответственность

Дата выдачи задания на выполнение выпускной квалификационной работы по линейному графику	

Задание выдал руководитель / консультант:

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

Задание принял к исполнению обучающийся:

Группа	ФИО	Подпись	Дата
0АМ13	Бакланова Юлия Валерьевна		

Tomsk – 2023

TOMSK POLYTECHNIC UNIVERSITY | ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
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«Национальный исследовательский Томский политехнический университет» (ТПУ)

School of Nuclear Science & Engineering
Education program 14.04.02 Nuclear physics and technology
Division Department of Nuclear Fuel Cycle

APPROVE BY:
Head of the PLO
_______ _______ Semenov A.O.
(Signature) (Data) (Full name)

ASSIGNMENT
for the Graduation Thesis completion

Student:

Group	Full name
0AM13	Baklanova Yuliya Valerievna

Topic of study work:

Study of ^{90}Sr/^{137}Cs ratios in the topsoil of the Karaganda region within the Semipalatinsk test site	
Approved by the order of the director (date, number)	*No. 33-46 dated 02.02.2023*

Deadline for students to submit completed work:	May 26, 2023

TERMS OF REFERENCE:

Initial date for research work *(name of the object of study or design; capacity or load; mode of operation (continuous, batch, cyclical, etc.); type of raw material or product material; product, product or process requirements; special requirements for the functioning (operation) of the object or product in terms of operational safety, environmental impact, energy costs; economic analysis, etc.)*	– Materials of research work, materials of a comprehensive environmental survey of the territory of the Semipalatinsk test site for the period 2008-2021. (activity of ^{137}Cs and ^{90}Sr in soil); – literary sources.
List of the issues to be investigated, designed and developed *(analytical review of literary sources with the purpose to study global scientific and technological achievements in the target field, formulation of the study purpose, design, construction, determination of the procedure for study, design, and construction, discussion of the study work results, formulation of additional sections to be developed; conclusions)*	– review of literary sources on the research topic; – formation of radioactive soil contamination during nuclear tests; – theoretical assessment of the value of the ratio depending on the fissile charge material (^{235}U and ^{239}Pu); – review of experimental data (results of measuring the activity of ^{90}Sr and ^{137}Cs) and their calculation based on the ratio of natural fission products; – statistical processing of experimental data (calculated ratios ^{90}Sr/^{137}Cs);

	– comparison of the results of the theoretical evaluation of the ratios ^{90}Sr/ ^{137}Cs and the ratios expected based on experimental data.
List of graphic material *(with exact specification of required drawings)*	– map of the location of soil sampling points; – map of the distribution of the ^{137}Cs activity in the soils of the object of research; – map of the distribution of ratios ^{90}Sr/^{137}Cs on the object of research; – graphic material of the distribution of ratios of fission products (^{90}Sr,^{137}Cs); – maps of the distribution of activity ^{90}Sr in the soils of the object of research; – presentation.

Advisors to the sections of the Master Thesis

Chapter	Consultant
Assessment of ^{90}Sr/^{137}Cs ratios from experimental data, followed by statistical processing. Comparison of results of theoretical evaluation of ^{90}Sr/^{137}Cs ratios and ^{90}Sr/^{137}Cs ratios calculated from experimental data.	Professor, Ph.D., Yakovleva V.S. Director of the IRSE NNC RK, Associate Professor, Ph.D. Aidarkhanov A.O.
Financial management, resource efficiency and resource saving	Associate Professor, Ph.D. Spitsyna L.Yu.
Social responsibility	Associate Professor, Ph.D. Perederin Yu.V.
Foreign language	Professor, Ph.D., Yakovleva V.S.

Titles of sections that must be written in a foreign language:
1 Literature review on the research topic
2 Formation of radioactive contamination of the environment during nuclear tests
3 Object of study
4 Theoretical evaluation of the ratios ^{90}Sr / ^{137}Cs depending on the fissile charge material
5 Estimation of ratios ^{90}Sr / ^{137}Cs according to experimental data
6 Financial management, resource efficiency and resource saving
7 Social Responsibility

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

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

Job title	Full name	Academic degree, title	Signature	date
Professor	Yakovleva V.S.	Ph.D		

Assignment accepted for execution by a student:

Group	Full name	Signature	date
0AM13	Baklanova Yuliya Valerievna		

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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«Национальный исследовательский Томский политехнический университет» (ТПУ)

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

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Обучающийся:

Группа	ФИО
0АМ13	Бакланова Юлия Валерьевна

Тема работы:

Исследование соотношений $^{90}Sr/^{137}Cs$ в поверхностном слое почвы на территории Карагандинской области в пределах Семипалатинского испытательного полигона

Срок сдачи обучающимся выполненной работы:	22-26.05.2023 г.

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
22.03.2023 г.	*Введение*	
29.03.2023 г.	*Литературный обзор по теме исследования*	
01.04.2023 г.	*Формирование радиоактивного загрязнения почвы при ядерных испытаниях*	
03.04.2023 г.	*Объект исследования*	
24.04.2023 г.	*Теоретическая оценка соотношений $^{90}Sr/^{137}Cs$ в зависимости от делящегося материала ядерного заряда*	
07.05.2023 г.	*Оценка соотношений $^{90}Sr/^{137}Cs$ по экспериментальным данным*	
26.05.2023 г.	*Заключение*	

СОСТАВИЛ:
Руководитель ВКР

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

СОГЛАСОВАНО:
Руководитель ООП / ОПОП

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

Обучающийся

Группа	ФИО	Подпись	Дата
0АМ13	Бакланова Ю.В.		

TOMSK POLYTECHNIC UNIVERSITY

ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

School of Engineering School of Nuclear Technology
Direction of training (OOP / OPOP) 14.04.02 Nuclear physics and technology
Level of education Master's degree
Department of School (REC) Department of Nuclear Fuel Cycle
Completion period (fall/spring semester 2022/2023 academic year)

CALENDAR RATING PLAN
completion of the master thesis

Student:

Group	Full name
0AM13	Baklanova Yuliya Valerievna

Topic of study work:

Study of $^{90}Sr/^{137}Cs$ ratios in the topsoil of the Karaganda region within the Semipalatinsk test site

Deadline for students to submit completed work:	May 22-26, 2023

Date control	Section (module) name / type of work (research)	Maximum section (module) score
15.03.2023	*Introduction*	10
29.03.2023	*Literature review on the research topic*	15
01.04.2023	*Formation of radioactive soil contamination during nuclear tests*	15
03.04.2023	*Object of research*	15
24.04.2023	*Theoretical assessment of $^{90}Sr/^{137}Cs$ ratios depending of nuclear charge fissile material*	20
07.05.2023	*Assessment of $^{90}Sr/^{137}Cs$ ratios by experimental data*	20
22.05.2023	*Conclusion*	5

COMPILED BY:

Scientific supervisor

Job title	Full name	Academic degree, title	Signature	date
Professor	Yakovleva V.S.	Ph.D.		

AGREED:

Head of the PLO

Job title	Full name	Academic degree, title	Signature	date
Associate Professor	Semenov A.O.	Ph.D.		

Student

Group	Full name	Signature	date
0AM13	Baklanova Yu.V.		

LEARNING OUTCOMES

Competence code	Competence name
Universal competences	
UC(U)-1	Ability to critically analyze problem-based situations using the systems analysis approach, and generate decisions and action plans.
UC(U)-2	Ability to run a project at all life-cycle stages.
UC(U)-3	Ability to organize and lead the teamwork and generate a team strategy to achieve the target goal.
UC(U)-4	Ability to use modern communication technologies, including in foreign languages for academic and professional interaction.
UC(U)-5	Ability to analyze and account for cultural diversity in the process of intercultural interaction.
UC(U)-6	Ability to set and pursue individual and professional activity priorities and ways to modify professional activity based on self-esteem.
General professional competences	
GPC(U)-1	Ability to formulate goals and objectives of the research study, select assessment criteria, identify priorities for solving problems.
GPC(U)-2	Ability to apply modern research methods, evaluate and present the results of the performed research.
GPC(U)-3	Ability to present research outcomes in the form of articles, reports, scientific reports and presentations using computer layout systems and office software packages.
Professional competences	
PC(U)-1	Ability to create theoretical and mathematical models in the field of nuclear physics and technology.
PC(U)-2	Readiness to apply methods of investigation and calculation of processes occurring in modern physical installations and devices in the field of nuclear physics and technology.
PC(U)-3	Readiness to develop practical recommendations for the use of research findings.
PC(U)-4	Ability to assess risk and determine safety measures for new installations and technologies, to draw up and analyze scenarios for potential accidents, and to develop methods to reduce the risk of their occurrence.
PC(U)-5	Ability to analyze technical and computational-theoretical developments, to take into account their compliance with the requirements of the laws of the Russian Federation in the field of nuclear and radiation safety and atomic energy.
PC(U)-6	Ability to objectively evaluate a proposed decision or project attitude to a modern world level, to prepare an expert opinion.
PC(U)-7	Ability to formulate technical specifications, use information technologies and application software packages in the design and calculation of physical installations, to use knowledge of methods for analyzing environmental and economic efficiency in the design.
PC(U)-8	Readiness to apply optimization methods, analysis of options, search for solutions to multi-criteria problems, taking into account uncertainties in the design.
PC(U)-9	The ability to solve problems in the field of science, technology and technology development, taking into account regulatory legal regulation in the field of intellectual property.
PC(U)-10	Readiness to teach in the main educational programs of higher education and additional professional education.

PC(U)-11	Ability to design and economic justification of innovative business, content, structure and procedure for developing a business plan.

Abstract

The graduation thesis contains 100 p., 12 fig., 28 tabl., 62 sources, 1 appx.

Keywords: Semipalatinsk Test Site (STS), Karaganda region, radionuclides, cesium-137 (^{137}Cs), strintium-90 (^{90}Sr), soil, activity, ^{90}Sr/^{137}Cs ratio.

The object of research is the distribution of ^{90}Sr/^{137}Cs ratios in the topsoil of the Karaganda region within the Semipalatinsk Test Site beyond its test locations.

The paper is aimed at assessing the determination efficiency of ^{90}Sr activity from that of ^{137}Cs in the topsoil in the territory of the Karaganda region within the Semipalatinsk Test Site beyond its test locations by calculation.

Scientific originality of the research work consists in determining the ^{90}Sr/^{137}Cs ratios in the topsoil of the Karaganda region within STS beyond its test locations and in carrying out a comparative analysis with a view to practically apply them to radioactively contaminated areas for assessing the boundaries of background areas and fallout plumes from various aboveground tests.

The practical relevance of findings is to possibly utilize estimated ratios of fission products of interest for radioactively contaminated areas to assess the boundaries of background areas and fallout plumes from various aboveground tests. Additionally, the results of the calculation of ^{90}Sr activity based on ^{137}Cs activity can be used for estimating dose loads on the population in case of their residence and economic activity on the investigated territory.

In the course of the work, the value of ^{90}Sr/^{137}Cs ratios was theoretically assessed versus the fissile material in the nuclear charge (^{235}U and ^{239}Pu), the available experimental data retrieved (measurements of ^{90}Sr and ^{137}Cs activities) and the ratios of fission products of interest calculated based upon it followed by statistically processing findings as well as research into regularities of ^{90}Sr/^{137}Cs ratio distribution in the topsoil was undertaken.

As a result of research, most of ^{90}Sr/^{137}Cs ratios were found to belong to the range of 0.5 ± 0.3, which suggests that fission products of interest similarly produce radioactive contamination in the territory of the Karaganda region within the Semipalatinsk Test Site beyond its test locations.

Basic design, technological, technical and operational characteristics: none.

Degree of implementation: a report at IV International Scientific Forum "Nuclear Science and Technology", (Almaty c. (Kazakhstan)). The total number of scientific publications: 1.

Scope: outputs are applicable to identify the boundaries of areas, which could have been radioactively contaminated due to aboveground nuclear tests.

The cost effectiveness/relevance of the work consists in using the estimated value of the ^{90}Sr/^{137}Cs ratio in order to reduce the load on the long-term radiochemical preparation of soil samples and thereby to simplify and cheapen the procedure of ^{90}Sr activity assessment. The

accuracy of such assessment is quite sufficient for accomplishing radioecological tasks that were set – conducting a comprehensive radioecological survey.

In the future, it is planned to continue the study of $^{90}Sr/^{137}Cs$ ratios in the area adjacent to the Semipalatinsk Test Site.

Designations and abbreviations

STS – Semipalatinsk Test Site;

IRSE NNC RK – Branch "Institute of Radiation Safety and Ecology" of the Republican State Enterprise "National Nuclear Center" of the Republic of Kazakhstan;

USSR – Union of Soviet Socialist Republics.

Contents

Introduction

The Semipalatinsk Test Site (STS) is one of the main test sites of the former Soviet Union used for various nuclear weapons tests. 1949 through 1989, 64% of all USSR nuclear tests were conducted here. Of them, 116 are atmospheric including aboveground (on the earth’s surface) and air nuclear explosions; and 340 underground nuclear tests. As a result of many years’ nuclear tests conducted at STS, a great deal of radionuclides with different half-lives were released into the atmosphere among which were fission products of a nuclear charge material. The mass number distribution of daughter fission products has two peaks ranging from 85 to 105 and 130 to 150. High yields of ^{137}Cs and ^{90}Sr are produced. They have relatively long half-lives (~30 years) and therefore pose a particular hazard to human health.

Aboveground nuclear explosions have led to the local radioactive contamination of the ground that is called fallout plumes. The spatial distribution of radionuclides was determined by the wind velocity and direction as well as by precipitation, which fostered a sooner fallout of radioactive particles onto the ground. It is safe to say that soil is the main environmental component that was exposed to radioactive contamination during nuclear tests. It is soil that accumulates and preserves all ecosystem contaminants including man-made radionuclides that resulted from nuclear testing.

2008 through 2021, the branch "Institute of Radiation Safety and Ecology" RSE NNC RK (IRSE NNC RK) conducted a comprehensive ecological survey of the STS territory. The main objective of this survey was to assess the radiological environmental health at the test site and the consequences of nuclear tests.

Gaining a complete understanding of the radioecological situation in the territory of the Karaganda region within the test site beyond its test locations requires the knowledge about the content of ^{90}Sr in the soil, which is characterized by a long half-life and high migration ability. No nuclear tests were carried out at the object of research; therefore, the existing surface contamination is formed mainly due to global fallouts being specific to the Northern hemisphere. ^{137}Cs activity is determined by a rapid and rather cheap gamma spectrometric technique. However, there is a problem of obtaining numerical values of ^{90}Sr activity in soils containing its low concentrations. The most reliable technique for determining ^{90}Sr low activity in the soil is a radiochemical analysis followed by a beta-spectrometric measurement. A range of radiochemical analysis operations is quite labor-intensive, which, given the high cost of a low-background beta-spectrometric equipment, predetermines the expensive determination of ^{90}Sr low activities by radiochemical isolation. That said, in most cases, measurements obtained are below detection limits of procedures and/or the equipment in use.

As an alternative, a technique of assessing the activity of ^{90}Sr through the correlation relationship with the activity of ^{137}Cs can be proposed. This approach is quite true since both radionuclides are fission products of the nuclear charge of both ^{235}U and ^{239}Pu producing high yields in fission reactions. Consequently, with this ratio it becomes possible to do without the radiochemical preparation of soil samples and thereby simplify and cheapen the procedure of ^{90}Sr activity assessment. The accuracy of such assessment is quite sufficient for accomplishing radioecological tasks – the conduct of comprehensive radioecological surveys.

The relevance of this work is primarily attributed to the identification of fallout plume boundaries in areas that could have been radioactively contaminated by atmospheric nuclear tests. Under these conditions, a reliable assessment of the activity of ^{90}Sr with respect to ^{137}Cs in the topsoil is necessary in order to rapidly evaluate the activity of ^{90}Sr in the topsoil to be used when determining the boundaries of radioactive contamination of the soil cover at nuclear test locations.

Thus, the work is aimed at evaluating the determination efficiency of ^{90}Sr activity from that of ^{137}Cs in the topsoil of the Karaganda region within the Semipalatinsk Test Site beyond its test locations using a calculation technique.

To achieve this goal, it will be necessary to accomplish the following tasks and write conclusions:

- review and analyze the literature on the research subject;
- theoretically assess the value of the $^{90}Sr/^{137}Cs$ ratio versus the fissile material in the nuclear charge (^{235}U and ^{239}Pu);
- calculate the $^{90}Sr/^{137}Cs$ ratios based upon experimental data (measurements of ^{90}Sr and ^{137}Cs activities), statistically process;
- reveal the relationship between measurement values of ^{90}Sr and ^{137}Cs activities and their ratios calculated;
- carry out a comparative analysis in order to practically apply ratios of fission products of interest in radioactively contaminated areas;
- evaluate the efficiency of a solution proposed;
- evaluate a social responsibility.

1 Literature review on the research subject

The STS territory is at the confluence of three regions in the Republic of Kazakhstan (Abai, Pavlodar, Karaganda), 130 kilometers northwest of the Semey city (previously named as Semipalatinsk) on the left bank of the Irtysh river [1]. The site of the Karaganda region within the STS beyond its test locations was chosen as the object of research in this graduation thesis.

The main source of surface radioactive contamination of the soil at STS are 86 air and 30 aboveground nuclear tests carried out at the Experimental Field site from 1949 to 1963. [1]. The radioactive fallout resulting from atmospheric tests is divided into local and global (tropospheric and stratospheric). Local fallout occurs on the first day in the area adjacent to the epicenter of a nuclear explosion. The size of particles that produce local precipitation ranges from 0.1 mm to 1 cm. The size of particles that produce tropospheric precipitation varies between 10 and 100 μm. These particles enter the troposphere to a height of 10–18 km, are captured by air currents and gradually fall out with precipitation onto the earth's surface. The fallout time of this precipitation can be up to 30 days. Stratospheric precipitation is produced by particles which are less than 10 μm. The precipitation event from the stratosphere occurs slowly, their residence time at an altitude of 20-25 km varies from several months to several years. Radioactive contamination of the soil cover from the stratospheric reservoir is taken as radioactive being produced by the global fallout. Due to the long residence of radionuclides in atmospheric layers, short-lived radioisotopes completely decay, and such long-lived fission products as ^{90}Sr and ^{137}Cs become radiologically important [2].

According to the literature data from various authors, ^{90}Sr and ^{137}Cs activity concentrations attributed to the global fallout in the Northern hemisphere range from 1 to 19 Bq/kg and 4 to 29 Bq/kg, respectively, and the $^{90}Sr/^{137}Cs$ ratio is 0.6 [3, 4, 5, 6, 7, 8, 9, 10].

The $^{90}Sr/^{137}Cs$ ratio being equal to 0.6 is the average for a long period of observations (1960-1971) of the global fallout of these radionuclides. The stability of the $^{90}Sr/^{137}Cs$ ratio indicates that the mechanisms of entry, distribution in there and the fallout of radionuclides of interest onto the earth's surface are the same [11].

Global radioactive contamination of the soil cover is not the same at different geographical latitudes and is roughly the same along each latitude band other than highly arid zones, mountainous areas and locally contaminated regions. The maximum distribution of long-lived isotopes deposited over the earth's surface was at 40–50°N [12]. The paper by V.N. Lavrenchik also says that in the 1950s–1960s of the last century, when the number of nuclear weapons tests conducted in the atmosphere was the greatest, the maximum density of the fallout was observed at 40-50°N [13]. The paper by I.V. Molchanova deals with the study of man-made contamination of the soil and land cover in the south of the Primorsky Krai. The content of radionuclides in soils of the Primorsky Krai was found not to differ from the current background level, which in the zone between 50 and 60° N is 1.3 kBq/m^2 for ^{90}Sr and 2.2 kBq/m^2 for ^{137}Cs, and ^{137}Cs/^{90}Sr is 1.7 [3], i.e. the ^{90}Sr/^{137}Cs is 0.6. Since these latitudes can also be reckoned among Kazakhstan, which is between 40 and 55°N, one may assume that the ^{90}Sr/^{137}Cs ratio of 0.6 is also specific to the study area.

To determine low activities of ^{90}Sr, radiochemical conditioning is traditionally used, which is labor-intensive and along with the costly low-background beta-spectrometric equipment, it provides for the high cost of ^{90}Sr determination. That said, in most cases, measurements obtained are below detection limits of procedures and/or the equipment in use.

As an alternative, a technique of assessing the activity of ^{90}Sr through the correlation relationship with the activity of ^{137}Cs can be proposed. This approach is quite true since both radionuclides are fission products in the nuclear charge of both ^{235}U and ^{239}Pu producing a high yield in fission reactions. Consequently, with this ratio, it becomes possible to do without the radiochemical preparation of soil samples and thereby simplify and cheapen the procedure of ^{90}Sr activity assessment.

