TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

Инженерная школа ядерных технологий
Направление подготовки: 14.03.02 Ядерные физика и технологии
Отделение ядерно-топливного цикла

БАКАЛАВРСКАЯ РАБОТА

Тема работы
Уровни гамма-фона в местах массового пребывания людей г. Томска

УДК 539.166.2:539.1.074(571.16)

Студент

Группа	ФИО	Подпись	Дата
0А8Д	Кейних Данил Дмитриевич		

Руководитель ВКР

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

Консультант

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

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОСГН	Якимова Т.Б.	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
Доцент ОЯТЦ ИЯТШ	Бычков П.Н.	к.т.н.		

Томск – 2022 г.

TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

School of Nuclear Science & Engineering
Field of training (specialty): 14.03.02 Nuclear Science and Technology
Nuclear Fuel Cycle Division

BACHELOR THESIS

Topic of research of work
Gamma background levels in public gathering places in Tomsk

UDC 539.166.2:539.1.074(571.16)

Student

Group	Full name	Signature	Date
0A8D	Keinih D.D.		

Scientific supervisor

Position	Full name	Academic degree, academic rank	Signature	Date
Professor of NFCF	Yakovleva V.S.	Professor, PhD		

Consultant

Position	Full name	Academic degree, academic rank	Signature	Date
Senior lecturer of NFCF	Poberezhnikov A.D.	-		

ADVISERS:

Section «Financial Management, Resource Efficiency and Resource Saving»

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Yakimova T.B.	PhD		

Section «Social Responsibility»

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Perederin Y.V.	PhD		

ADMITTED TO DEFENSE:

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

Tomsk – 2022 г.

РЕЗУЛЬТАТЫ ОБУЧЕНИЯ ПО ООП

Код компетенции	Результаты освоения ООП (компетенции)
Универсальные	
УК(У)-1	Способен осуществлять поиск, критический анализ и синтез информации, применять системный подход для решения поставленных задач
УК(У)-2	Способен определять круг задач в рамках поставленной цели и выбирать оптимальные способы их решения, исходя из действующих правовых норм, имеющихся ресурсов и ограничений
УК(У)-3	Способен осуществлять социальное взаимодействие и реализовывать свою роль в команде
УК(У)-4	Способен осуществлять деловую коммуникацию в устной и письменной формах на государственном языке Российской Федерации и иностранном(-ых) языке(-ах)
УК(У)-5	Способен воспринимать межкультурное разнообразие общества в социально-историческом, этическом и философском контекстах
УК(У)-6	Способен управлять своим временем, выстраивать и реализовывать траекторию саморазвития на основе принципов образования в течение всей жизни
УК(У)-7	Способен поддерживать должный уровень физической подготовленности для обеспечения полноценной социальной и профессиональной деятельности
УК(У)-8	Способен создавать и поддерживать безопасные условия жизнедеятельности, в том числе при возникновении чрезвычайных ситуаций
УК(У)-9	Способен проявлять предприимчивость в профессиональной деятельности, в т.ч. в рамках разработки коммерчески перспективного продукта на основе научно-технической идеи
Общепрофессиональные	
ОПК(У)-1	Способен использовать базовые знания естественнонаучных дисциплин в профессиональной деятельности, применять методы математического анализа и моделирования, теоретического и экспериментального исследования
ОПК(У)-2	Способен осуществлять поиск, хранение, обработку и анализ информации из различных источников и баз данных, предоставлять ее в требуемом формате с использованием информационных, компьютерных и сетевых технологий
ОПК(У)-3	Способен использовать в профессиональной деятельности современные информационные системы, анализировать возникающие при этом опасности и угрозы, соблюдать основные требования информационной безопасности, в том числе защиты государственной тайны
Профессиональные компетенции	
ПК(У)-1	Способен использовать научно-техническую информацию, отечественный и зарубежный опыт по тематике исследования, современные компьютерные технологии и информационные ресурсы в своей предметной области

ПК(У)-2	Способен проводить математическое моделирование процессов и объектов атомной отрасли с использованием стандартных методов и компьютерных кодов для проектирования и анализа
ПК(У)-3	Готов к проведению физических экспериментов по заданной методике, составлению описания проводимых исследований и анализу полученных экспериментальных данных
ПК(У)-4	Способен использовать технические средства для измерения основных параметров объектов исследования
ПК(У)-5	Готов к составлению отчета по выполненному заданию, к участию во внедрении результатов исследований и разработок
ПК(У)-6	Способен использовать информационные технологии при разработке новых установок, материалов и приборов, к сбору и анализу исходных данных для проектирования объектов атомной отрасли
ПК(У)-7	Способен к расчету и проектированию деталей и узлов приборов и установок в соответствии с техническим заданием
ПК(У)-8	Готов к разработке проектной и рабочей технической документации, оформлению законченных проектно-конструкторских работ
ПК(У)-9	Способен к контролю соответствия разрабатываемых проектов и технической документации стандартам, техническим условиям, требованиям безопасности и другим нормативным документам
ПК(У)-10	Готов к проведению предварительного технико-экономического обоснования проектных решений при разработке установок и приборов
ПК(У)-11	Способен к контролю за соблюдением технологической дисциплины и обслуживанию технологического оборудования
ПК(У)-12	Готов к эксплуатации современного физического оборудования, приборов и технологий
ПК(У)-13	Способен к оценке ядерной и радиационной безопасности, к оценке воздействия на окружающую среду, к контролю за соблюдением экологической безопасности, техники безопасности, норм и правил производственной санитарии, пожарной, радиационной и ядерной безопасности, норм охраны труда
ПК(У)-14	Готов разрабатывать способы применения ядерно-энергетических, плазменных, лазерных, сверхвысокочастотных и мощных импульсных установок, электронных, нейтронных и протонных пучков, методов экспериментальной физики в решении технических, технологических и медицинских проблем
ПК(У)-15	Способен к составлению технической документации (графиков работ, инструкций, планов, смет, заявок на материалы, оборудование), а также установленной отчетности по утвержденным формам