The same technique of assessing the residual activity of ^{90}Sr, following a partial decay by its relative fission yield, was used to describe the radiological situation at former French nuclear test sites in Algiers assuming that these radionuclides with respect to ^{137}Cs were not fractionated during deposition [14].

The monograph entitled "Scientific aspects of agricultural production under post-Chernobyl conditions" edited by A.G. Podolyak contains information that prior to the accident at the Chernobyl nuclear power plant, the ^{90}Sr/^{137}Cs ratio fluctuated from 1:1.7 to 1:2.0, which corresponds to the release of fission products during nuclear explosions. The density of the Belarus territory contamination with ^{137}Cs at that point in time ranged from 1.85 to 5.92 kBq/m^2, the one with ^{90}Sr - 1.11 to 2.96 kBq/m^2 [15].

The ratio technique of these fission products was used to assess the activity of ^{90}Sr in the surface water layer of the Black sea. The ^{137}Cs/^{90}Sr ratio was approximately 2 in 1964, 1 in 1971, and less than 1 in 1977 [16].

Thus, we can see that the global community is taking experimental efforts to use the ratio technique of fission products of interest in o carry out a rapid assessment the activity of ^{90}Sr from that of ^{137}Cs.

Section conclusions

Analysis of the scientific literature on the research subject showed that different countries are making experimental efforts to use the technique ratio of fission products of interest in order to assess the activity of ^{90}Sr by activity ^{137}Cs.

2 Formation of radioactive soil contamination during nuclear tests

During nuclear tests, a mixture of radionuclides gets into the environment and spreads there.

In 1996, a list of all nuclear tests conducted by the USSR between 1949 and 1990 was published [17]. That list contains information about the location (test site) and the test date as well as the total yield in TNT equivalent (kt). In 1998, the list was supplemented with data on the detonation height of nuclear devices and bombs [18], which is a highly important characteristic of an explosion since the ratio between the detonation height above the underlying surface and the yield affects whether or not the fireball reaches the earth's surface at the time of its stabilization. As defined in [17, 18], nuclear tests conducted at STS can be divided into 3 groups:

- aboveground explosion is a nuclear test on the earth’s surface or on a test tower. By physical criteria, all nuclear tests at a detonation height of 35 m/kt$^{1/3}$ at most count as aboveground explosions; a resulting expanding fireball reaches the earth's surface;
- an air explosion is a nuclear test in the atmosphere at a detonation height of at least 100 m/kt$^{1/3}$, an expanding fireball does not touch the ground;
- an underground explosion is a nuclear test, in which the explosive device was located under the ground. Under normal conditions, this does not lead to radioactive contamination of the earth's surface except for soil excavation explosions and tests in case of an off-normal radiological situation resulting in surface contamination.

Of 116 atmospheric tests conducted in the STS territory, aboveground explosions have affected the environment most of all (mainly the soil cover) (30 tests). All aboveground tests were conducted at the "Experimental Field" site. At the same time, in 5 cases, nuclear devices malfunctioned under normal conditions [19]. The number of nuclear tests conducted at the test site by years is listed in the table (Table 1). The total energy release from atmospheric nuclear tests in terms of a conventional explosive equivalent of (trinitrotoluene) was 6.6 megatons of TNT.

Table 1 – Distribution of the number of nuclear tests at "Experimental Field" by years

Year	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
air explosion	1	0	1	0	1	3	3	3	0	0	0	0	6	12
aboveground	0	0	1	0	4	6	2	5	11	8	0	0	22	27
Total	1	0	2	0	5	9	5	8	11	8	0	0	28	39

Fallout plumes produced by 11 aboveground nuclear tests went beyond the test site, and the remaining 14 tests were conducted to cause the maximum deposition of nuclear debris right within the test site boundary [20].

Initially, radionuclides that are produced during a nuclear explosion, like all the other particles that get into a fireball, are in a gaseous state. Cooling down over time, radionuclides condense and settle on fog droplets and dust particles and remain like this in the nuclear cloud. That said, if any aboveground explosions are conducted, some of radioactive substances diffuses into fritted ground particles involved in the fireball. During air explosions, radionuclides condense onto dust particles and fog droplets producing the global fallout. The global fallout is subdivided into tropospheric and stratospheric. The tropospheric fallout consists of aerosols that are not transported through the tropopause and deposited roughly within 30 days. Over this period, radionuclides that have entered the troposphere are dispersed in the latitudinal band, into which they were brought by a nuclear explosion, along paths defined by the wind pattern. The stratospheric fallout is attributed to particles that later give rise to a large-scale global fallout characteristic of the hemisphere in which a nuclear explosion took place. They account for the bulk of residual long-lived fission products – ^{90}Sr and ^{137}Cs.

Sizes of radioactive particles in the nuclear cloud are very small - their diameters vary from thousandths to deciles of a millimeter. When the nuclear cloud moves, radioactive particles settle on the ground under gravity producing a fallout plume in the major direction of the nuclear debris wind (remnants of fissile material, fission fragments, neutron activation products) and contaminating the environment. In some cases, a fallout plume may be branched if at the time of testing the wind direction and velocity change at different heights. The decay of fission fragments is the major radiation contributor to the environment. This impact depends both on the total activity of fragments and activities of individual nuclides as well as on their time variations.

Radionuclides deposited on the earth's surface are incorporated in migration processes. The migration of radionuclides in the soil is a complex enough process leading to the redistribution of radionuclides between different soil phases and conditions, the vertical and horizontal movement of radionuclides affected by physical and chemical processes, the activity of microorganisms and animals and the anthropogenic activity. At the same time, radionuclides do not cause changes in basic properties of soil – pH, the ratio of mineral nutrition elements, the level of fertility.

Many papers are dedicated to studying the behavior of man-made radionuclides in soils. The overwhelming majority of these deal with the behavior of long-lived fission products like ^{90}Sr and ^{137}Cs in the soil and fallout. In global fallouts (rain, snow, fog), ^{90}Sr radionuclide is predominantly present in water-soluble and exchangeable forms, and ^{137}Cs is in the acid-soluble (1N HCl) form [6]. According to studies, the solubility of ^{90}Sr in the soil from the global fallout depends on many factors including soil types and the residence time in the soil.

The results characterizing the distribution of radionuclides in subtypes and varieties of chestnut soils in the study area illustrate that under conditions of a non-percolative water regime, man-made radionuclides resulted from nuclear tests are mainly in surface horizons of soils and do migrate a lot deep down the soil profile. As a whole, radionuclides are concentrated in the topsoil and are mostly found to a depth of 15-20 cm. The 0-5 cm layer contains about 89 % of ^{137}Cs, 77 % of ^{90}Sr. In the 0-10 cm layer, this value for these radionuclides is 95 % and 87 %, respectively [25].

Undoubtedly, ^{90}Sr and ^{137}Cs will subsequently behave different in the environment owing to various migration abilities but, in general, they can be considered as pathfinder elements using ratios of their activities for practical purposes.

Section conclusions

1. Radioactive contamination of soil in aerial nuclear tests depends on the fissile material of the nuclear charge, the height of detonation of the charge (aboveground or air), the migration abilities of radionuclides, etc.

2. The 0-5 cm layer contains about 89% of ^{137}Cs, 77% of ^{90}Sr. In the 0-10 cm layer, this value for these radionuclides is 95% and 87%, respectively.

3 Object of research

3.1 Landform and geographical description

The area of the Semipalatinsk Test Site is ~18.5 thousand km^2, of which the Abay region (previously named Semipalatinsk and East-Kazakhstan region) occupies 54%, the Pavlodar and Karaganda regions – 39% and 7%, respectively. The STS location on the map of Kazakhstan is depicted in Figure 1.

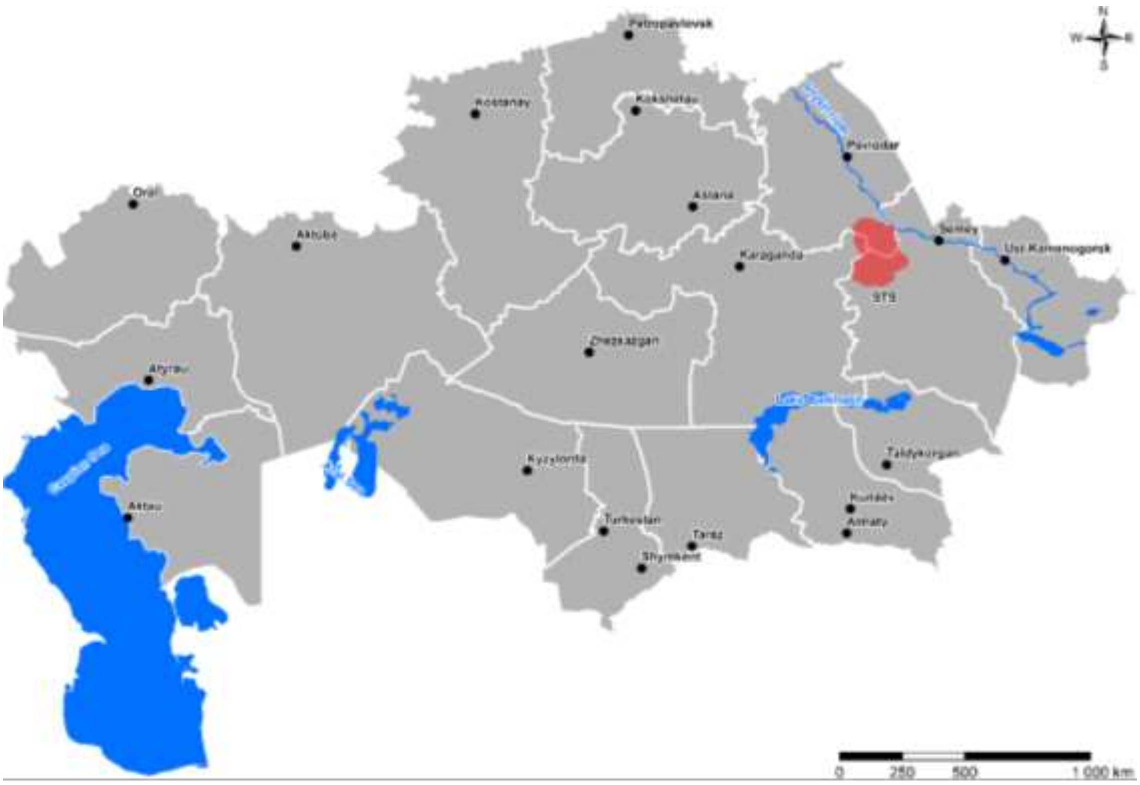


Figure 1 –STS location on the map of Kazakhstan

About 1,300 km^2 section in the Karaganda region within STS is in close proximity to the former "Experimental Field" testing location at which atmospheric explosions (aboveground and air) were conducted thereby making the major contribution to the radioactive contamination of the study area [21]. Also, in the Karaganda region, within STS, there is a "4" testing site where tests were conducted using radiological warfare agents [1]. These test locations at STS are depicted in the figure (Figure 2). Other sites are located farther than 50 km away (Figure 2). Other sites are located farther than 50 km away.

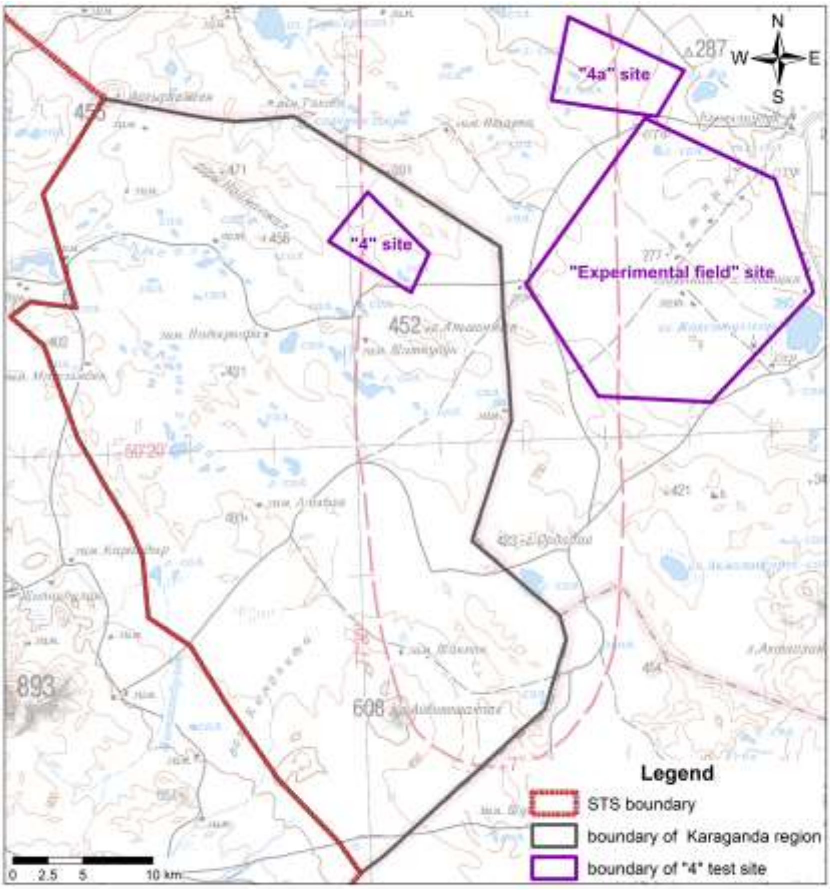


Figure 2 – Locations of the "Experimental Field", "4" and "4A"

Since no nuclear tests were conducted right in the territory of the Karaganda region within the test site beyond its test locations, radioactive contamination may be attributed to the global and local fallout that resulted from atmospheric tests at the "Experimental Field" site or radiological warfare agent tests at the "4" site. Presumably, the existing surface contamination is produced by the global fallout specific to the Northern hemisphere and the local fallout from nuclear explosions conducted at STS test locations.

The following landform types occur in the Karaganda region within STS [22]:

1. Low-hill terrains, which are built up predominantly by tuffs, tufoporphyrites, granites.

2. High ridge and steeply-sloping hummocks with outcropping granites, quartzites, tuffs on bald peak tops.

3. Low hummocks (low bald peaks with outcropping bedding rocks of both granites and quartzites).

4. Deluvial-proluvial plains characterized by motley grass steppe vegetation.

5. Deep depressions with partly nonperennial or perennial lakes that represent sors.

6. Anthropogenically disturbed areas due to economic activities.

Surface waters are represented by saline lakes and temporary water streams that dry up in the dry season.

The territory of the Karaganda region within the test site is refers to reserve lands in accordance with the Governmental Decree of the Republic of Kazakhstan dated February 7, 1996 No. 172 "On the release of the former Semipalatinsk Nuclear Test Site lands to reserve lands". According to cl. 143 of the "Land Code of the Republic of Kazakhstan" "... Land plots where nuclear weapon tests were conducted cannot be transferred by the Government of the Republic of Kazakhstan into ownership or land use until after all remediation measures are taken concerning nuclear consequences and a comprehensive environmental survey is complete, if the Environmental Impact Assessment opinion is positive…".

3.2 Soil cover description

In terms of soil and geography, the STS territory covers two subzones of the steppe zone: the subzone of dry steppes with a zonal subtype of chestnut soils and the subzone of desert steppes on light chestnut soils. Chestnut soils are common in the west and northwest of the test site area, light chestnut soils occupy its central, eastern and southern parts.

The territory of the Karaganda region within STS is hilly with a low-hill terrain and high hummocks developed having the peaks of Aibikeshokpak – 608 m (in the southern part of the territory), Alshinzhal – 453 m, Kamennaya – 442 m, in the north – Naimanzhal mountains (471 m); actual elevations of the deluvial-proluvial plains range from 320 to 422 m. The southern part is represented by the Kyndykty valley, the Sarymsaktobe stow is located here, and the Alybay stow is in the central part. Parent rocks in the survey area are represented by loamy, rocky and stony, crushed stony-loamy, argillaceous soils [23].

The object of research is an area of zonal chestnut soils beneath various types of dry steppes. This area has outcropping effusive rocks (lavas, tuff porphyries and tuffs of base and acidic composition), a portion of hummocks is formed by sedimentary rocks (conglomerates, jaspers, shales) and quartz-bearing limestones. Granites are common on bald peak tops [24].

In most of the Karaganda region, within STS, zonal chestnut underdeveloped and incompletely developed soils are common. These soils are formed on slopes of bald peaks built up by firm bedding rocks. Parent rocks are thin eluvial-deluvial crushed stony loams, closely underlain by marl or slightly weathered rocks. The thickness of the skeletonless layer gradually increases from tops of bald peaks to their feet. At the same time, the fragmentation rate of clastic material in soils increases.

According to natural zoning [23], the territory of the Karaganda region within STS covers the part of the 13th natural area, which is a region of small bald peaks on underdeveloped chestnut and solonets soils beneath the dry steppe.

Research findings obtained by the IRSE NNC RK show that under conditions of the arid zone, without additional soil moisture, the maximum content of man-made radionuclides that resulted from nuclear tests is only concentrated in 0-5 and 5-10 cm epipedons depending on a soil type [25].

Section conclusions

1. The area of the Semipalatinsk Test Site is ~18.5 thousand km^2, of which the Abay region (previously named Semipalatinsk and East-Kazakhstan region) occupies 54%, the Pavlodar region is 39% and Karaganda region is 7%.
2. The territory of the Karaganda region within STS is an area of zonal chestnut soils beneath various types of dry steppes.
3. The territory of the Karaganda region within STS covers the part of the 13^{th} natural area, which is a region of small bald peaks on underdeveloped chestnut and solonets soils beneath the dry steppe.

4 Theoretical assessment of $^{90}Sr/^{137}Cs$ ratios depending of nuclear charge fissile material

Before theoretically estimating the fission products ratio of ^{90}Sr to ^{137}Cs, it is necessary to briefly consider the physical processes that occur during a nuclear explosion. A nuclear explosion is produced by an uncontrolled fission chain reaction of heavy element nuclei of the fissile material in the nuclear charge (^{235}U or ^{239}Pu) under the action of neutrons. A heavy nucleus is excited by neutron capture and deforms under the action of Coulomb repulsion forces, which then delays into two (rarely three) highly excited fission products.

The kinetic energy of the produced fragments (~172 MeV for ^{235}U and ~178 MeV for ^{239}Pu [26]) is converted after some time (about 10^{-12} s [27]) into the thermal energy of the explosion due to braking in the nuclear charge substance. Two to three neutrons emerge from the excited fragments after a time equal to 10^{-16}-10^{-15} s, whose energy spectrum is well described by the Maxwell distribution, with the most probable energy En ~1 MeV and an average neutron energy ~2 MeV [28]. Residual excitation of fission fragments is removed after a time of the order of 10^{-12} - 10^{-9} s by the emission of 6-8 gamma-quanta with an average energy of ~1 MeV. Once the excitation is removed, unstable fission fragments are produced, experiencing a chain of radioactive transformations with the emission of delayed neutrons, beta particles, antineutrinos, gamma-quanta and even alpha particles. The fission of ^{235}U or ^{239}Pu can produce up to 300 radioactive isotopes with half-lives ranging from 10^{-4}s to many tens or hundreds of years. Since the predecessors of ^{90}Sr and ^{137}Cs are short-living elements, that decay almost completely within an hour, calculations were made for this time interval:

$$Br^{90} \xrightarrow[\beta^-,1.9сек]{} Kr^{90} \xrightarrow[\beta^-,\gamma,33.2сек]{} Rb^{90} \xrightarrow[\beta^-,\gamma,2.9мин]{} Sr^{90} \xrightarrow[\beta^-,28.8лет]{} Y^{90} \xrightarrow[\beta^-,\gamma,64,3ч]{} Zr^{90}(стаб)$$

$$I^{137} \xrightarrow[\beta^-,\gamma,24.4сек]{} Xe^{137} \xrightarrow[\beta^-,\gamma,3.8мин]{} Cs^{137} \xrightarrow[\beta^-,30.1лет]{} Ba^{137}(стаб)$$

The quantity of each radionuclide produced in the fission process of nuclear charge material is characterized by the value of the absolute independent yield (probability of its production including neutron emission) – Y(A,Z) when normalized to 200% for all isotope yields, including stable ones elements. The value of the absolute independent yield Y(A,Z) can be found using the formula:

$$Y(A,Z) = Y_f(A,Z) \cdot Y_t(A),$$

where Y_t(A,Z) re the total (cumulative) yields of all isotopes with a given mass number A;

Y_f (A,Z) – relative independent yields (probabilities of formation of a given isotope after instantaneous neutron escape), normalised by:

$$\sum Y_f(A,Z)\,|_{A=const} = 1.$$

At present, extensive experimental information on Yt(A) in the fission of ^{235}U and ^{239}Pu by different neutrons has been accumulated and tables of recommended values for them are available [29, 30]. The relative independent yields Y_f (A,Z are usually determined from measured data or an empirical expression derived from them:

$$Y_f(A,Z) = (c \cdot \pi)^{-1/2} \cdot exp\left[-\frac{(Z - Z_p)^2}{c}\right],$$

where Z_p – the most probable charge for this isobaric chai;

Z – isobar charge, for which an independent yield is determined;

c = 2*(σ^2+1/12), where σ^2 – variance of the Gaussian distribution, 1/12 – Sheppard correction for discreteness of change in Z, data of Z_p and σ^2 for ^{235}U and ^{239}Pu are also shown in the table in [30].

Knowing the value of the absolute independent yield Y(A,Z), the activity of any fission products for a 1kT explosion at the initial time (t = 0) can be determined by the formula:

$$Q(A,Z) = \frac{N_f \cdot \ln(2) \cdot Y(A,Z)}{T_{1/2} \cdot 3{,}7 \cdot 10^8}, \text{Ки}.$$

where half-life $T_{1/2}$ – In seconds, a Y(A,Z) – in %.

Substituting numerical table values, we get the following:

$$Q(A,Z) = \frac{2{,}66 \cdot 10^{10} \cdot Y(A,Z)}{T_{1/2}}, \text{Ки, (для } ^{235}\text{U)},$$

$$Q(A,Z) = \frac{2{,}59 \cdot 10^{10} \cdot Y(A,Z)}{T_{1/2}}, \text{Ки, (для } ^{239}\text{Pu)}.$$

The total activity of each element of a branched isobaric chain is obtained by summing the activities of all members of linear chains. For a nuclear explosion, the change in activity of all isotopes in a linear isobaric chain of length n with time (the kinetics of change with time) is described by a chain of differential equations:

$$\frac{dQ_1}{dt} = -\lambda \cdot Q_1(t)$$

$$\frac{dQ_2}{dt} = -\lambda \cdot Q_2(t) + \lambda \cdot Q_1(t)$$

$$\dots$$

$$\frac{dQ_n}{dt} = -\lambda \cdot Q_n(t) + \lambda \cdot Q_{n-1}(t).$$

For the nth term in the chain, the solution to the system of equations is:

$$Q_n(t) = \sum c_{ni} \cdot \exp(-\lambda_i t),$$

where i = 1,2, ... n is the current number of the isobaric chain.

The coefficients before the exponent are found from the recurrence relations:

$$c_{ni} = c_{n-1,i} \cdot \frac{\lambda_n}{\lambda_n - \lambda_i}, \text{ (if } n \neq i),$$

$$c_{nn} = Q_n(t = 0) - \sum c_{ni}, \text{ (if } n = i).$$

The methodology for calculating nuclear fission products is described in detail in the handbook by N.G. Gusev, which also presents data on the cumulative yields of all fission products with a given mass number in nuclear fission ^{235}U и ^{239}Pu by instantaneous and thermal neutrons. However, researchers can also calculate fission fragments themselves using current data on the half-lives of radionuclides [30].

In the figure (Figure 3) isobaric chains for mass numbers are presented A=90 and A=137 (chains of formation ^{90}Sr and ^{137}Cs)

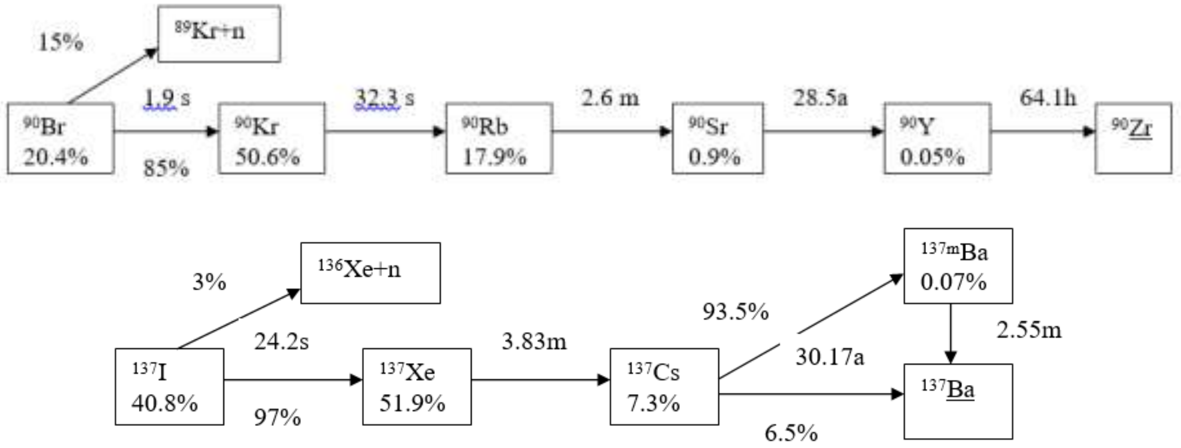


Figure 3 – Isobaric chains for mass numbers A=90, 137

Since there is no documented data on the type of charges used in the STS nuclear tests, calculations have been made for different fissile materials ^{235}U и ^{239}Pu. Leaving mathematics aside, according to background information and calculations it has been established that the value of the ratio $^{90}Sr/^{137}Cs$ depends on the fissile material and remains constant for one test. The figure (Figure 4) shows the $^{90}Sr/^{137}Cs$ ratios in the first hour after a nuclear explosion for different types of neutrons and different fissile materials (^{235}U, ^{239}Pu).

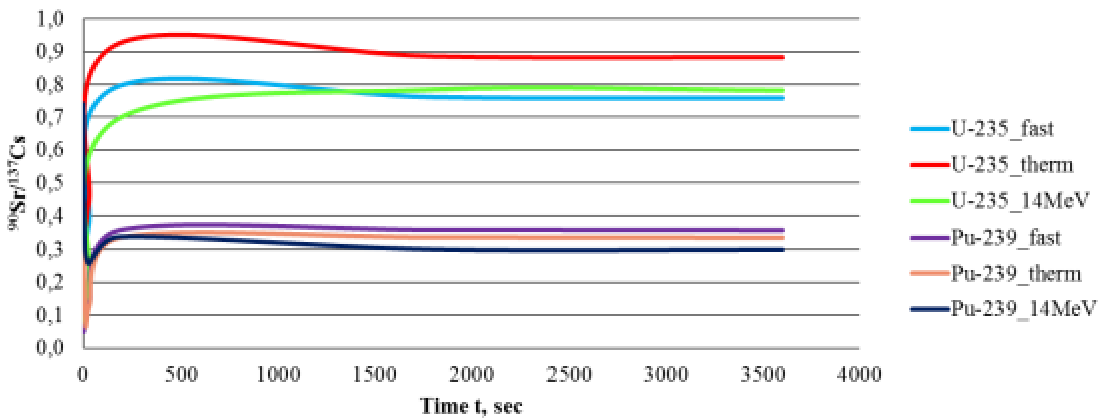


Figure 4 – $^{90}Sr/^{137}Cs$ ratios in the first hour after a nuclear explosion for ^{235}U and ^{239}Pu

Researchers conducted by staff at the IRSE NNC RK showed that nuclear tests were carried out predominantly with a plutonium charge, or with a mixed type of uranium-plutonium charge [1, 31]. On this basis, it is assumed that the initial ratio of $^{90}Sr/^{137}Cs$ from the nuclear tests is in the range 0.30 ÷ 0.88. This difference in the value of the fission product ratios is due to the fact that for a nuclear test with a plutonium charge, the ^{90}Sr yield is more than half that for a nuclear test with a uranium charge.

Section conclusions

1. Since there is no documented data on the type of charges used in the STS nuclear tests, calculations have been made for different fissile materials ^{235}U и ^{239}Pu.
2. For a nuclear test with a plutonium charge, the ^{90}Sr yield is more than half that for a nuclear test with a uranium charge.
3. The initial ratio of $^{90}Sr/^{137}Cs$ from the nuclear tests is in the range 0.30 ÷ 0.88.

5 Assessment of $^{90}Sr/^{137}Cs$ ratios by experimental data

5.1 Methodology for assessing the radioecological state of the soil cover

The main goal of researching into parameters of surface contamination resulting from fallout due to nuclear tests is to delimit radioactively contaminated areas using optimal radioecological survey schemes.

During research, results of laboratory analyses of soil samples collected as part of the comprehensive ecological STS survey were used. The methodology of the comprehensive ecological STS survey conducted in 2008-2021 is described in detail in the monograph [1].

Activities of man-made radionuclides in the soil cover are determined to know the rate of radioactive contamination of the survey area, to identify its areas containing elevated concentrations of radionuclides of interest in the soil and to delimit radioactive contamination. A methodology for assessing the radiological state of the topsoil at the object of research is schematically presented in the figure (Figure 5).

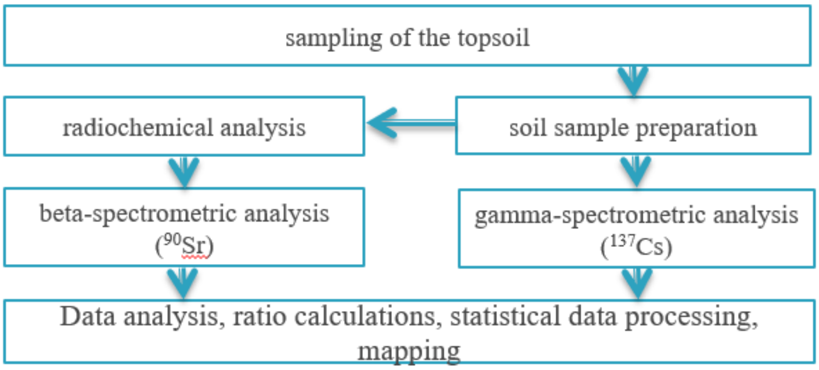


Figure 5 – Methodology for radioactive contamination assessment of topsoil

5.1.1 Topsoil sampling methodology

During the comprehensive ecological survey of the Karaganda region within the test site, the state of the soil cover was defined by sampling soil at junction points over the 1×1 km grid followed by laboratory tests. This survey grid makes it possible to reveal vast radioactively contaminated areas comparable to the size of a pasture area and a hayfield. This type of radioactive contamination, in most cases, includes fallout plumes from aboveground nuclear tests, excavation explosions and off-normal tests.

The topsoil was sampled using a point technique: a shallow pit was dug at the sampling point and a 5 cm soil layer was sampled on one of the pit’s vertical sides using a sampling tool (a 10×10×5 cm stainless steel trowel).

The topsoil was sampled as per GOST 17.4.3.01-83. The area of each point soil sample was 200 cm^2, and the sampling depth was 5 cm [1].

Just before each sample was collected, radiation parameters (EDR, β-particle fluence) were measured at the sampling point by means of a MKS-AT6130 radiometer-dosimeter, and geographic coordinates were set with a GPS receiver having a GARMIN satellite navigation system. The sample collected was packed in a plastic bag and supplied with a data sheet stating a sample number, a sampling point, the sampling date, geographical coordinates and field radiometry results.

Thus, 1,300 topsoil samples were collected from the territory of the Karaganda region within the Semipalatinsk Test Site beyond its test locations. A schematic map of their arrangement is depicted in the figure (Figure 6).

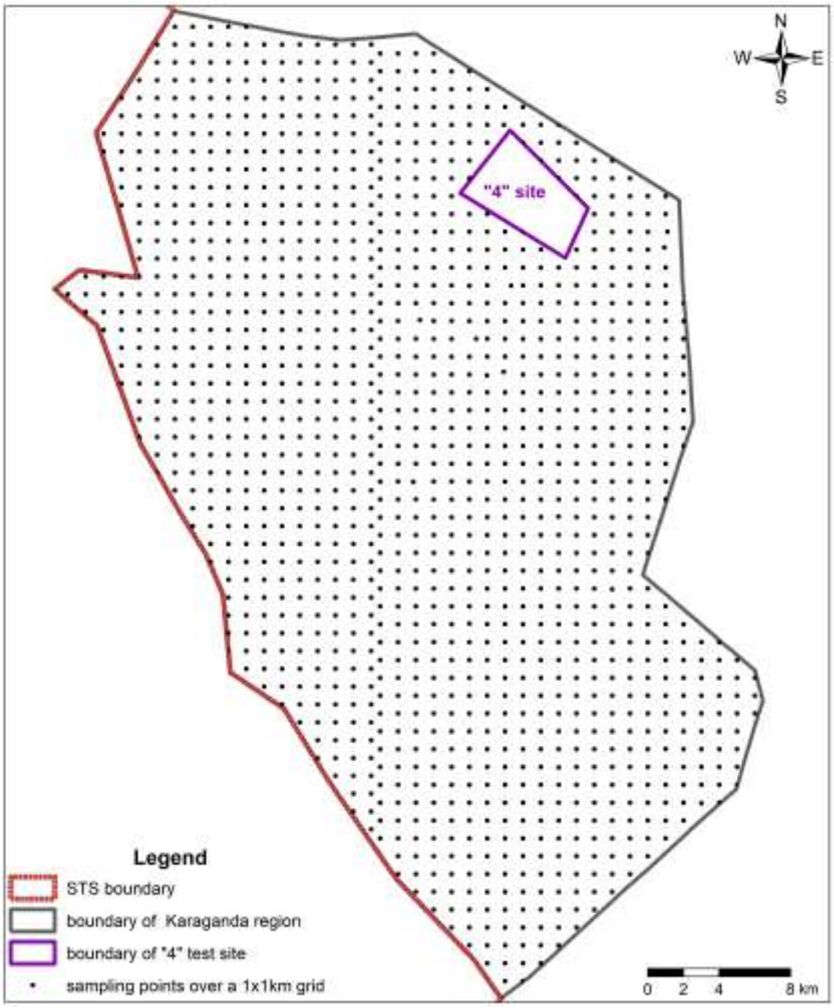


Figure 6 – Soil sampling points

The analysis of radiation parameters showed that the β-particle fluence in the study area is <10 p/(cm^2·min), EDR on the soil surface varies from 0.1 to 0.2 μSv/h. Values for each parameter totaled 1300.

5.1.2 Laboratory analysis methodology

The methodology for conducting laboratory analyses in the soil during a comprehensive ecological STS survey conducted 2008-2021 is described in detail in the monograph [1].

Determination of ^{137}Cs activity

The preparation of soil samples for the determination of ^{137}Cs activity consisted in air-drying a soil sample, separating inclusions (vegetation and stones) from the bulk of soil, sieving a dried sample through a 2 × 2 mm mesh, collecting an averaged 500–900 g subsample from the total soil sample by quartering and placing it in a plastic container that was sent to the gamma spectrometric analysis.

^{137}Cs activity in soil samples was determined with solid-state gamma spectrometers as per the measurement procedure using the SpectraLine software [1].

The exposure time of soil samples was 2 hours depending on the activity of a measured sample. The determination accuracy of ^{137}Cs activity concentration was verified by periodically measuring reference standards (OMACH, Russia).

Determination of ^{90}Sr activity

The activity concentration of ^{90}Sr was determined in 10% of the total number of topsoil samples that underwent a gamma spectrometric analysis to determine the activity concentration of ^{137}Cs.

Sample preconditioning to determine the content of ^{90}Sr consisted in collecting a 150 g soil subsample from an air-dry sample that was measured by gamma-spectrometry using the squaring technique; powdering that soil subsample in the laboratory mill; in collecting a 60-70 g soil subsample from the soil sample after powdering followed by placing it in the porcelain crucible; calcinating the subsample in the porcelain crucible for 8 hours in the muffle furnace at a temperature of 550 ° C to remove organic matter (plant, animal fragments etc.) [1].

Yttrium isotopes were separated from strontium isotopes by precipitating a slightly soluble compound, calcium fluoride (CaF2). The resulted precipitate was separated from the stock solution by centrifugation, dissolved in boiling in a weak 0.5 mol/l solution of hydrochloric acid, and, in order to purify it from interfering radionuclides and matrix elements, it was passed through glass columns filled up with extractant-coated fluoroplastic shavings - Di-2-ethyl-hexyl phosphoric acid (D2EHPA). Yttrium isotopes were eluted with a 6 mol/l hydrochloric acid and postpurified by isolating a slightly soluble yttrium hydroxide (Y(OH)3) from the solution. The resulted precipitate was separated from the stock solution and dissolved with a 1M HNO_3 solution. The resulted solution was quantitatively transferred into the scintillation vial followed by measuring ^{90}Y activity – the decay product of ^{90}Sr assuming that ^{90}Y measured activity is equal to that of ^{90}Sr [1]. Prior to the measurement, the vial with the solution isolated is aged for 14 days to achieve a radioactive equilibrium between ^{90}Sr and ^{90}Y.

Thus, ^{90}Sr activity in samples was determined by directly measuring the activity concentration of the daughter radionuclide ^{90}Y in the sample solution by Cherenkov radiation with a liquid scintillation beta spectrometer [1]. The exposure time was 2 hours.

5.2 Results of laboratory analyses of the topsoil in the territory of the Karaganda region within STS beyond its test locations

Based on results of laboratory analyses, ranges of activity concentrations of fission products in the topsoil of the Karaganda region within STS beyond its test locations were determined (Table 2). Values totaled: for ^{137}Cs – 1,300, for ^{90}Sr – 130.

Table 2 – Value ranges of activity concentrations in the topsoil (0-5 cm)

Parameter	^{137}Cs	^{90}Sr
Range of activity concentration, Bq/kg	<0.8 to 420	<1.0 to 140

Measurements show that in 75% of points surveyed, the activity concentration of ^{137}Cs in the topsoil in the territory of the Karaganda region within STS beyond its test locations is at the background level of the global fallout (≤29 Bq/kg) and exceeds it only in 25% (326 samples). The activity concentration of ^{90}Sr, in most cases (90%), is at the background level of the global fallout (≤19 Bq/kg) and exceeds it only in 10% (13 samples).

To map the distribution of ^{137}Cs in the study area, maps were constructed using the regression kriging technique by color differentiation of the activity concentration of this radionuclide. The color gradation in use makes it possible to visually characterize the actual activity of this radionuclide in the topsoil. (Figure 7).

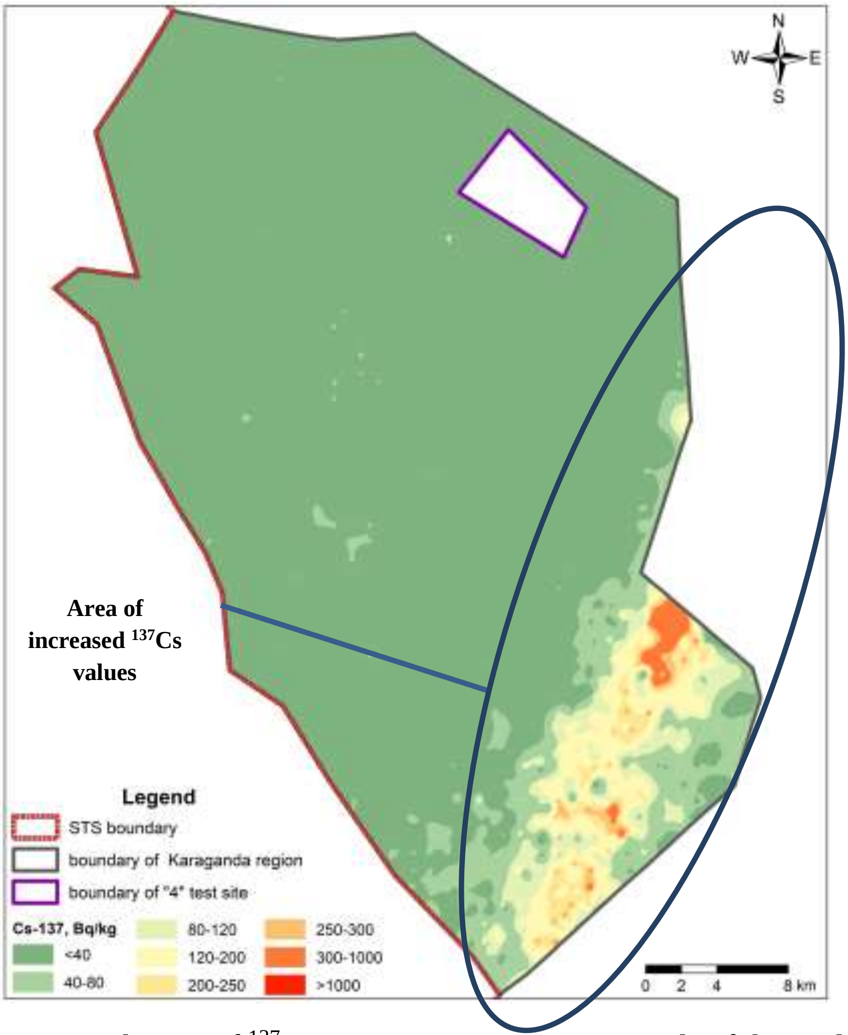


Figure 7 – Distribution of ^{137}Cs activity concentration in soils of the study area

The analysis of map documents showed that there are 2 zones noted in the Karaganda region within STS beyond its test locations – one area of elevated values of ^{137}Cs activity in soils (the fallout plume from an aboveground test on September 24, 1951, 38 kt) and second area of background activity levels in which the level of radioactive contamination is comparable to that of the global fallout.