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«Национальный исследовательский Томский политехнический университет» (ТПУ)

Инженерная школа ядерных технологий
Направление подготовки: 14.03.02 Ядерные физика и технологии
Отделение ядерно-топливного цикла

УТВЕРЖДАЮ:
Руководитель ООП
________ __________ Бычков П.Н.
(Подпись) (Дата) (ФИО)

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

В форме:

бакалаврской работы

Студенту:

Группа	ФИО
0А8Д	Кейних Данил Дмитриевич

Тема работы:

Уровни гамма – фона в местах массового пребывания людей г. Томска	
Утверждена приказом директора (дата, номер)	01.02.2022 г., № 32-52/с

Срок сдачи студентом выполненной работы:	10.06.2022

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе	
Перечень подлежащих исследованию, проектированию и разработке вопросов	- Обзор литературных источников; - Выбор измерительных приборов; - Проведение измерений уровня гамма-фона в выбранных локациях города Томска; - Анализ и описание результатов; - Финансовый менеджмент, ресурсоэффективность и ресурсосбережение; - Социальная ответственность; - Заключение по работе.
Перечень графического материала	Презентация для защиты ВКР
Консультанты по разделам выпускной квалификационной работы	
Раздел	**Консультант**
Социальная ответственность	Передерин Ю.В.

Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	Якимова Т.Б.

Дата выдачи задания на выполнение выпускной квалификационной работы по линейному графику	15.03.2022

Задание выдал руководитель / консультант:

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

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

School of Nuclear Science & Engineering
Field of training (specialty): 14.03.02 Nuclear Science and Technology
Nuclear Fuel Cycle Division

APPROVED BY:
Program Director
_____________ Bychkov P.N.
«___»__________ 2022

ASSIGNMENT
for the Graduation Thesis completion

In the form:

Bachelor Thesis

For a student:

Group	Full name
0A8D	Keinih Danil Dmitrievich

Тема работы:

Gamma background levels in public gathering places in Tomsk	
Approved by the order of the Director of School of Nuclear Science & Engineering (date, number):	01.02.2022 г., № 32-52/c

Deadline for completion of Bachelor Thesis:	10.06.2022

TERMS OF REFERENCE:

Initial date for research work:	
List of the issues to be investigated, designed and developed	- To review the literature; - To formulate the goals and objectives of the study; - To Measure gamma background radiation in urban environment; - To Calculate of radiation doses; - To compare calculated radiation dose with recommended safe limits and world average values; - Analysis of the results; - Financial management, resource efficiency and resource conservation; - Social responsibility; - Conclusion
List of graphic material	Presentation for the defense of the FQP

Advisors to the sections of the Bachelor Thesis	
Section	**Advisor**
Social Responsibility	Perederin Y.V.
Financial Management, Resource Efficiency and Resource Saving	Yakimova T.B.

Date of issuance of the assignment for Bachelor Thesis completion according to the schedule	15.03.2022

Assignment issued by a scientific supervisor / advisor:

Position	Full name	Academic degree, academic rank	Signature	Date
Professor of NFCF	Yakovleva V.S.	Professor, PhD		
Senior lecturer of NFCF	Poberezhnikov A.D.	-		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

Группа	ФИО
0А8Д	Кейних Данил Дмитриевич

Школа	ИЯТШ	**Отделение школы (НОЦ)**	ОЯТЦ
Уровень образования	Бакалавриат	**Направление/специальность**	Ядерные физика и технологии

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. Стоимость ресурсов: материально-технических, энергетических, финансовых, информационных и человеческих	*Стоимость материальных ресурсов в соответствии с рыночными ценами г. Томска. Тарифные ставки исполнителей в соответствии со штатным расписанием НИ ТПУ.*
2. Нормы и нормативы расходования ресурсов	*Коэффициенты для расчета заработной платы.*
3. Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования	*Коэффициент отчислений во внебюджетные фонды – 30,2 %.*
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. Оценка коммерческого потенциала, перспективности и альтернатив проведения исследования с позиции ресурсоэффективности и ресурсосбережения	*Потенциальные потребители результатов исследования. Анализ конкурентных технических решений. Проведение SWOT-анализа*
2. Планирование и формирование бюджета	*Определение трудоемкости работ. Разработка графика проведения научного исследования. Формирование бюджета затрат научно-исследовательского проекта*
3. Определение ресурсной (ресурсосберегающей), финансовой, бюджетной, социальной и экономической эффективности	*Проведение оценки сравнительной эффективности проекта.*
Перечень графического материала:	
1. Диаграмма Ганта	