5.3 Calculation of ^{90}Sr/^{137}Cs ratios from results of laboratory analyses followed by statistical processing

5.3.1 Statistical processing of measurement results

Spectrometric measurements of soil samples and ^{90}Sr/^{137}Cs ratios calculated were statistically analyzed since statistical processing allows making reasonable conclusions under uncertainty conditions, which improves the efficiency of radioecological studies.

For statistical processing of the dataset, such statistical techniques as an arithmetic mean (m) or geometric mean (g), a median, a root mean square deviation (σ) (Table 4) [32].

Outliers were determined and eliminated from the general dataset using standardized deviation, which is the indicator of the measurement value with respect to the general dataset [33]. Following outlier elimination, the above statistical parameters were calculated again.

The hypothesis on the distribution conformity of a random variable to the normal distribution law was verified using the Pearson criterion (χ^2). In case $\chi^2 > \chi_\alpha^2(f)$, then the hypothesis on the normal distribution is rejected – a confirmation that a retrieval of interest was chosen from the normal distribution is disproved. But if $\chi^2 < \chi_\alpha^2(f)$, the hypothesis proves true.

For the correct interpretation of data, only numerical values of ^{90}Sr and ^{137}Cs activity concentrations were taken into account, values of activity concentrations below detection limits of techniques in use (for the correct interpretation of data) were excluded.

The total number of topsoil samples selected to determine the experimental value of the ratio of interest was 92. Ranges adjusted for fission products studied are listed in the table (Table 3).

Table 3 – Value ranges of activity concentrations in the topsoil (0-5 cm)

Parameter	^{137}Cs	^{90}Sr
Activity concentration range, Bq/kg	1.8 to 170	2.0 to 140

In the territory of the Karaganda region within STS beyond its test locations, the $^{90}Sr/^{137}Cs$ ratio ranges from 0.05 to 12.8.

The ratio of ^{90}Sr to ^{137}Cs in the topsoil of the study area is graphically illustrated in the figure (Figure 8).

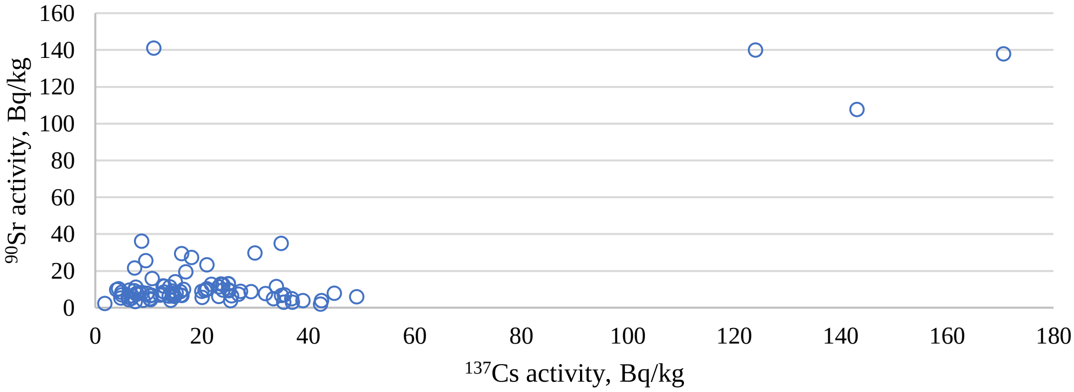


Figure 8 – The ratio of ^{90}Sr to ^{137}Cs in the study area

The analysis of data plotted showed that the distribution pattern of the ^{90}Sr-to-^{137}Cs relationship in the territory of the Karaganda region within STS is rather heterogeneous, which is attributable to different sources of radioactive contamination.

To verify this hypothesis, it was decided to map points of ^{90}Sr/^{137}Cs ratios for the study area. A schematic map of their arrangements is shown in the figure (Figure 9).

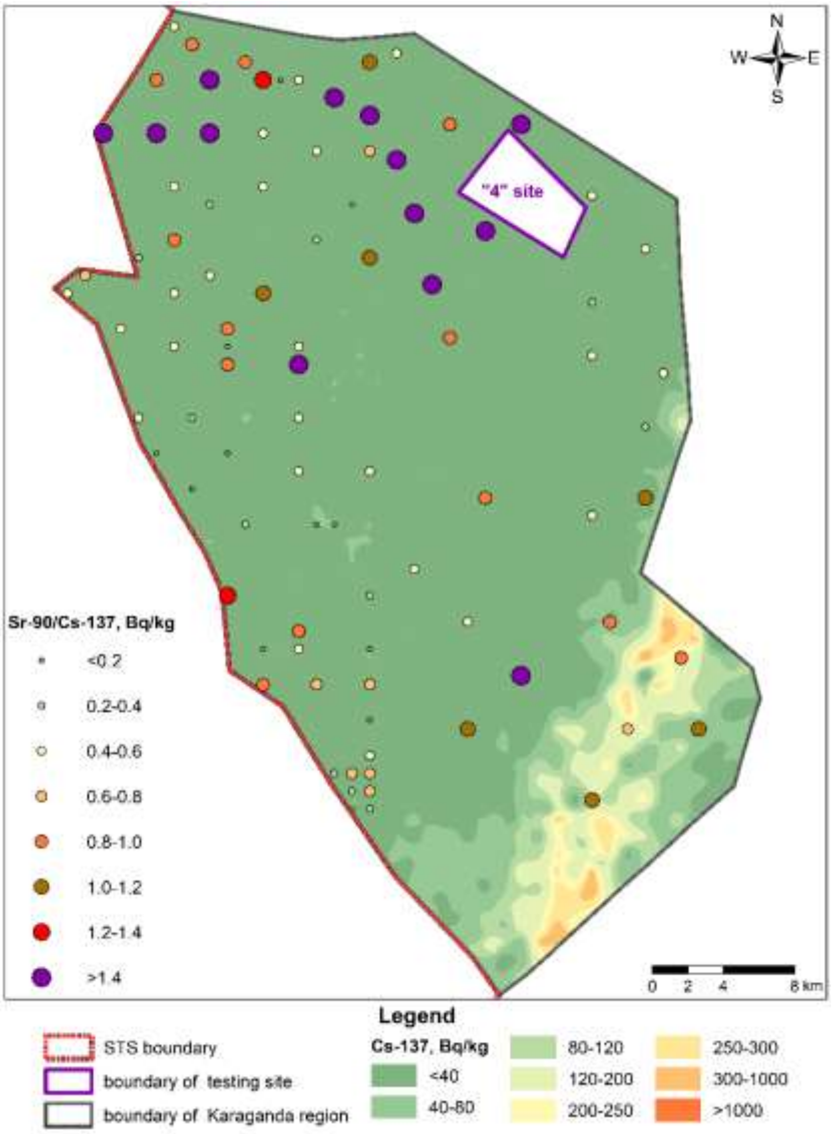


Figure 9 – Distribution of ^{90}Sr/^{137}Cs ratios in the study area

3 zones can be noted on the map in the figure (Figure 9): 2 zones of fallout plumes and a zone of low ratio values for fission products studied. Southeast of the Karaganda region, within STS, there is an area of fallout from an aboveground nuclear test conducted at the Experimental Field site on September 24, 1951 (38 kt, "southern plume"). The average ratio of fission products studied in this region is 1.0. North of the study area, despite low activity concentrations of ^{90}Sr and ^{137}Cs, there are higher than normal values of ^{90}Sr/^{137}Cs ratios, the average value of which is 2.0.

Such $^{90}Sr/^{137}Cs$ ratios are assumed to be typical of hydronuclear test locations or off-normal nuclear tests with a low nuclear energy release and if just few fission products are produced. This graduation thesis takes this plume as the one from an off-normal nuclear test.

Consequently, based on results of $^{90}Sr/^{137}Cs$ ratios calculated, 3 zones can be noted in the study area:

- a section of the fallout plume from a nuclear test;
- a section of the fallout plume from an off-normal nuclear test;
- the rest ("background") area of the Karaganda region within STS.

Table 4 – Results of statistically processed data

Parameter	Section of a fallout plume from a nuclear test	Section of a fallout plume from an off-normal nuclear test	"Background" area of Karaganda region within STS
minimum value	0,8	1,1	0,05
maximum value	1,1 (2,9)*	2,7 (12,8)*	1,3
mean value	1,0 (1,2)*	2,0 (2,8)*	0,5 (0,9) *
median	1,0 (1,1)*	1,6 (1,7)*	0,5 (0,6) *
root mean square deviation	0,2 (0,7)*	0,5 (3,1)*	0,3 (1,4)*
* - in brackets are values of statistical parameters prior to the elimination of higher than normal outliers			

Following the elimination of high values of $^{90}Sr/^{137}Cs$ ratios from the retrieval related to fallout plumes, a distribution histogram of $^{90}Sr/^{137}Cs$ ratios was constructed for the "background" area of the Karaganda region within STS (Figure 10). This histogram is based on 71 values.

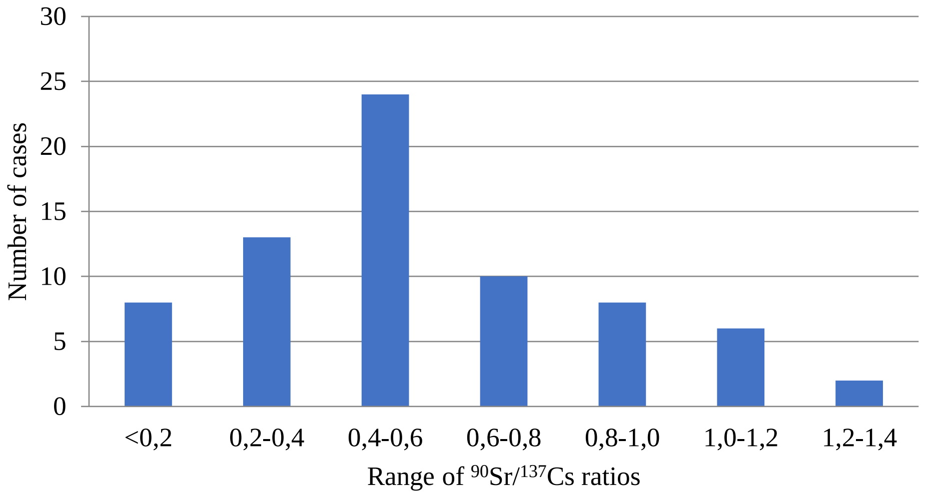


Figure 10 – Distribution histogram of numerical values of $^{90}Sr/^{137}Cs$ ratios by frequency of cases

The resulted distribution is normal, which was confirmed by the Pearson criterion. The $^{90}Sr/^{137}Cs$ ratio ranges as 0.05 ÷ 1.7 with an arithmetic mean of 0.5. The median of this retrieval is also 0.5. The equality of the median and the arithmetic mean also indicates a normal distribution.

Values of $^{90}Sr/^{137}Cs$ exceeding 0.5 are typical of areas near test locations and possible axes of passing fallout plume. More than 65% of $^{90}Sr/^{137}Cs$ ratios in the topsoil of the Karaganda region within STS beyond its test locations are within 0.5 ± 0.3, which suggests that ^{90}Sr and ^{137}Cs originate from the same source.

Where a supposed plume area of an off-normal nuclear test is passing, despite low values of activity concentrations, the $^{90}Sr/^{137}Cs$ ratio ranges as 1.0 ÷ 2.7 averaging 2.0 ± 0.9.

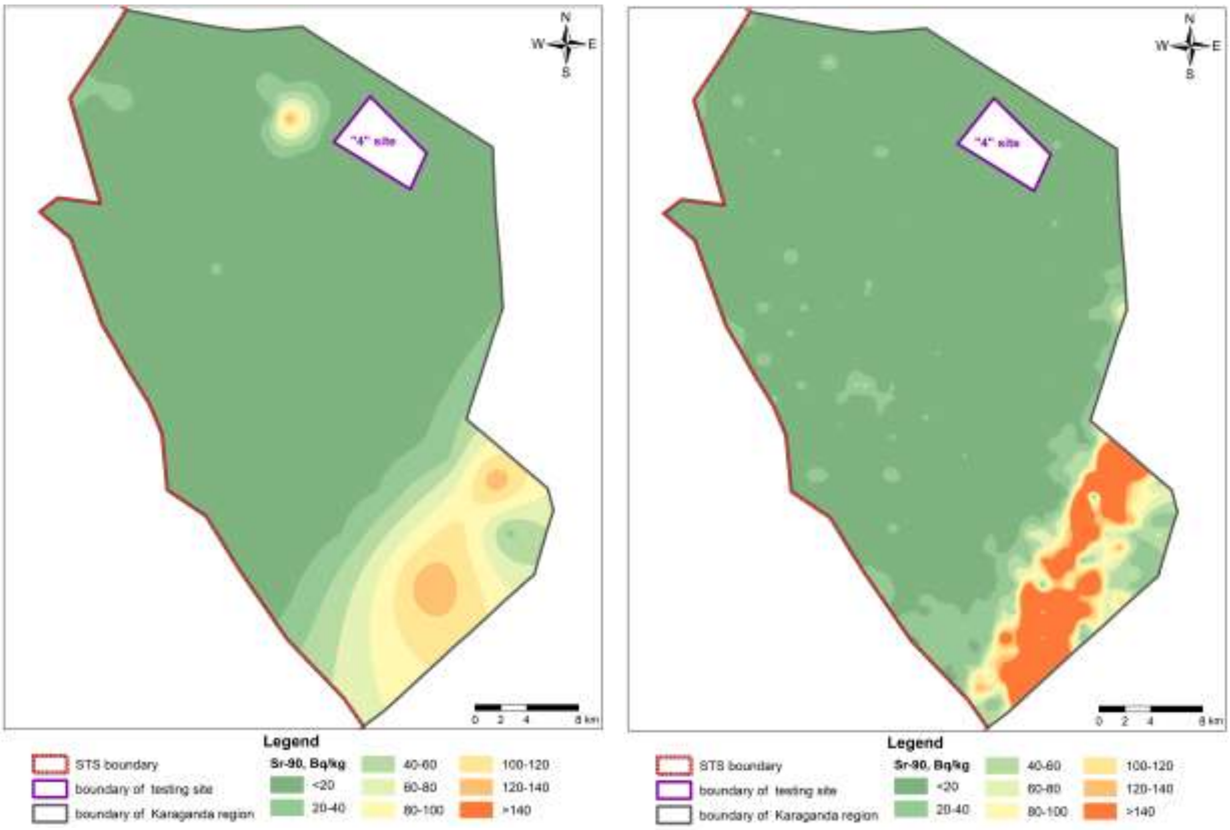
In the region of the passing plume from an aboveground test (September 24, 1951), the $^{90}Sr/^{137}Cs$ ratio ranges as 0.8 ÷ 1.1 averaging 1.0 ± 0.2.

Thus, grounds have been obtained for using $^{90}Sr/^{137}Cs$ ratios in the territory of the Karaganda region within STS beyond its test locations given zoning for the rapid assessment of ^{90}Sr activity in the topsoil. In addition, $^{90}Sr/^{137}Cs$ ratios are characterized by different values in fallout plumes and in areas of background activity levels, which makes it possible to use them for identifying boundaries of background areas and aboveground test locations.

5.4 Comparison of results on ^{90}Sr activity concentration from experimental and estimated data

For map documents, data on ^{90}Sr activity concentration was used. That said, for comparison, both experimental (measured ^{90}Sr activity concentrations) data and data calculated using the ratio technique (Figure 11) was used. When mapping the distribution of ^{90}Sr activity concentration using the ratio technique, a differentiated approach was applied: for the fallout plume from a nuclear test, the $^{90}Sr/^{137}Cs$ ratio equal to 1.0, for the fallout plume from an off-normal nuclear test, the $^{90}Sr/^{137}Cs$ ratio equal to 2.0, and in the rest ("background") of the territory – the $^{90}Sr/^{137}Cs$ equal to 0.5 were used.

For visual perception of ^{90}Sr distribution in the territory of the Karaganda region within STS beyond its test locations, maps were also constructed using the regression kriging technique by color differentiation.

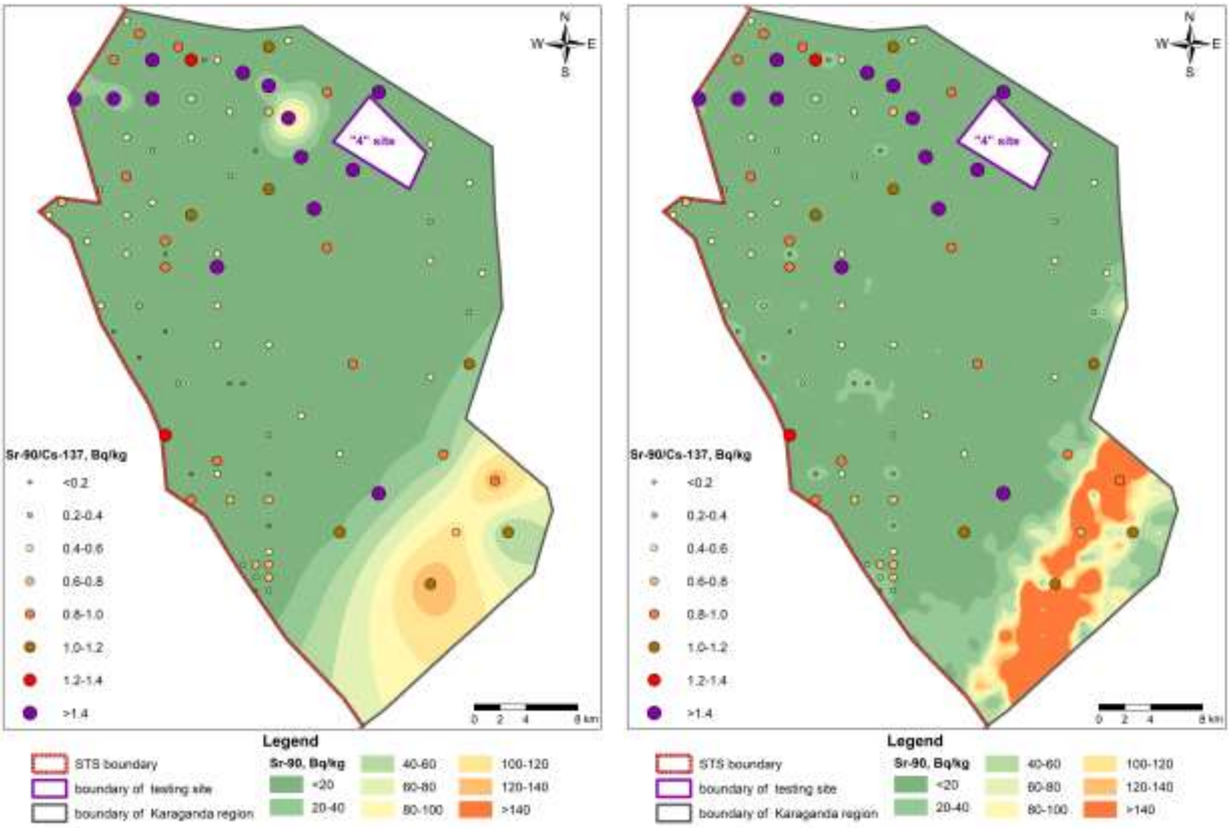


a) b)

a) experimental technique; b) ratio technique

Figure 11 – Distribution of ^{137}Cs activity concentration in soils of the study area

As can be clearly seen on the maps, the radioactive contamination with ^{90}Sr and ^{137}Cs in the study area coincides with the fallout plume from the aboveground nuclear test (September 24, 1951) (Figure 7, Figure 11). At the same time, a plume from the off-normal nuclear test was not identified either by means of values calculated for ^{90}Sr activity concentration using the ratio technique or by means of measured activity concentration values.



a) b)

a) experimental technique; b) ratio technique

Figure 12 – Distribution of ^{90}Sr/^{137}Cs ratios in the study area

This proves the fact that the ^{90}Sr/^{137}Cs ratio technique should be used to identify boundaries of fallout plumes since not all of them are identifiable on ^{90}Sr or ^{137}Cs distribution maps.

An additional advantage is the possibility of estimating public radiation exposure to ^{90}Sr by calculation from ^{137}Cs activity when living and carrying out economic activities in the study area.

Section conclusions

1. Values of $^{90}Sr/^{137}Cs$ exceeding the level of global fallout (0.6) were found to be typical of those survey areas that are in the impact zone fallout plumes from aboveground nuclear tests.

2. In topsoil of the territory of the Karaganda region within STS beyond its test locations, most of $^{90}Sr/^{137}Cs$ ratios range as 0.5 ± 0.3, which suggests a similar radioactive contamination with fission products of interest.

3. $^{90}Sr/^{137}Cs$ ratios in the study area and fallout plumes from nuclear tests and off-normal nuclear tests are characterized by different values, which makes it possible to use them for assessing boundaries of background areas and aboveground test locations.

4. Using ^{90}Sr activity obtained by calculation from that of ^{137}Cs, it is possible to evaluate public radiation exposure to this radionuclide when living and carrying out economic activities in the study area.

ЗАДАНИЕ К РАЗДЕЛУ
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Обучающемуся:

Группа	ФИО
0АМ13	Баклановой Юлии Валерьевне

Школа	**ИЯТШ**	**Отделение школы (НОЦ)**	**ОЯТЦ**
Уровень образования	магистр	**Направление/ООП/ОПОП**	14.04.02 Ядерные физика и технологии

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. *Стоимость ресурсов научного исследования (НИ): материально-технических, энергетических, финансовых, информационных и человеческих*	*Бюджет проекта – не более 426887,0 руб., в т.ч. затраты по оплате труда – не более 197438,89 руб. При проведении исследований используется материально-техническая база филиала ИРБЭ РГП НЯЦ РК, в исследовании задействованы 3 человека: руководитель, консультант ВКР (эксперт) и исполнитель. Тарифные ставки исполнителей определены штатным расписанием НИ ТПУ и филиала ИРБЭ РГП НЯЦ РК.*
2. *Нормы и нормативы расходования ресурсов*	*Значение показателя интегральной ресурсоэффективности – не менее 1 балла из 1*
3. *Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования*	*Отчисления во внебюджетные фонды составляют 30 %, накладные расходы составляют 15 %.*
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. *Оценка коммерческого и инновационного потенциала НТИ*	*Анализ потенциальных потребителей результатов исследования, конкурентных технических решений, проведение SWOT-анализа.*
2. *Разработка устава научно-технического проекта*	*Определение целей и результатов проекта, организационной структуры проекта.*
3. *Планирование процесса управления НТИ: структура и график проведения, бюджет, риски и организация закупок*	*Формирование плана и графика проекта: - определение структуры работ; - определение трудоемкости работ. Формирование бюджета затрат проекта.*
4. *Определение ресурсной, финансовой, экономической эффективности*	*Расчет показателей сравнительной эффективности проекта, интегрального показателя ресурсоэффективности*

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

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

Дата выдачи задания к разделу в соответствии с календарным учебным графиком	

Задание выдал консультант по разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:

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

Задание принял к исполнению обучающийся:

Группа	ФИО	Подпись	Дата
0АМ13	Бакланова Юлия Валерьевна		

TASK FOR SECTION
«FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING»

To the student:

Group	Full name
0AM13	Baklanova Yuliya Valerievna

School	Nuclear Science & Engineering	Division	Nuclear Fuel Cycle
Degree	Master	**Education program**	14.04.02 Nuclear physics and technology

Input data to the section «Financial management, resource efficiency and resource saving»:	
4. Resource cost of scientific and technical research (STR): material and technical, energetic, financial and human	*The project budget is no more than 426,887.0 rubles, incl. costs by weight of labor - no more than 197438.89 rubles. The research uses the material and technical bases of the IRSE NNC RK, in which 3 people participate: the leader, the WRC consultant (expert) and the performer. Tariff rates for executors of responsible staff positions of NR TPU and IRSE NNC RK.*
5. Expenditure rates and expenditure standards for resources	*The value of the indicator of integral resource efficiency is at least 1 point out of 1*
6. Current tax system, tax rates, charges rates, discounting rates and interest rates	*Deductions to off-budget funds unexpectedly 30%, overhead costs 15%.*
The list of subjects to study, design and develop:	
5. Assessment of commercial and innovative potential of STR	*Consumer analysis Research results, competitive technical solutions, conducting a SWOT analysis.*
6. Development of charter for scientific-research project	*Defining the goals and results of the project, the organizational structure of the project.*
7. Scheduling of STR management process: structure and timeline, budget, risk management	*Formation of the project plan and schedule:* *- definition of the structure of work;* *- determination of the labor intensity of work.* *Formation of the project cost budget.*
8. Assessment of resource, financial, economic efficiency	*Calculation of project performance indicators, integral indicator of resource efficiency*
List of graphic material *(with exact listing of required drawings):*	
6. Segmentation of the market *7. Assessment of the competitiveness of technical solutions* *8. SWOT matrix* *9. Timetable and budget of STR* *10. Assessment of resource, financial and economic efficiency of STR*	

Assignment date for section according to schedule	

Task issued by consultant in the section "Financial management, resource efficiency and resource saving":

Job title	Full name	Academic degree, title	Signature	date
Associate Professor	Spitsyna Lyubov Yurievna	Ph.D.		

Task was accepted by the student:

Group	Full name	Signature	date
0AM13	Baklanova Yuliya Valerievna		

6 Financial Management, Resource Efficiency and Resource Saving

The prospects for the results of scientific research are determined not so much by the magnitude of the discovery, which is difficult to assess in the early stages of the resulting product lifecycle, as by the commercial value of the development. Today's realities have shown that assessing the commercial potential of development is a prerequisite for finding sources of research funding and commercializing its results. At the same time, the commercial attractiveness of scientific research results is determined not only by the excess of technical parameters over previous developments, but also by how quickly the researcher will answer such questions as whether the product will be in demand in the market, what it will cost to satisfy the consumer, what is the budget of the research project, how long it will take to enter the market, etc [34].

In this paper, we evaluated the effectiveness of activity detection ^{90}Sr by activity ^{137}Cs in the surface layer of the soil on the territory of the Karaganda region within the Semipalatinsk test site outside the test sites using the calculation method by conducting a comparative analysis of the results of theoretical and experimental data. This section includes identifying the prospects and success of a research project, developing a management mechanism, and supporting specific project decisions at the implementation stage.

The following tasks were solved during this work:

- assessment of the commercial potential and prospects of scientific research;
- development of the charter of a scientific and technical project;
- planning the research project management process;
- determination of the resource (resource-saving), financial, and economic efficiency of research.

6.1 Pre-project analysis

6.1.1 Potential customers consumers of research results

To analyze the results of consumer research, it is necessary to study the target market and segment it.

The essence of this thesis is applied scientific research - determination of activity ^{90}Sr in relation to activity ^{137}Cs in the surface layer of the soil, necessary for the purpose of rapid assessment of activity ^{90}Sr for establishing the boundaries of radioactive contamination of the soil cover in territories whose radioactive contamination could have been formed as a result of atmospheric nuclear tests. The target market includes organizations that perform radioecological researches of the soil cover at ground and air nuclear testing sites.

Analysis of market segmentation showed that the development will be relevant for any country that conducted atmospheric tests in the arid zone (Table 5).

Table 5 – Market segmentation map

Countries	Number of active and closed nuclear test sites
The USSR	>5
The USA	5
United Kingdom	4
France	4
China	1
India	1
Pakistan	1
North Korea	1

6.1.2 Analysis of competitive technical solutions from the perspective of resource efficiency and resource saving

Detailed analysis of competing events that exist in the market should be carried out systematically, since the markets are in constant motion. The analysis of competitive technical solutions makes it possible to evaluate the efficiency from the point of view of resource efficiency and resource conservation, which is considered in this paper by the model of using calculated ratios ^{90}Sr/^{137}Cs (Activity Detection ^{90}Sr in relation to activity ^{137}Cs in the surface layer of the soil according to the ratios of the studied fission products using the calculated method) in comparison with the used analog (determination of activity ^{90}Sr with preliminary radiochemical preparation and subsequent beta-spectrometric measurement).

For this work, this analysis was carried out using an evaluation map, which contains evaluation points for two approaches to studying these objects. Here K1, K2 are the competitiveness of the corresponding methods: 1 - determination of activity ^{90}Sr in relation to activity ^{137}Cs in the surface layer of the soil according to the ratios of the studied fission products by the calculation method, and 2 – the classical method for determining the activity of the soil ^{90}Sr with preliminary radiochemical preparation and subsequent beta-spectrometric measurement. The expert assessment is based on technical and economic criteria on a five-point scale, where 1 is the weakest position and 5 is the strongest. The total weight of all indicators in total should be 1.

Analysis of competitive technical solutions is determined by the formula:

$$K = \sum \text{B}_i \cdot S_i$$

where K – the project's competitiveness;

B_i– indicator weight (in fractions of one);

S_i– indicator score.

Table 6 – Evaluation map for comparing competitive technical solutions (methods)

Evaluation criteria	Criteria weight	Scores		Competitiveness	
		$S_{к1}$	$S_{к2}$	$K_{к1}$	$K_{к2}$
1	2	3	4	5	6
Technical criteria for evaluating resource efficiency					
1. User productivity (speed of calculation/laboratory analysis)	0,1	5	3	0,5	0,3
2. Easy calculation/laboratory analysis	0,05	5	3	0,25	0,15
3. The need to equip chemical laboratories	0,15	5	5	0,75	0,75
4. The need for spectrometric equipment	0,15	4	4	0,6	0,6
5. Completeness and reliability of the obtained data	0,15	3	4	0,45	0,6
6. Data running time	0,05	5	3	0,25	0,15
Economic criteria for evaluating efficiency					
1. Competitiveness of the method	0,05	3	3	0,15	0,15
2. Cost of analysis supplies	0,1	3	2	0,3	0,2
3. Cost of equipment used	0,15	3	3	0,45	0,45
4. Financing of scientific development	0,05	5	4	0,25	0,2
Total	1	41	34	3,65	3,55

The analysis of competitive technical solutions from the point of view of resource efficiency and resource saving showed that the developed model for determining the activity of the company is based on the following criteria: ^{90}Sr in relation to activity ^{137}Cs in the surface layer of the soil according to the ratios of the studied division products can be used by the calculation method (result 3.65). Competing method (result 3.55) for determining activity ^{90}Sr with preliminary radiochemical preparation and subsequent beta-spectrometric measurement is characterized by significant labor intensity, which, taking into account the high cost of low-background beta-spectrometric equipment, determines the expensive determination of low activities ^{90}Sr by the method with radiochemical isolation. Estimation accuracy activities ^{90}Sr sufficient for conducting comprehensive environmental surveys in areas that may have been exposed to surface radioactive contamination as a result of atmospheric nuclear tests. The calculation method makes it possible to avoid carrying out extremely expensive laboratory tests with preliminary radiochemical preparation for determining the degree of radiation exposure. ^{90}Sr by executing them only to confirm the received data.

6.1.3 SWOT-analysis

SWOT – Strengths, Weaknesses, Opportunities and Threats – is a comprehensive research analysis. SWOT analysis is used to study the external and internal work environment.

Strengths are factors that characterize the competitive side of R & D. Strengths indicate that a job has a distinctive advantage or special resources that are special from the point of view of competition.

Weaknesses are shortcomings, omissions, or limitations of research that hinder the achievement of its goals. This is something that does not work well within the framework of the work or where it has insufficient capabilities or resources compared to competitors.

Opportunities include any preferred situation in the present or future that occurs in the work environment, such as a trend, change, or perceived need that supports the demand for work results and allows the work management to improve its competitive position.

A threat is any undesirable situation, trend, or change that is disruptive or threatening to its competitiveness in the present or future.

The table (Table 7) shows a SWOT analysis of this work, which shows the results of intersections of strengths and weaknesses with opportunities and threats.

Table 7 – SWOT-analysis of research work

strengths and weaknesses / opportunities and threats	Strengths of the work: S1. Relevance of the selected topic. S2. Reliability of the received data. S3. Expanding the scope of applicability. S4. Qualified personnel. S5. Availability of budget funding.	Weaknesses of the work: W1. Potential consumers do not have qualified personnel to work with the methodology. W2. Lack of necessary equipment for conducting laboratory tests. W3. Long processing time for results. W4. Lack of awareness of this type of research.
Opportunities: B1. Using the infrastructure of the IRSE NNC RK. B2. The novelty of the research will lead to the emergence of interested parties. B3. Planning for the construction of nuclear power plants in Kazakhstan.	Results of analysis of the interactive matrix of the project fields "Strengths and opportunities": 1. Conclusion of contracts for contractual work for the IRSE NNC RK. 2. The study of this topic can be continued in more depth, which makes it possible to write publications. 3. Planning for the construction of nuclear power plants in Kazakhstan provides an opportunity for cooperation and professional development of personnel in the framework of assessing the impact of the studied fission products on the soil.	Results of analysis of the interactive matrix of the project fields "Weaknesses and opportunities": 1. Consumers do not have the necessary equipment to perform laboratory tests. 2. The lack of qualified personnel for working with the methodology among potential consumers makes it possible to conduct training for staff. 3. Lack of a large number of research orders.
Threats: T1. No demand for a more time-consuming calculation method.	Results of the analysis of the interactive matrix of the project of the "Strengths and threats" fields:	Results of analysis of the interactive project matrix of the "Weaknesses and threats" fields:

T2. Lack of funds for conducting laboratory tests.	1. Good reliability and completeness of the data obtained significantly increases competitiveness. 2. The cost of carrying out single laboratory tests with the subsequent calculation method is significantly lower than the similar costs carried out for a larger number of laboratory tests.	1. The high cost of laboratory testing supplies and equipment may be the main reason for the lack of demand. 2. A sufficiently long time to obtain the results of the analysis may not meet the requirements of the consumer, which reduces the demand for the methodology.

The table (Table 8) provides an interactive work matrix that shows the ratio of strengths to opportunities, which allows you to consider the development prospects in more detail. Here, the intersection of strengths and opportunities has a certain result: "plus" – a strong match between strengths and opportunities," minus " – a weak ratio," 0 " – doubts about compliance.

Table 8 – Interactive matrix of the project "Strengths and opportunities"

		Project strengths				
		S1	S2	S3	S4	S5
Project opportunities	O1	+	+	0	+	+
	O2	+	-	+	0	+
	O3	+	+	+	+	+

When analyzing this interactive table, you can identify the following correlating strengths and opportunities: O1S1S2S4S5, O2S1S3S5, O3X1S2S3X4S5, O5S1S4. Based on the interactive matrix data, we can conclude that the project's strengths are related to the capabilities of the external environment, and, thanks to them, research work can be in demand in the market.

6.2 Project initiation

6.2.1 Development of the charter of a scientific and technical project

The project charter documents the business needs, current understanding of the project customer's needs, and the new product, service, or result that is planned to be created.

The purpose of the project work is to evaluate the effectiveness of activity detection ^{90}Sr by activity ^{137}Cs in the surface layer of the soil on the territory of the Karaganda region within the Semipalatinsk test site outside the test sites using the calculated method.

The result of this research is to obtain reliable coefficients of relations ^{90}Sr/^{137}Cs in the surface layer of the soil for the study area and assessment of the possibility of their application for activity definitions^{90}Sr by activity ^{137}Cs in the soil by calculation method. Using this method, it is possible to identify the boundaries of traces of radioactive fallout in areas that may have been exposed to surface radioactive contamination as a result of atmospheric nuclear tests.

Research institutes and organizations that carry out scientific research and/or radioecological surveys of territories that may have been exposed to surface radioactive contamination as a result of atmospheric nuclear tests, remediation work, etc.may be interested in the project (Table 9).

Table 9 – Project stakeholders and their expectations

Project stakeholders	Stakeholder expectations
Research institutes	Possibility to continue research work for deeper study ratios $^{90}Sr/^{137}Cs$ in fission of nuclear fuel in research and industrial reactors; remediation of territories that have been exposed to surface radioactive contamination as a result of atmospheric nuclear tests.
State bodies and institutions performing sanitary and epidemiological surveillance	Assessment of radioactive contamination of the soil cover by fission products exposed to surface radioactive contamination as a result of atmospheric nuclear tests..
Organizations that perform radiation and environmental surveys	Identification of the boundaries of radioactive contamination; remediation of areas that have been exposed to surface radioactive contamination as a result of atmospheric nuclear tests; assessment of dose loads on personnel and the population.

В таблице (Table 10) provides information about the hierarchy of project goals and criteria for achieving goals.

Table 10 – Project goals and their results

Project goals	Comparison of the results of modeling the intake of radionuclides into the human body with the results of biophysical measurements
Expected results of the project	Factors affecting the value of ratios $^{90}Sr/^{137}Cs$ factors in the surface layer of the soil (the degree of their influence). Regularities in the distribution of ratios $^{90}Sr/^{137}Cs$ in the surface layer of the soil. Evaluating the effectiveness of activity detection^{90}Sr by activity ^{137}Cs in the soil by calculation method.
Criteria acceptances the result of the project	1. Correct processing of the data array. 2. There is a step-by-step development of the method with a description and analysis.
Requirements to the result of the project	1. Project must to be completed before May of 26, 2023. 2. Received data results must satisfy criteria acceptances the result of the project. 3. Availability of conclusions on comparison of experimental and calculated specific activity ^{90}Sr in the topsoil and the application of the ratio method $^{90}Sr/^{137}Cs$.

The organizational structure of the project is presented in the table (Table 11).

Table 11 – Project working team

Full name, main place of work, position	Role in the project	Functions	Labor costs, hour
Yakovleva V. S., TPU, Professor	Scientific supervisor	Project coordination	24
Aidarkhanov A. O., IRSE NNC RK, Branch Director	Scientific consultant	Project co-coordination	24
Baklanova Yu. V., IRSE NNC RK Team lead	Executor	Literature review, calculation part, statistical processing of results, report preparation	544
Total labor costs, hour			592

Limitations and assumptions of the project. Project restrictions are all factors that can limit the degree of freedom of project team members.

Table 12 – Project restrictions

Factor	Limitations/ assumptions
3.1. Project budget	414653 rub.
3.1.1. Source of funding	government funding
3.2. Project terms	0,2 year
3.2.1. Date of approval of the project management plan	13.03.2023 г.
3.2.2. Project completion date	26.05.2023 г.
Other limitations and assumptions	Time limit for project participants ' work

Thus, the goals and results of the project have been established, the organizational structure of the project has been reviewed, and the limitations and assumptions of the project have been determined.

6.3 Planning the process of managing a research project

6.3.1 Structure of works in the framework of scientific research

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

The order of drawing up stages and works, the distribution of performers by these types of work is shown in the table (Table 13).

Table 13 – Project calendar plan

Work code	Title	Duration, days	Start date	Completion date	Composition of participants
1	Writing and approval of the master's thesis assignment	2	13.03.2023	15.03.2023	Scientific supervisor
2	Drafting and approval of terms of reference	3	15.03.2023	18.03.2023	Scientific supervisor
3	Choosing direction of research	9	18.03.2023	27.03.2023	Scientific supervisor, Scientific consultant, Executor
4	Selecting and studying materials on the topic of research	2	27.03.2023	29.03.2023	Executor
5	Work scheduling	1	29.03.2023	30.03.2023	Scientific supervisor, Scientific consultant, Executor
6	Study of existing calculation methods	2	30.03.2023	01.04.2023	Executor
7	Mastering the calculation methodology in practice	2	01.04.2023	03.04.2023	Executor
8	Making calculations	21	03.04.2023	24.04.2023	Executor
9	Analysis of the received data	3	24.04.2023	27.04.2023	Scientific consultant, Executor
10	Summarizing and evaluating results	10	27.04.2023	07.05.2023	Scientific supervisor, Scientific consultant, Executor
11	Writing a report on the work	19	07.05.2023	26.05.2023	Executor

As part of project execution planning, a calendar schedule is constructed using a Gantt chart. Planned works on the research topic are represented by extended time periods, characterized by the start and end dates of the work. The schedule is constructed in the form of a table with a breakdown by months and decades (10 days) for the period of time when the scientific work is completed. At the same time, work on the chart is highlighted with different hatching or color depending on the performers responsible for this or that work [34].

The table below shows the schedule of scientific research (Table 14).

Table 14 – Schedule of works

Work code	Title	Composition of participants	T_k, cal. days	Продолжительность работ								
				March			April			May		
				1	2	3	1	2	3	1	2	3
1	Writing and approval of the master's thesis assignment	Scientific supervisor	2									
2	Drafting and approval of terms of reference	Scientific supervisor	3									
3	Choosing direction of research Selecting and studying materials on the topic of research Work scheduling	Scientific supervisor, Scientific consultant, Executor	9									
4	Study of existing calculation methods	Executor	2									
5	Mastering the calculation methodology in practice Making calculations Analysis of the received data	Scientific supervisor, Scientific consultant, Executor	1									
6	Summarizing and evaluating results	Executor	2									
7	Writing a report on the work	Executor	2									
8	Writing and approval of the master's thesis assignment	Executor	32									
9	Drafting and approval of terms of reference Choosing direction of research	Scientific consultant, Executor	3									
10	Selecting and studying materials on the topic of research Work scheduling Study of existing calculation methods	Scientific supervisor, Scientific consultant, Executor	10									

Work code	Title	Composition of participants	T_k, cal. days	Продолжительность работ								
				March			April			May		
				1	2	3	1	2	3	1	2	3
11	Mastering the calculation methodology in practice	Executor	29									
– Scientific supervisor		– Scientific consultant	– Executor									

Thus, the management plan of the scientific project is built, the types of work are defined, the dates of the beginning and end of work and the composition of participants are set.

6.4 Research budget

When planning the research budget, it should be ensured that all types of expenses associated with its implementation are fully and reliably reflected. In the process of creating a budget, the following grouping of costs by item is used:

- raw materials (excluding returnable waste), purchased products and semi-finished products;
- special equipment for scientific (experimental) work;
- basic salary;
- additional salary;
- social contributions;
- research and production trips;
- payment for work performed by third-party organizations and enterprises;
- other direct expenses;
- overhead costs;
- total planned production cost.

6.4.1 Raw materials, materials, components and purchased semi-finished products

The main costs of performing this research are the cost of purchasing office supplies.

The cost of these material costs is calculated according to the current price lists or contractual prices. The cost of material costs includes transport and procurement costs, which are accepted within 3-5 % of the cost of materials.

The results of calculations for material costs are shown in the table (Table 15).

Table 15 – Raw materials, materials, components and purchased semi-finished products

Title	Brand, size	Quantity	Price per unit, rub.	Amount, rub.
Paper, packaging	SvetoCopy, A4	1	385	385
Print A4 format	–	460	7	3220
Handle, pcs.	Cello MAXRITER XS	1	75	75
Total for materials				3680
Transport and procurement expenses				184
Total for the item $С_м$				3864

6.4.2 Special equipment for scientific (experimental)work

This article includes all costs associated with the purchase of special equipment necessary for carrying out work on a specific topic.

In this research work, the special equipment required for the experimental work includes a computer. Since the work was carried out on an existing computer, only its depreciation was taken into account in this section. It is assumed that the computers of the scientific supervisor, the scientific consultant and the executor were manufactured at the same time, have the same parameters and the same purchase price.

According to data on purchases of computer equipment for TPU, the cost of university personal computers is 37,844. 00 rubles [35]. According to the Classification approved by the Decree of the Government of the Russian Federation No. 1 of January 1, 2002, computers belong to the second depreciation group. Therefore, for these items of fixed assets, the useful life is from 25 to 36 months inclusive [36].

Equipment depreciation costs are calculated using the formula:

$$C_{dep} = \frac{С_{eq}}{\text{Т}},$$

where C_{eq} – cost of equipment (rub);

Т – service life (days).

$$C_{dep} = \frac{37844}{1000} = 37{,}844 \text{ rub./day.}$$

The equipment was used for $t_{use} = 74$ days, thus, the cost of equipment (n = 3 computers) made up:

$$С_{dep}^{tot} = C_{dep} \cdot t_{use} \cdot n = 37{,}844 \cdot 74 \cdot 3 = 8401{,}37\ rub.$$

Table 16 – Calculation of costs for the item "Special equipment for scientific works"

Equipment name	Number of pieces of equipment	Unit price of equipment, thousand rub.	Total cost of equipment, thousand rub.
Computer	3	37,844	8,40137

6.4.3 Basic salary

The article includes the basic salary of employees directly engaged in scientific work (including bonuses and supplements) and additional salaries and is calculated according to the following formula:

$$C_{sal} = S_{bas} + S_{\text{add}},$$

where S_{bas} – basic salary;

S_{add} – additional salary.

Basic salary (S_{bas}) of participants calculated using the following formula:

$$S_{\text{bas}} = S_{\text{day}} \cdot \text{T}_w,$$

where S_{bas} – basic salary of one employee;

T_w – duration of work performed by a scientific and technical employee, working days;

S_{day} – average daily salary of an employee, rubles.

The average daily salary is calculated using the formula:

$$S_{\text{day}} = \frac{S_m \cdot \text{M}}{F_d},$$

where S_M – monthly official salary of the employee, rubles;

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

for a vacation of 24 hours. day M =11.2 months, 5-day week;

for a vacation of 48 hours. days M=10.4 months, 6-day week;

F_d – actual annual fund of working hours of scientific and technical personnel, working days (Table 17).

Table 17 – Balance of working days

Working time indicators	Scientific supervisor	Scientific consultant	Tead lead (Executor)
Calendar number of days	365	365	365
Non-working days: – weekends – holidays	 52 14	 52 14	 52 14
Loss of working time: – vacation; – sick leave	 60 –	 60 –	 40 –
Actual annual working time	239	239	250

The executor has a monthly salary of 22500 rubles. The average daily salary is:

$$S_{day} = \frac{22500 \cdot 11{,}2}{250} = 1008 \text{ rub./day}$$

The main earnings of the executor during this work is:

$$S_{bas} = 1008 \cdot 69 = 69552 \text{ rub.}$$

Monthly official salary of the executor:

$$S_m = S_{тс} \cdot k_{р} = 22500 \cdot 1{,}3 = 29250 \text{ rub.},$$

where $S_{тс}$ – salary, according to the tariff rate, rub.;

$k_{р}$ – the district coefficient is equal to 1.3 (for Tomsk).

Average daily salary of the scientific supervisor is:

$$S_{day} = \frac{39400 \cdot 11{,}2}{239} = 1846{,}36 \text{ rub./day.}$$

The basic salary of the scientific supervisor is:

$$S_{bas} = 1846{,}36 \cdot 24 = 44312{,}64 \text{ rub.}$$

Monthly salary of a scientific supervisor is:

$$S_m = S_{тс} \cdot k_{р} = 39400 \cdot 1{,}3 = 51220 \text{ rub./month.}$$

Average daily salary of the scientific consultant is:

$$S_{day} = \frac{55500 \cdot 11{,}2}{239} = 2600{,}84 \text{ rub./day.}$$

The basic salary of the scientific consultant is:

$$S_{bas} = 2600{,}837 \cdot 22 = 57218{,}41 \text{ rub.}$$

Monthly salary of the scientific consultant is:

$$S_m = S_{тс} \cdot k_{р} = 55500 \cdot 1{,}3 = 72520 \text{ rub./ month.}$$

The results of the calculation of the basic salary of the scientific supervisor, the scientific consultant and the executor are presented in the table (Table 18).

Table 18 – Calculation of the basic salary

Исполнители НИР	S_b, rub	$k_{р}$	S_m, rub	S_{day}, rub	T_w, $workdays$	S_{bas}, rub
Scientific supervisor	39400	1,3	51220	1846,36	24	44312,64
Scientific consultant	55500	1,3	72150	2600,84	22	57218,41
Executor	22500	1,3	29250	1008	69	69552
Total:						171083

6.4.4 Additional salary of the performers of the topic

The costs of additional salaries of performers of the topic take into account the number of surcharges provided for by the Labor Code of the Russian Federation for deviations from normal working conditions, as well as payments related to guarantees and compensations.

The additional salary is calculated based on 10-15 % of the basic salary of employees directly involved in the implementation of the topic:

$$S_{\text{add}} = k_{\text{add}} \cdot S_{\text{bas}},$$

where S_{add} – additional salary, rub.;

k_{add} – the coefficient of additional salary (12 %);

S_{bas} – basic salary, rub.

Additional salary of the executor is:

$$S_{\text{add}} = 69552 \cdot 12\% = 8346{,}24\ rub.,$$

Additional salary of the p scientific supervisor:

$$S_{\text{add}} = 44312{,}64 \cdot 12\% = 5317{,}52\ rub.,$$

Additional salary of the scientific consultant:

$$S_{\text{add}} = 62420{,}08 \cdot 12\% = 7490{,}41\ rub.,$$

The results of the calculation of the basic and additional salaries of performers of scientific research are presented in the table (Table 19).

Table 19 – Performers' salaries

Salary, rub.	Scientific supervisor	Scientific consultant	Executor
Basic salary	44312,64	57218,41	69552
Additional salary	5317,52	6866,21	8346,24
Performers' salary	49630,15	64084,62	77898,24
Total	191613,01		

6.4.5 Social contributions

The amount of deductions to extra-budgetary funds is 30% of the amount of labor costs for employees directly engaged in research work.

The amount of contributions to extra – budgetary funds is determined based on the following formula:

$$C_{\text{cont}} = k_{\text{cont}} \cdot (S_{\text{bas}} + S_{\text{add}}),$$

where k_{cont} – the coefficient of deductions for payment to extra-budgetary funds (pension fund, compulsory medical insurance fund, etc.).

Based on paragraph 1 of Article 427 of the Tax Code of the Russian Federation, a reduced rate of insurance premiums is applied to educational institutions of higher education that are budgetary institutions, and autonomous institutions until 2019, from 2019 a total rate of 30 % is applied to educational organizations (for OPS – 22 %, in case of temporary disability and in connection with maternity – 2.9 %, on compulsory medical insurance 5.1%) [62].

The amount of contributions to extra - budgetary funds is:

$$C_{\text{cont}} = 0{,}3 \cdot 191613{,}01 = 59231{,}67 \text{ rub.}$$

6.4.6 Scientific and occupational business trips

When performing this research work, scientific and industrial business trips are not provided.

6.4.7 Payment for work performed by third-party organizations and enterprises

When performing this research work, it is not envisaged to involve third-party organizations and enterprises in the work.

6.4.8 Overhead costs

This article includes management and maintenance costs. In addition, this includes the costs of maintenance, operation and repair of equipment, production tools and inventory, buildings, structures, etc.

Overhead costs are calculated according to the following formula:

$$C_{\text{накл}} = k_{\text{накл}} \cdot (S_{\text{bas}} + S_{\text{add}}),$$

where $k_{\text{накл}}$ – overhead factor.

Overhead costs amount to 80-100% of the amount of the basic and additional wages of employees directly involved in the implementation of the topic. For this work, it is accepted $k_{\text{накл}} = 80$ %.

$$C_{\text{накл}} = 80\% \cdot 191613{,}01 = 153290{,}4 \text{ rub.}$$

6.4.9 Formation of the budget for the costs of research work

The calculated value of the costs of research work is the basis for the formation of the budget for the costs of work, which, when forming a contract with the customer, is protected by a scientific organization as the lower limit of the costs of developing scientific and technical products.

The table (Table 20) shows the definition of the cost budget for a research project for each execution option.

Table 20 – Budget of scientific research work

Name of the article	Сумма, rub.
1. Raw materials, materials, components and purchased semi-finished products	3864,0
2. Special equipment for scientific (experimental)work	8401,37
3. Basic salary	171083,04
4. Additional salary	20529,97
5. Social contributions	57483,9
6. Scientific and occupational business trips	-
7. Payment for work performed by third-party organizations and enterprises	-
8. Overhead costs	153290,40
Budget of scientific research	414652,7

6.5 Determination of the resource (resource-saving), financial, budgetary, social and economic efficiency of the study

6.5.1 Evaluation of the comparative effectiveness of the study

The evaluation of the effectiveness is based on the calculation of the integral indicator of the effectiveness of scientific research. This work has one execution, therefore, the determination of effectiveness is based on the calculation of the integral indicator of the effectiveness of scientific research. Its finding is associated with determining the value of resource efficiency.

The integral financial indicator of the development is defined as:

$$I_f^p = \frac{F_{pi}}{F_{max}},$$

where I_f^p – integral financial indicator of development;

F_{pi} – the cost of the i-th version of the execution;

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

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

Since this project has one execution, then:

$$I_f^p = 1.$$

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

$$I_m^{\text{p}} = \sum_{i=1}^{n} a_i \cdot b_i,$$

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

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

b_i – the point rating of the i-th version of the development is determined by an expert method according to the selected evaluation scale;

n – the number of comparison parameters (in this paper is 1).

The calculation of the integral indicator of resource efficiency is presented in the form of a table (Table 21).

Table 21 – Evaluation of project performance characteristics

Parameter / Criteria	The weighting factor of the parameter	Evaluation of the current project
1. Labor productivity in use (calculation execution speed)	0,05	3
2. Ease of calculation	0,1	3
3. The need to equip chemical laboratories	0,15	3
4. The need for spectrometric equipment	0,1	4
5. Completeness and reliability of the data obtained	0,2	5
6. Operating time of the data	0,05	3
Total	1	35

$$I_m^{\text{p}} = 0{,}05 \cdot 3 + 0{,}1 \cdot 3 + 0{,}15 \cdot 3 + 0{,}1 \cdot 4 + 0{,}2 \cdot 5 + 0{,}05 \cdot 3 = 2{,}45$$

The integral indicator of the effectiveness of the development options ($I_{\text{финр}}^{\text{р}}$) is determined on the basis of the integral indicator of resource efficiency and the integral financial indicator according to the formula:

$$I_{fin}^{\text{p}} = \frac{I_m^{\text{p}}}{I_f^{\text{p}}} = \frac{2{,}45}{1},$$

Comparative effectiveness of the project (E_{cp}) is:

$$E_{\text{cp}} = \frac{I_{fin}^{\text{p}}}{I_{fin}^{a}},$$

Table 22 – Development efficiency

Indicators	Score
Integral financial indicator of development	1
Integral indicator of resource efficiency	2,45
Integral performance indicator	0,41

Comparing the values of integral performance indicators allows you to choose a more effective solution to the task from the standpoint of financial and resource efficiency. Since in this case, one solution to the problem is considered, therefore, it is assumed to be the best.

Section conclusions

1. The analysis of competitive methods has shown that the developed model for determining the activity of ^{90}Sr in relation to the activity of ^{137}Cs in the surface layer of soil by the ratios of the studied fission products by the calculation method can be successfully applied. Its closest competitor is the experimental determination of ^{90}Sr activity with preliminary radiochemical preparation and subsequent beta-spectrometric measurement, which is characterized by significant labor intensity, which, taking into account the high cost of low-background beta-spectrometric equipment, determines the expensive determination of low 90Sr activities by the method with radiochemical isolation.

2. During the planning, a schedule was developed for the execution of work stages for the manager and the student, which allows to evaluate and plan the working time of the performers. The total number of calendar days to complete the work was determined – 74 days, the total number of calendar days during which the student worked was 68 days, the total number of calendar days during which the scientific supervisor – 24 days and scientific consultant worked – 22 days.

3. The cost budget of this research work has been determined, which amounted to 414653 rub.

4. In this work performed, economic and technical efficiency criteria were achieved due to the functional capabilities of the development, as well as social ones due to the demand for research in the market.

ЗАДАНИЕ К РАЗДЕЛУ
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Обучающемуся:

Группа	ФИО
0АМ13	Баклановой Юлии Валерьевне

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

Исходные данные к разделу «Социальная ответственность»:	
1. Характеристика объекта исследования (вещество, материал, прибор, алгоритм, методика, рабочая зона) и области его применения.	Оценка эффективности определения активности ^{90}Sr по активности ^{137}Cs в почве расчетным методом.
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. Правовые и организационные вопросы обеспечения безопасности: – специальные (характерные при эксплуатации объекта исследования, проектируемой рабочей зоны) правовые нормы трудового законодательства; – организационные мероприятия при компоновке рабочей зоны.	– Трудовой кодекс Российской Федерации от 30.12.2001 N 197; ГОСТ 12.2.032-78 ССБТ. – СанПиН 2.2.4.548-96 «Гигиенические требования к микроклимату производственных помещений». – ССБТ ГОСТ 12.1.005-88 «Общие санитарно-гигиенические требования к воздуху рабочей зоны». – СП 60.13330.2020. Отопление, вентиляция и кондиционирование воздуха. – СанПиН 1.2.3685-21 «Гигиенические нормативы и требования к обеспечению безопасности и (или) безвредности для человека факторов среды обитания». – СН 2.2.4/2.1.8.562-96. «Шум на рабочих местах, в помещениях жилых, общественных зданий и на территории жилой застройки»; утв. постановлением Госкомсанэпиднадзора РФ от 31.10.1996 г. – ГОСТ 12.1.003-2014 ССБТ. ШУМ. Общие требования безопасности. – СанПиН 1.2.3685-21 «Гигиенические нормативы и требования к обеспечению безопасности и (или) безвредности для человека факторов среды обитания». – ГОСТ Р ИСО 9241-5-2009 Эргономические требования к проведению офисных работ с использованием видеодисплейных терминалов (VDT). Часть 5. Требования к расположению рабочей станции и осанке оператора.

	– ГОСТ 12.0.003-2015. Система стандартов безопасности труда (ССБТ). Опасные и вредные производственные факторы. Классификация. М.: Стандартинформ, 2016 – Р 2.2.2006-05. 2.2. Гигиена труда. Руководство по гигиенической оценке факторов рабочей среды и трудового процесса. Критерии и классификация условий труда. – МР 2.2.9.2311-07. 2.2.9. Состояние здоровья работающих в связи с состоянием производственной среды. – ГОСТ 12.1.038-82 «Система стандартов безопасности труда. Электробезопасность. Предельно допустимые значения напряжений прикосновения и токов». – ГОСТ Р 12.1.019-2017 «Электробезопасность. Общие требования и номенклатура видов защиты» – введ. 2019-01-01.
2. Производственная безопасность: 2.1. Анализ выявленных вредных и опасных факторов 2.2. Обоснование мероприятий по снижению воздействия.	– отклонение показателей микроклимата; – электромагнитное излучение; – превышение уровня шума; – недостаточная освещенность рабочей зоны; – психофизиологические нагрузки; – поражение электрическим током.
3. Экологическая безопасность:	–
4. Безопасность в чрезвычайных ситуациях:	– падение с высоты собственного роста; – удар электрическим током; – пожар. – анализ типичных ЧС – пожар на рабочем месте, буря; – превентивные меры и порядок действий при возникновении ЧС.

Дата выдачи задания к разделу в соответствии с календарным учебным графиком	

Задание выдал консультант по разделу «Социальная ответственность»:

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0АМ13	Бакланова Юлия Валерьевна		

TASK FOR SECTION "SOCIAL RESPONSIBILITY"

To the student:

Group	Full name
0AM13	Baklanova Yuliya Valerievna

School	Nuclear Science & Engineering	Department	Nuclear Fuel Cycle
Degree	Master	**Education program**	14.04.02 Nuclear physics and technology

Initial data for the section "Social responsibility" :	
1. Information about object of investigation (matter, material, device, algorithm, procedure, workplace) and area of its application	Assessment of the efficiency of the determination of ^{90}Sr activity by the activity of ^{137}Cs in soil by calculation method.
The list of subjects to study, design and develop:	
1. Legal and organizational issues to provide safety: – special (specific for operation of objects of investigation, designed workplace) legal rules of labor legislation; – organizational activities for layout of workplace.	– Labor Code of the Russian Federation of December 30, 2001 N 197; – GOST 12.2.032-78 SSBT. – SanPiN 2.2.4.548-96 "Hygienic requirements for the microclimate of industrial premises". – SSBT GOST 12.1.005-88 "General sanitary and hygienic requirements for the air of the working area". – SP 60.13330.2020. Heating, ventilation and air conditioning. – SanPiN 1.2.3685-21 "Hygienic standards and requirements for safety and (or) harmlessness for human environmental factors." – CH 2.2.4/2.1.8.562-96. “Noise at workplaces, in residential buildings, residential buildings and in residential areas”; approved Decree of the State Committee for Sanitary and Epidemiological Supervision of the Russian Federation dated October 31, 1996 No. – GOST 12.1.003-2014 SSBT. NOISE. General safety requirements. – SanPiN 1.2.3685-21 "Hygienic standards and requirements for safety and (or) harmlessness for human environmental factors." – GOST R ISO 9241-5-2009 Ergonomic requirements for the requirements of office work using video display terminals (VDTs). Part 5. Requirements for the placement of the workstation and the posture of the operator. – GOST 12.0.003-2015. System of labor safety schemes (SSBT). Dangerous and harmful

	production factors. Classification. M.: Standartinform, 2016. – Guidelines 2.2.2006-05. 2.2. Occupational hygiene. Guidelines for the hygienic assessment of the factors of the working environment and the labor process. Criteria and classification of working conditions. – MR 2.2.9.2311-07. 2.2.9. The state of health in connection with the state of the working environment. – GOST 12.1.038-82 "Occupational safety registration system. Electrical safety. Maximum allowable values of touches and currents. – GOST R 12.1.019-2017 "Electrical safety. General requirements and nomenclature of types of protection "- introduction. 01/01/2019.
2. Work Safety: 2.1. Analysis of identified harmful and dangerous factors. 2.2. Justification of measures to reduce probability of harmful and dangerous factors.	– deviation of microclimate indicators; – electromagnetic radiation; – exceeding the noise level; – insufficient lighting of workplace; – psychophysiological factors; – danger of electric shock
3. Ecological safety:	–
4. Safety in emergency:	– falling from its own height; – electric shock; – fire; – analysis of typical emergencies – fire at the workplace, storm; – the order of actions in case of emergency.

Assignment date for section according to schedule	

Task issued by consultant in the section "Social responsibility":

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

Task was accepted by the student:

Group	Full name	Signature	date
0AM13	Baklanova Yuliya Valerievna		

7 Social Responsibility

In this work, an assessment is made activities ^{90}Sr in relation to ^{137}Cs in the surface layer of the soil, it is necessary for the purpose of conducting an express assessment of activity ^{90}Sr in the surface layer of the soil to use when defining limits of radioactive contamination of the soil cover at nuclear test sites.

To complete the task, you need to perform a theoretical estimate of the value of the ratio $^{90}Sr/^{137}Cs$ depending on the fissile material of the nuclear charge(^{235}U and ^{239}Pu), calculate based on experimental data (activity measurement results ^{90}Sr and ^{137}Cs) Ratios $^{90}Sr/^{137}Cs$, perform statistical processing, match activity measurement results ^{90}Sr and ^{137}To carry out a comparative analysis with a view to the possibility of practical application of the ratios of the studied fission products in radioactively contaminated territories..

The obtained data will allow us to evaluate the possibility of using the calculated ratios $^{90}Sr/^{137}Cs$ in radioactively contaminated areas to assess the boundaries of background areas and traces of radioactive fallout from various ground tests.

The thesis work was performed on a personal computer installed on a computer table, the corresponding peripheral equipment (computer keyboard, mouse, etc.) and software (MS Office (Word, Excel)) in room No. 15 of building No. 23 of the IRSE NNC RK (office room, area of 30 m^2).

Taking into account the above, this section discusses dangerous and harmful factors that affect the student in the process of performing the assigned task, as well as legal and organizational issues, as well as measures in emergency situations within the framework of the legislation of the Russian Federation.

7.1 Legal and organizational security issues

7.1.1 Legal provisions in labor law

The main provisions on labor legislation regarding labor protection are set out in the Labor Code of the Russian Federation [37].

According to Article 21 of Chapter 2 of the Labor Code of the Russian Federation, every employee has the right to:

- workplace that meets labor protection requirements;
- compulsory social insurance against industrial accidents and occupational diseases;
- obtaining reliable information from the employer, relevant state bodies and public organizations about working conditions and occupational safety at the workplace, about the

existing risk of health damage, as well as about measures to protect against exposure to harmful and (or) hazardous production factors;

- refusal to perform work in case of danger to his life and health due to violation of labor protection requirements;
- provision of individual and collective protective equipment in accordance with the requirements of labor protection at the expense of the employer;
- training in safe working methods and techniques at the expense of the employer;
- personal participation or participation through their representatives in the consideration of issues related to ensuring safe working conditions at their workplace, and in the investigation of an industrial accident or occupational disease that has occurred with them;
- an extraordinary medical examination in accordance with medical recommendations with the retention of the place of work (position) and average earnings during the specified medical examination;
- guarantees and compensations established in accordance with this Code, a collective agreement, an agreement, a local regulatory act, or an employment contract, if the employee is engaged in work with harmful and / or dangerous working conditions.

Article 91 of Chapter 15 of the Labor Code of the Russian Federation states that the normal working time can not exceed 40 hours per week, the employer is obliged to keep records of the time worked by each employee. Article 94 of Chapter 15 of the Labor Code of the Russian Federation defines the duration of the working day when working with harmful or dangerous working conditions, which is 8 hours (for a 36-hour working week) and 6 hours (for a 30-hour working week). According to Article 96 of Chapter 15 of the Labor Code of the Russian Federation, at night, the shift duration is reduced by 1 hour without further work.

The rest period provided for an employee's rest break and meals is defined in Article 108 of Chapter 18 of the Labor Code of the Russian Federation. Its duration should not exceed 2 hours and not less than 30 minutes, which are not taken into account in working hours.

The working time regime for the implementation of the WRC is provided in the form of a 40-hour working week with 2 days off; the beginning, end and total duration of the working day are determined by agreement of the parties. During the working day, a break for rest and food of 1.5 hours is provided, which is not included during working hours.

7.1.2 Ergonomic requirements for the correct location and layout of the work area

According to paragraph 3.4 of Sanitary-Epidemiological Rules and Regulations 2.2.2/2.4.1340-03, the area per workstation of users of electronic computers with flat discrete screens (liquid crystal, plasma) must be at least 4,5 m^2 [38].

Room No. 15 of building No. 23 of the IRSE NNC RK branch has an area of 30 m^2, which is allowed when using flat discrete PC screens – 4.5 m^2 each per computer operator.

In accordance with GOST 12.2.032–78, which defines the general ergonomic requirements for workplaces when performing work in a sitting position when designing new and upgrading existing equipment and production processes, the dimensional characteristics of the workplace [39]:

- the design of the workplace should ensure that labor operations are performed within the reach of the motor field;
- when organizing a workplace, women's anthropometric indicators should be taken into account;
- the design of the workplace should ensure the optimal position of the worker, which is achieved by adjusting the height of the seat and footrest for a worker with a height below 1800 mm.

Legroom should meet the following parameters:: the legroom height is at least 600 mm, the seat distance to the lower edge of the work surface is at least 150 mm, and the seat height is 420 mm [40].

The following requirements are imposed on the organization of the workplace: the design of the work chair (chair) must ensure the maintenance of a rational working posture when working on a computer, allow changing the pose in order to reduce static tension of the neck-shoulder area and back muscles to prevent the development of fatigue. The type of work chair (s) should be selected taking into account the user's height, the nature and duration of work with the computer. The work chair (s) must be lift-and-turn, adjustable in height and angles of inclination of the seat and back, as well as the distance of the back from the front edge of the seat, while the adjustment of each parameter must be independent, easily performed and have a reliable fixation [38].

GOST R ISO 9241-4-2009 specifies keyboard requirements [46]:

- there is no hand rest, so the area between the keyboard row and the front edge of the keyboard should be as narrow as possible;
- the preferred height of the main row of the keyboard, which is the starting position for the operator's fingers when entering data, is no more than 30 mm;
- the recommended positive relative to the horizon keyboard tilt angle is from 5° to 12°.

Requirements for computer positioning and operator posture are set out in accordance with GOST R ISO 9241-5-2009 [47]:

- the design of the workstation should include the possibility of placing a movable seat on the workplace;
- the work surface should provide support for the display, data entry devices, and auxiliary equipment and materials, as well as for the user's hands and elbows.;
- the user should be able to tilt or rotate the video display in such a way as to maintain an undisturbed working position regardless of the height of the eye level with minimal effort, and the screen should not experience annoying reflections and glare. The viewing angle must not exceed 40° over the entire active area of the screen.

7.2 Industrial safety

7.2.1 Analysis of harmful and dangerous factors that may occur in the workplace during research work

Industrial conditions at the workplace are characterized by the presence of dangerous and harmful factors, which are classified as by element groups: physical, chemical, biological, psychophysiological [49]. A hazardous production factor is a production factor whose impact in certain conditions leads to injury or other sudden, sharp deterioration of health [40].

All stages of this work were performed on a computer. The list of dangerous and harmful factors in the premises No. 15 of building No. 23 of the IRSE NNC RK, which can affect the personnel, is presented in the table (Table 23).

Table 23 – Possible hazardous and harmful factors

Factors	Regulatory documents
Deviation of microclimate indicators	SanRN 2.2.4.548-96 Physical factors of the production environment. Hygiene requirements for microclimate of production premises. Sanitary rules and norms. - M.: Standartinform, 2002. GOST 12.1.005-88 Occupational safety standards system. General sanitary and hygienic requirements for working area air. Code of Practice 60.13330.2020. Heating, Ventilation and Air Conditioning. - Moscow: Ministry of Regional Development of Russia, 2021.
Electromagnetic emission	SanRN: 2.2.2.542-96 "Hygienic requirements for VDT and PC. Organization of work" – introduction 1996-04-14

Factors	Regulatory documents
Exceeding the noise level	40.SanRN 1.2.3685-21. Sanitary and epidemiological rules and regulations "Hygienic standards and requirements to ensure safety and (or) harmlessness for humans of environmental factors". [Text]. - introduced. 2021-01-28. Sanitary standards 2.2.4/2.1.8.562-96 . "Noise in the workplace, in the premises of residential, public buildings and on the territory of residential development"; approved by the resolution of the State Sanitary and Epidemiological Supervision of the Russian Federation dated 31.10.1996 GOST 12.1.003-2014 SSBT. NOISE. General safety requirements.
Insufficient lighting of the work area	SanRN 1.2.3685-21 "Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans"
Psychophysiological loads	GOST 12.0.003-2015. The system of Occupational Safety Standards. Dangerous and harmful production factors. Classification. Guidelines 2.2.2006-05. 2.2. Occupational hygiene. Guidelines for the hygienic assessment of the factors of the working environment and the labor process. Criteria and classification of working conditions MR 2.2.9.2311-07. 2.2.9. The state of health of workers in connection with the state of the production environment
Electrical safety	GOST 12.1.038-82 "System of occupational safety standards. Electrical safety. Maximum permissible values of touch voltages and currents" GOST R 12.1.019-2017 "Electrical safety. General requirements and nomenclature of types of protection"
Fire and explosion hazard	SP 12.13130.2009 "Definition of categories of premises, buildings and outdoor installations for explosion and fire hazard" GOST 12.1.004-91. The system of occupational safety standards. Fire safety. General requirements.

7.2.1.1 Deviation of microclimate indicators

Standards of the industrial microclimate are established in SanRN 2.2.4.548-96 "Hygienic requirements for the microclimate of industrial premises" and GOST 12.1.005-88 "General sanitary and hygienic requirements for the air of the working area". The working area air (microclimate) of industrial premises is determined by the following parameters: temperature, relative humidity, air velocity [50, 51].

Temperature, relative humidity, and air velocity affect heat exchange, and their combined effects must be taken into account. Violation of heat exchange can cause hypothermia or overheating.

When working on a computer, the category of work is light (Ia), since there is no systematic physical exertion.

The optimal microclimate standards of industrial premises for work performed while sitting and not requiring systematic physical exertion (category Ia) are given in the table (Table 24) [50].

Table 24 – Optimal microclimate parameters

<table>
<tr><th>Period years</th><th>Work category by level energy consumption, W</th><th>Temperature of air, ºC</th><th>Temperature surfaces, ºC</th><th>Relative value humidity of air, %</th><th>Speed movements of air, m/s</th></tr>
<tr><td>Cold</td><td rowspan="2">Ia (up to139)</td><td>22-24</td><td>21-25</td><td rowspan="2">40-60</td><td rowspan="2">0,1</td></tr>
<tr><td>Warm</td><td>23-25</td><td>22-26</td></tr>
</table>

Acceptable microclimatic conditions are established according to the criteria of acceptable thermal and functional state of a person for the period of an 8-hour work shift. They are established in cases when, due to technological requirements, technical and economically justified reasons, optimal values cannot be provided. Acceptable values of microclimate characteristics are given in the table (Table 25) [50].

Table 25 – Acceptable microclimate parameters

<table>
<tr><th rowspan="2">Period years</th><th rowspan="2">Work category by level energy consumption, W</th><th colspan="2">Temperature of air, ºC</th><th rowspan="2">Temperature surfaces, ºC</th><th rowspan="2">Relative value humidity of air, %</th><th colspan="2">Speed movements of air, m/s</th></tr>
<tr><th>range below optimal values</th><th>range above optimal values</th><th>range below optimal values</th><th>range above optimal values</th></tr>
<tr><td>Cold</td><td>Ia (up to139)</td><td>20,0-21,9</td><td>24,1-25,0</td><td>19-26</td><td>15-75</td><td colspan="2">no more than 0,1</td></tr>
<tr><td>Warm</td><td>Ia (up to 139)</td><td>21,0-22,9</td><td>25,1-28,0</td><td>20-29</td><td>15-75</td><td>no more than 0,1</td><td>no more than 0,2</td></tr>
</table>

To ensure the established standards of microclimatic parameters and air cleanliness in workplaces and in premises, ventilation is used. General exchange ventilation is designed to maintain the required parameters of the air environment in the entire volume of the room. Air humidity should be monitored periodically. Air conditioning systems should be used in high temperatures in the summer.

The following volumes of outdoor air must be supplied to the room: if the room volume is up to 20 m^3 per person-at least 30 m^3/h per person; if the room volume is more than 40 m^3 per person and there is no release of harmful substances, natural ventilation is allowed [50].

The area of room No. 15 of building No. 23 of the IRSE NNC RK branch is 30 m^2, volume is 90 m^3, air exchange rate is 3 h^{-1} [52]. Consequently, the room's air exchange rate is 270 m3/h.

The FPZ SCL K06 TD 7.5 vortex blower with a capacity of 7.5 kW and a maximum capacity of 312 m3/h is suitable for this air exchange value [53].

There is no release of harmful substances. This room has natural ventilation (air enters and leaves through windows, doors) and supply and exhaust ventilation.

During the cold season, the building must have a heating system that provides sufficient, constant and uniform heating of the air. Radiators should be installed in niches covered with wooden or metal grilles. In case of insufficient efficiency of central heating, oil-based electric heaters or air-conditioning systems of the "winter-summer" type should be used. At the same time, the temperature on the surface of heating devices should not exceed 95 °C to prevent dust burning [52].

The microclimate indicators in room No. 15 of building No. 23 of the IRSE NNC RK fully comply with the standards established by the legislation of the Russian Federation [50, 52].

7.2.1.2 Electromagnetic emission

he screen and computer system blocks produce electromagnetic emission. The main part of it comes from the system unit and the video cable. The electromagnetic field strength at a distance of 50 cm around the screen in terms of the electrical component should correspond to the values indicated in the table (Table 26) [54].

Table 26 – Acceptable levels of electromagnetic field parameters

Parameters		Acceptable level value
Electromagnetic field strength	Frequency range 5 Hz-2 kHz	25 V/m
	Frequency range 2 kHz-400 kHz	2,5 V/m
Magnetic flux density	Frequency range 5 Hz-2 kHz	250 nTl
	Frequency range 2 kHz-400 kHz	25 nTl
Electrostatic potential of the video monitor screen		500 V

To protect against electromagnetic emission, if the permissible levels may be exceeded, the following protection measures are taken:

- increasing the distance between the electromagnetic radiation source and the work area;
- placement of current-carrying elements of apparatuses and devices in special shells.

A liquid crystal-based monitor was used to perform this work, which made it possible to minimize the impact of electromagnetic radiation. Regulated breaks were also set 1.5-2.0 hours after the start of the work shift and after a lunch break of 20 minutes each.

In addition, the location of the computer and the user's workplace in room No. 15 of building No. 23 of the IRSE NNC RK ensure that the established standards for electromagnetic radiation are not exceeded [54].

7.2.1.3 Exceeding the noise level

Noise in the workplace has a harmful effect on the employee's body, namely on the hearing organs and on the entire body through the central nervous system. As a result, attention is weakened, memory worsens, reaction decreases, and the number of errors during work increases. Sources of noise in room No. 15 of building No. 23 of the IRSE NNC RK when performing this work can be a computer cooling system, a printer, a work phone.

Based on the time characteristics of noise, the following parameters are distinguished:

- constant noise, the sound level of which during an 8-hour working day or during measurement in the premises of residential and public buildings, on the territory of residential development changes in time by no more than 5 dBA when measured on the time characteristic of the sound level meter "slowly";
- non-constant noise, the level of which during an 8-hour working day, working shift, or during measurement in the premises of residential and public buildings, on the territory of a residential development changes over time by more than 5 dBA when measured on the time characteristic of the sound level meter "slowly".

The main indicators that can be used for hygienic noise regulation purposes and are measured at the workplace to check compliance with established hygiene standards: equivalent sound level, peak sound level with frequency correction, sound pressure level in frequency bands [55].

Hygiene standards used to assess the levels of noise exposure in the workplace are the equivalent sound level (LpAeqT, dBA); the level that affects a worker during a work shift (measured or calculated relative to 8 hours of a work shift). The standard equivalent sound level (LpAeqT, dBA) in the workplace is 80 dBA [40, 41].

The noise level from the computer system unit is 72.7 dB [42]. Thus, the noise from the computer system unit is within the limits of the established norms, and no special protection measures are required [43].

The noise level of the HP LaserJet P2035 black-and-white laser printer is 54 dB in normal print mode [44]. This printer has a Quiet mode, which is designed for continuous printing at a low noise level.

The noise level from a landline phone is ~50 dB.

In room No. 15 of building No. 23 of the IRSE NNC RK are no sound sources that can exceed the normalized indicators established by the legislation of the Russian Federation [40, 41].

7.2.1.4 Insufficient lighting of the work area

Light sources can be either natural or artificial objects. The natural source in the room is the sun, artificial are electric light bulbs. Insufficient illumination of the work area can occur as a result of insufficient natural light, malfunctions in the operation of lighting devices, as well as in case of emergency situations (de-energization of the building, breakdowns, disruptions in the operation of power lines and substations) or a complete lack of lighting in the work area. Lack of light for a person leads to diseases of the visual organs, as well as to disorders in the central nervous system and, as a result, reduces labor productivity.

According to SanRN 1.2.3685-21, the illumination on the table surface in the working document placement area should be 300-500 lux. Lighting should not create glare on the screen surface. The screen surface illumination must not exceed 300 lux [40].

The main method of protection against insufficient lighting is compliance with the lighting standards established in the SanRN 1.2.3685-21 [40]. So, in in the room with III by category visual devices works' with high with accuracy illumination level must compile 300 lc, but ratio ripple effects 15 %. Ripple effects lighting conditions caused by small by inertia radiation sources gas-discharge devices lamps, light source flow from which ones it's throbbing by alternating current industrial frequencies.

Number of luminaires n it is calculated for the room:

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

where E – is the normalized illumination, 300 lux;

S – area of the room, 30 m^2;

Z – correction factor of the lamp, 1.2;

K – the margin factor that takes into account the decrease in illumination during operation, 1,4;

F – luminous flux of one lamp, LD 40 (double-cap fluorescent lamp), 760 lm;

U – utilization rate, 0.6;

m – number of lamps in the luminaire, 4,

$$n = \frac{300 \cdot 30 \cdot 1{,}2 \cdot 1{,}2}{760 \cdot 0{,}55 \cdot 4} = 8{,}28.$$

Rounded up to exclude areas with insufficient illumination, the minimum number of luminaires for premises No. 15 of building No. 23 of the IRSE NNC RK is 9.

The organization of the workplace can also protect against insufficient lighting. The illumination of the workplace should be uniform. The desk should be located in a well-lit area, preferably near a window. The person at the desk should be positioned with his face or left side to the window (for left-handers-right side) in order to avoid the formation of a shadow from the person's body or hand. The artificial lighting fixture should be positioned relative to the human body in the same way.

In room No. 15 of building No. 23 of the IRSE NNC RK, the illumination of the workplace meets the standards established by the legislation of the Russian Federation [40].

7.2.1.5 Psychophysiological loads

Psychophysiological dangerous and harmful production factors are divided into physical overloads (static, dynamic) of the movement apparatus (uncomfortable body position, inactivity, etc.) and neuropsychic overloads (mental overstrain, monotony of work, overstrain of the hearing and/or vision organs, emotional overloads) [49].

The state of health is negatively affected by hypodynamia – a violation of the body's functions (musculoskeletal system, blood circulation, respiration, digestion, etc.) with limited motor activity, reduced muscle resistance forces. Prevention of physical inactivity involves the exclusion of static work, changing the working posture during work, performing industrial gymnastics with a rational set of physical exercises, etc.

The main source of emotional stress is the degree of responsibility for the result of one's own activity, that is, the significance of the error. Erroneous actions lead to additional effort on the part of the employee and lead to an increase in emotional stress [48]. An increase in emotional stress leads to the development of professional stress.

The performance of this work belongs to class 3.1. on emotional loads according to classification of working conditions by indicators of labor intensity [48]. To prevent emotional overload, in addition to observing the established work and rest schedule, it is necessary to perform tasks in accordance with the plan and set deadlines.

The main sources of mental overexertion are [45]:

- with mental stress – a long and irregular working day with shift work, work in a state of time deficit, the duration of focused attention, a high degree of complexity of the task, expressed responsibility;
- with visual load – high accuracy of the work performed, the need for high coordination of sensory and motor elements of the visual system, the time spent working with the screen of monitors and computers.

Prolonged and intense exposure to unfavorable factors of the labor process forms professional stress: a consistent transition of the functional state from tension to fatigue, to overexertion and to overwork. To reduce the negative impact of this factor, it is necessary to allocate time intervals for rest and eating in the work schedule. With a high visual load, it is necessary to provide time for gymnastics for the eyes.

The main source of long-term focused observation is concentration or concentration of attention on some ideal object (in the context of work – on the monitor). This factor can lead to poor vision and emotional stress.

The average time of focused observation for researchers is up to 25% of the total shift time (up to 2 hours) [48].

To prevent violations caused by the duration of concentrated surveillance, it is necessary to strictly observe the established work and rest regime.

When working in room No. 15 of building No. 23 of the IRSE NNC RK, the main psychophysiological factor is mental overstrain, which causes fatigue. The most effective prevention of fatigue in the workplace is the means that normalize the active labor activity of a person. In the normal course of work processes, one of the most important physiological measures against fatigue is the correct mode of work and rest, established in accordance with the Labor Code of the Russian Federation [37].

Room No. 15 of building No. 23 of the IRSE NNC RK meets the established standards for psychophysiological loads [40, 48,].

7.2.1.6 Electrical safety

A dangerous factor when working with a computer is electric shock. The computer and its peripherals are powered by a single-phase AC network with a frequency of 50 Hz and a voltage of 220 V. A voltage of no more than 40 V is considered safe for humans. The current flowing in the household electrical network is 5-10 A. Thus, if a person touches live parts, it can lead to serious injury – electric shock. An electric current strikes suddenly, at the moment when a person is "included" in the current transmission circuit.

Passing through the human body, electric current produces thermal, electrolytic, mechanical and biological effects.

The thermal effect of the current is manifested in burns to areas of the body, heating to a high temperature of blood vessels, nerves, heart and other organs located in the path of the current, which causes serious functional disorders in them.

The electrolytic effect of the current is expressed in the decomposition of organic fluids, including blood (plasma), which is accompanied by significant violations of their physico-chemical composition.

The mechanical effect of the current is expressed in stratification, rupture, and other similar injuries to various tissues of the body, including muscle tissue, blood vessel walls, lung tissue vessels, and other tissues as a result of the electrodynamic effect, as well as instantaneous explosive vapor formation from superheated tissue fluid and blood.

The biological effect of electric current is manifested in the irritation and excitation of living tissues of the body, in violation of internal biological processes. Overexcitation of nerve endings can lead to an unnaturally powerful contraction of muscle tissue, when numerous injuries of internal organs (both due to compression and rupture), bone fractures occur as side effects. Moreover, muscle contraction in certain situations can cause a fracture of the spinal column and, as a result, death.

The most dangerous consequences of electric shock are cardiac arrest, fibrillation, and electric shock.

Knowledge of the permissible current and voltage values for a person allows you to correctly assess the risk of damage and determine the requirements for protective measures against electric shock. GOST 12.1.038-82 [56] sets the maximum permissible levels of touch voltages and currents flowing through the human body (Table 27). Touch voltage refers to the voltage between two points in the current circuit that are simultaneously touched by a person.

Table 27 – Maximum permissible values of contact voltage and amperage

Current type and frequency	Maximum allowed value	
	$U_{пр}$, V	I_h, mA
Variable, 50 Hz	2	0,3
Variable, 400 Hz	3	0,4
Constant	8	1,0

For people working in conditions of high temperature and humidity (relative humidity greater than 75%), these standards should be reduced by three times [56].

Depending on the conditions that increase or decrease the risk of human electric shock, in accordance with the REI-7 in force in the Russian Federation, all premises are divided into several groups [57]:

1. Non-hazardous premises – premises where there are no conditions that create an increased or special danger.

2. Rooms with increased danger – rooms characterized by the presence of one of the following conditions that create an increased danger: dampness (damp rooms) or conductive dust (dusty rooms); conductive floors (metal, earth, reinforced concrete, brick, etc.); high temperature

(hot rooms); the possibility of simultaneous human contact with the metal structures of buildings connected to the ground, technological devices, mechanisms, etc., on the one hand, and to the metal housings of electrical equipment (open conducting parts), on the other.

3. Particularly dangerous premises – premises characterized by the presence of one of the following conditions that create a particular danger: special dampness (particularly wet rooms); chemically active or organic environment (rooms with a chemically active or organic environment); two or more high-risk conditions at the same time.

4. Territories where outdoor electrical installations are located. With regard to the risk of electric shock to people, these areas are considered to be particularly dangerous premises.

In order to assign a particular room to a particular hazard group, you need to know the existing types of rooms. Consider them. Depending on the parameters of the microclimate and the presence of harmful industrial factors, the following types of premises are distinguished: dry premises (premises in which the relative humidity of the air does not exceed 60 %), wet premises (premises in which the relative humidity of the air exceeds 60 %, but does not exceed 75 %), wet premises (premises in which the relative humidity of the air humidity exceeds 75 %), particularly damp rooms (rooms with relative humidity of more than 50%). air humidity is close to 100% (the ceiling, walls, floor and objects in the room are covered with moisture)), hot rooms – rooms where the temperature under the influence of various thermal radiation exceeds constantly or periodically (more than 1 day) +35 °C (for example, rooms with dryers, kilns, boilers), dusty rooms (rooms in which, according to the production conditions, technological dust is released, which can settle on current-carrying parts, penetrate into machines, apparatuses, etc.), rooms with a chemically active or organic environment (rooms that constantly or for a long time contain aggressive vapors, gases, liquids, deposits or mold that destroy insulation and current-carrying parts of electrical equipment). In turn, dusty rooms are divided into rooms with conductive dust and rooms with non-conductive dust.

Normal ones these are rooms where the relative humidity of the air does not exceed 60%, there is no chemically active or organic medium, the temperature does not exceed constantly or periodically (more than 1 day) +35 °C, and also according to the production conditions, technological dust is not released, which can settle on current-carrying parts, penetrate into machines, apparatuses, etc.

The main ones measures to protect against electric shock are [57]:

- ensuring unavailability of live parts by using insulation in equipment housings;
- application of collective protection against electric shock;
- use of protective earthing, protective zeroing, protective disconnectionI;
- usage uninterruptible power supply devices.

Technical methods and tools can be used either separately or in combination with each other to ensure optimal protection.

Organizational measures on electrical safety for personnel are briefings:

- primary – it is carried out before the start of the proposed work, directly at the workplace, and is intended for all employees, including those who are transferred between structural divisions;
- repeated-designed for electrical and electrical engineering personnel, its frequency is every 3 months;
- unscheduled – carried out when technological processes change, an employee violates the requirements for electrical safety, when new regulations on electrical safety are introduced or existing ones are revised;
- wholeevoy – is intended for electrical or electrical engineering personnel when performing one-time work not provided for in the employment contract, eliminating the consequences of accidents or natural disasters.It is also used in situations where it is necessary to issue a work permit or a special order to carry out work.

All non-electrical personnel must be certified for the first electrical safety qualification group [58].

Room No. 15 of building No. 23 of the IRSE NNC RK meets the established standards for electrical safety and belongs to the 1st group "room without increased danger" [57].

7.2.2 Fire and explosion safety

According to explosion and fire hazards, premises are divided into categories A (high explosion and fire hazard), B (explosion and fire hazard), B1-B4 (fire hazard), D (moderate fire hazard) and E (low fire hazard), and buildings are divided into categories A, B, C, D and E [60].

The appropriate category of premises and buildings is determined based on the type of combustible substances and materials located in the premises, their quantity and fire-hazardous properties, as well as on the spatial planning solutions of the premises and the characteristics of technological processes carried out in them [60].

Determination of fire-hazardous properties of substances and materials is made on the basis of test results or calculations according to standard methods, taking into account state parameters (pressure, temperature, etc.), while it is allowed to use officially published reference data on fire-hazardous properties of substances and materials and use fire hazard indicators for mixtures of substances and materials for the most dangerous component [60].

Fire safety of any object is ensured by fire prevention and fire protection systems, including organizational and technical measures [60]. Fire protection must be achieved by using one of the following methods or a combination of them [60]:

- use of fire extinguishing equipment and appropriate types of fire equipment;
- application of automatic fire alarm and extinguishing systems;
- application of basic building structures and materials, including those used for structural linings, with normalized fire hazard indicators;
- application of impregnation of objects ' structures with flame retardants and application of flame-retardant paints (compounds)on their surfaces;
- devices that limit the spread of fire;
- organization with the help of technical means, including automatic, timely notification and evacuation of people;
- use of collective and individual protection equipment against fire hazards;
- use of smoke protection equipment.

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

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

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

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

- elimination of the formation of a combustible environment (equipment sealing, air control, operational and emergency ventilation);
- application of non-combustible or hard-to-burn materials in the construction and decoration of buildings;
- proper operation of the equipment (proper connection of the equipment to the electric power supply network, control of heating of the equipment);
- proper maintenance of buildings and territories (excluding the formation of an ignition source - preventing spontaneous combustion of substances, limiting fire operations);
- training of production personnel in fire safety regulations;
- publication of instructions, posters, and an evacuation plan;

- compliance with fire safety rules and regulations in the design of buildings, electrical wiring and equipment, heating, ventilation, lighting;
- correct placement of equipment;
- timely preventive inspection, repair and testing of equipment.

Room No. 15 of building No. 23 of the IRSE NNC RK belongs to category B4 in terms of fire and explosion safety [60]. Fire protection of building No. 23 is provided with fire extinguishing equipment (fire hose, fire extinguisher) and automatic fire alarm systems.

7.3 Safety in emergency

An emergency incident is a situation that can lead to breakage of parts and injury to the worker.

Emergency situation is a situation in a certain territory that has developed as a result of an accident, a dangerous natural phenomenon, a catastrophe, the spread of a disease that poses a danger to others, a natural or other disaster that may or may not result in human casualties, damage to human health or the environment, significant material losses and violation of the living conditions of people.

According to the origin of an emergency, it is divided into 2 types:

- technogenic;
- natural.

Man-made emergencies include fires, explosions, sabotage, and toxic emissions. Natural emergencies include natural disasters.

Accident hazards include a sudden and uncontrolled source of energy: a moving object, uncontrolled movement, or energy [60].

Consider possible emergency incident and in room No. 15 of building No. 23 of the IRSE NNC RK, namely:

- falling on a plane (from your own height);
- electric shock;
- appearance a fire;
- the storm.

Measures to prevent emergency incidents and emergency situation to eliminate the above-mentioned are presented in the table (Table 28).

Table 28 – Possible emergencies and emergencies, measures to prevent them and eliminate their consequences

emergency incident and emergency situation	Measures to prevent emergency incidents and emergency situation	Measures to eliminate emergency incident and emergency situation
Injury when falling on a plane (from the height of one's own height)	1. Timely briefing. 2. Maintenance of the premises in proper order. 3. Limit the working space.	Possible injuries – bruise, sprain, dislocation, fracture, concussion. 1. Examine or interview the victim, if necessary, call an ambulance by calling 112 or 103. 2. Depending on the injury, provide rest to the injured part of the body (for example, make a light dressing of the injury site when stretching, apply a splint in case of a severe bruise or suspected fracture) or stop the bleeding if it is present. 3. If the head, abdomen, spine or swelling is bruised and the pain increases, you should consult a trauma doctor at the emergency room. 4. In case of injury in the form of dislocation or fracture, it is necessary to provide the victim with complete rest and call an ambulance.
Electric shock	1. Timely briefing. 2. Grounding of all electrical installations. 3. Ensuring that live computer parts and peripherals are inaccessible. 4. Limit the working space..	1. Quickly release the victim from the electric shock. 2. Call an ambulance by calling 112 or 103. 3. If the victim has lost consciousness, but he still has breath, then he should be comfortably laid down, unbuttoned tight clothing, create an influx of fresh air and ensure complete rest. 4. The victim should be given a sniff of ammonia, sprinkle the face with water, rub and warm the body.
Fire	1. Timely briefing. 2. Installation of automatic fire extinguishing equipment in the premises. 3. Install smoke and fire detectors. 4. Providing escape routes and maintaining them in proper condition. 5. Monitoring the operation of electrical appliances.	1. De-energize the room, stop the air supply. 2. Immediately report a fire to the head of the unit and/or the responsible person for fire safety in building No. 23, call the fire service by calling 112 or 101. 3. If possible, take measures to evacuate people, extinguish a fire, and save property.
Storm	1. Timely briefing.	Storm caught me at work: 1. Close windows, doors, and attics. 2. Remove things from windowsills. 3. Take a position away from the windows. 4. Do not go outside immediately after the wind slackens: the gust may recur in a few minutes. The storm caught on the street. 1. Take shelter in the nearest building (if possible). 2. Quickly lie down on the bottom of a ditch, pit, or roadside ditch. 3. Cover your head with a bag, briefcase, or any other object. 4. Stay away from buildings and trees, bridges and overpasses, billboards, pavilions.

emergency incident and emergency situation	Measures to prevent emergency incidents and emergency situation	Measures to eliminate emergency incident and emergency situation
		5. Beware of injuries from flying glass, slate, pieces of roofing iron. 6. After a storm, stay away from buildings, poles, and high fences – they may collapse. Beware of broken electrical wires.

Section conclusions

In this section, issues of social responsibility were considered as part of the process of studying the $^{90}Sr/^{137}Cs$ ratios in the surface soil layer on the territory of the Karaganda region within the Semipalatinsk test site. The analysis of harmful and dangerous factors arising during the research process is carried out:

- microclimate [50, 52];
- electromagnetic emission [54];
- noise [40, 41];
- lighting [40];
- psychophysiological loads [40, 48];
- поражение электрическим током [57].

Room No. 15 of building No. 23 of the IRSE NNC RK is referred to:

- electrical safety is 1st group "no high-risk premises" [57];
- fire and explosion safety are B4 group [60].

The section also discusses possible emergency incidents and emergency situation that may occur in the room No. 15 of the building No. 23 of the IRSE NNC RK, and measures to prevent them and eliminate their consequences.

It should be noted that compliance with the instructions on safety and labor protection, fire safety, standards and working conditions of personnel, as well as the rules of operation of the hardware base minimizes possible injuries.

Conclusion

As a result of the graduation thesis, most of $^{90}Sr/^{137}Cs$ ratios were found to range as 0.5 ± 0.3 for the topsoil of the Karaganda region within STS beyond its test locations, which suggests a similar radioactive contamination with fission products of interest. $^{90}Sr/^{137}Cs$ values exceeding the level of global fallout (0.6) are typical of survey areas in the impact zone of fallout plumes from aboveground tests.

Thus, by applying the ratio technique to determine ^{90}Sr activity from that of ^{137}Cs in topsoil, it should be taken into account that $^{90}Sr/^{137}Cs$ ratios are characterized by different values for fallout plumes and in areas of background activity levels, which makes it possible to identify boundaries of background areas and aboveground test locations. An additional advantage is a possibility to assess dose loads from ^{90}Sr obtained by the calculated method on the population in the case of their residence and economic activity in the study area.

The total cost budget of the research work is 414653 rubles.

It was found that the microclimate indicators in room 15 of building No. 23 of the IRSE NNC RK fully comply with the standards established by the legislation of the Russian Federation. The room is classified as category B4 for fire and explosion safety and Group 1 for electrical safety "non-hazardous premises". Possible emergencies in room 15 of building No. 23 of the IRSE NNC RK (fall on the plane (from own height), electric shock, fire, storm) were considered. It is noted that compliance with health and safety instructions, fire safety, personnel standards and working conditions, as well as the rules of the hardware equipment, minimizes possible injuries.

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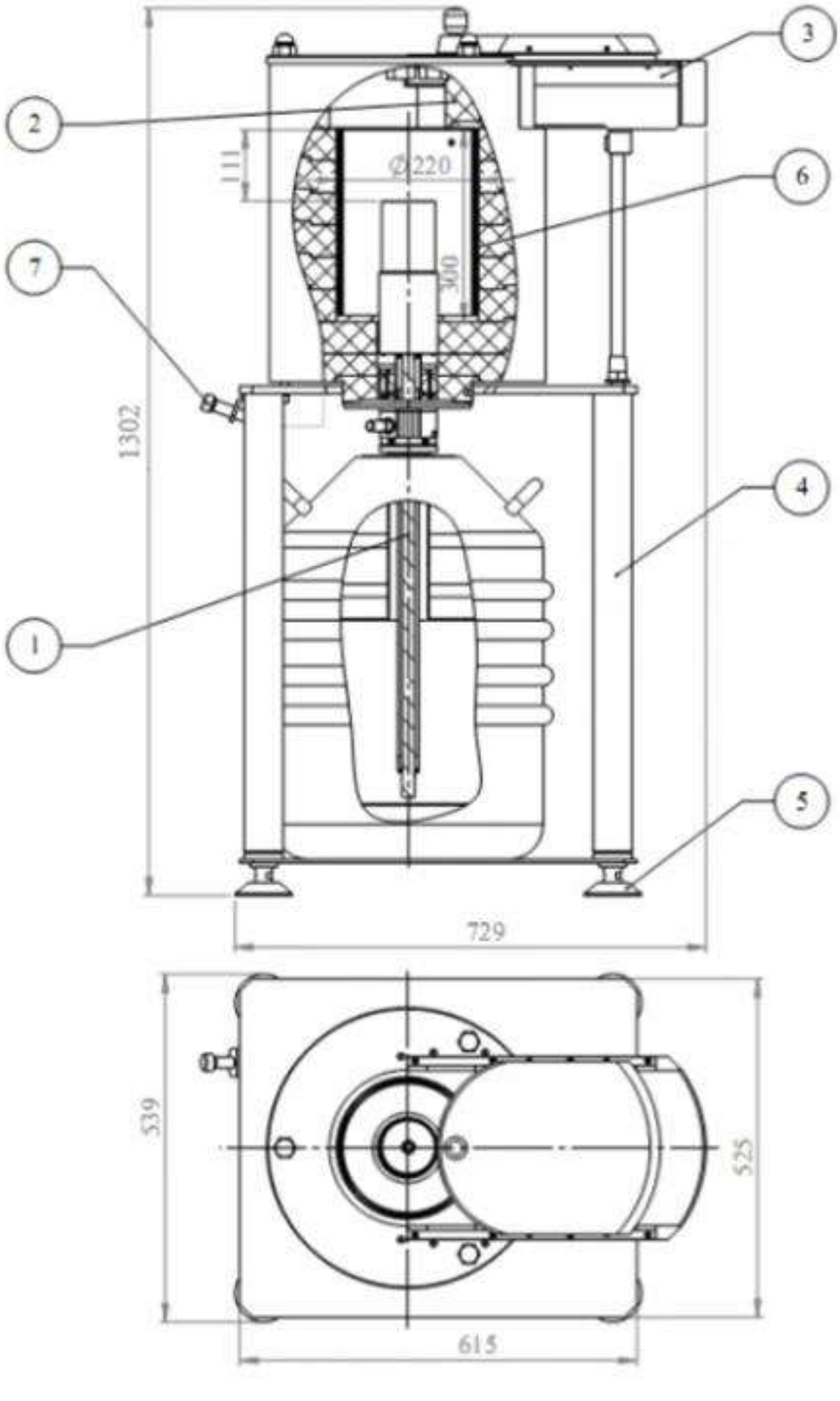
Annex A

ФЮРА.14.04.02.001



Перв. примен.

Справ.№

Подп. и дата

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Изм.	Кол.	№ докум.	Подп.	Дата
Разработал		Бакланова Ю.В.		15.05.2023
Проверил		Яковлева В.С.		15.05.2023
Т.контр.				
Н.контр.				
Утвердил		Семёнов А.О.		

Полупроводниковый гамма-спектрометр в низкофоновой защите

Лит.	Масса	Масштаб
У		1:1
Лист	Листов	

НИ ТПУ ИЯТШ
Группа 0АМ13

Позиция	Наименование	Количество	Примечание
1	Блок детектирования	1	
2	Свинцовая защита	1	
3	Передвижная крышка свинцовой защиты	1	
4	Стол для размещения свинцовой защиты	1	
5	Ножки стола	4	
6	Медное покрытие толщиной 9 мм	1	
7	Устройство для заправки сосуда Дьюара жидким азотом	1	

Разработал	Бакланова Ю.В.		15.05.2023	ФЮРА.14.04.02.001			
Проверил	Яковлева В.С.		15.05.2023	Спецификация к полупроводниковому гамма-спектрометру в низкофоновой защите	Стад.	Лист	Листов
						1	1
Н.контр.					НИ ТПУ ИЯТШ Группа 0АМ13		
Утвердил	Семёнов А.О.						

Подп. и дата | Инв. № дубл. | Взам. инв. № | Подп. и дата | Инв. № подл.