Дата выдачи задания для раздела по линейному графику	15.03.2022

Задание выдал консультант:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент ОСГН	Якимова Т.Б.	к.э.н.		15.03.2022

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А8Д	Кейних Д.Д.		15.03.2022

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

To the student:

Group	Full name
0A8D	Keinih Danil Dmitrievich

School	Nuclear Science and Engineering	**Division**	Nuclear Fuel Cycle
Degree	Bachelor	**Educational Program**	Nuclear physics and technologies

Input data to the section «Financial management, resource efficiency and resource saving»:	
1. The cost of resources: material, technical, energy, financial, information and human	*The cost of material resources in accordance with the market prices of Tomsk. The tariff rates of performers in accordance with the staffing schedule of the TPU.*
2. Norms and standards of resource expenditure	*Coefficients for calculating wages.*
3. The system of taxation used, the rates of taxes, deductions, discounting and lending	*The coefficient of contributions to extra–budgetary funds is 30.2%.*
The list of subjects to study, design and develop:	
1. Assessment of commercial potential, prospects and alternatives for conducting research from the perspective of resource efficiency and resource conservation	*Potential consumers of the research results. Analysis of competitive technical solutions. Conducting SWOT analysis*
2. Planning and budgeting	*Determination of the labor intensity of the work. Development of a schedule for conducting scientific research. Formation of the cost budget of a research project*
3. Determination of resource (resource-saving), financial, budgetary, social and economic efficiency	*Conducting an assessment of the comparative effectiveness of the project.*
A list of graphic material	
1. Gantt Chart	

Date of issue of the task for the section according to the schedule	15.03.2022

Task issued by adviser:

Position	Full name	Academic degree, academic rank	Signature	Date
Professor	Yakimova T.B.	PhD		15.03.2022

The task was accepted by the student:

Group	Full name	Signature	Date
0A8D	Keinih D.D.		15.03.2022

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Студенту:

Группа	ФИО
0А8Д	Кейних Данил Дмитриевич

Школа	ИЯТШ	**Отделение школы (НОЦ)**	ОЯТЦ
Уровень образования	Бакалавриат	**Направление/специальность**	Ядерные физика и технологии

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. Характеристика объекта исследования (вещество, материал, прибор, алгоритм, методика, рабочая зона) и области его применения	*Объектом исследования является радиационного фон вблизи объектов техносферы в городской среде.*
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. Правовые и организационные вопросы обеспечения безопасности	*Трудовой кодекс Российской Федерации от 30.12.2001 № 197-ФЗ (ред. от 30.04.2021).*
2. Производственная безопасность: – Анализ выявленных вредных и опасных факторов – Обоснование мероприятий по снижению воздействия	*Вредные и опасные факторы:* *– параметры микроклимата;* *– повышенный уровень ионизирующих излучений;* *– вредные вещества;* *– вентиляция;* *– шум;* *– недостаток естественного и искусственного освещения;* *– электрический ток;* *– электромагнитные поля;* *– пожароопасность.*
3. Безопасность в чрезвычайных ситуациях	*– падение с высоты собственного роста;* *– падение с лестницы;* *– удар электрическим током;* *– пожар.*

Дата выдачи задания для раздела по линейному графику	15.03.2022

Задание выдал консультант:

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А8Д	Кейних Д.Д.		

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

To the student:

Group	Full name
0A8D	Keinih Danil Dmitrievich

School	Nuclear Science and Engineering	**Division**	Nuclear Fuel Cycle
Degree	Bachelor	**Educational Program**	Nuclear physics and technologies

Input data to the section «Financial management, resource efficiency and resource saving»:	
1. Information about object of investigation (matter, material, device, algorithm, procedure, workplace) and area of its application	*Measurement of the radiation background of the surface atmosphere and carrying out various types of analysis.*
The list of subjects to study, design and develop:	
1. Legal and organizational issues to provide safety:	*The Labor Code of the Russian Federation No. 197-FZ dated 30.12.2001 (as amended on 30.04.2021).*
2. Work Safety: – Analysis of identified harmful and dangerous factors – Justification of measures to reduce probability of harmful and dangerous factors	*Harmful and dangerous factors:* *– microclimate parameters;* *– increased level of ionizing radiation;* *– harmful substances;* *– ventilation;* *– noise;* *– lack of natural and artificial lighting;* *– electric current;* *– electromagnetic fields;* *– fire hazard.*
3. Safety in emergency situations:	*– falling from the height of your own growth;* *– falling down the stairs;* *– electric shock;* *– fire.*

Date of issue of the task for the section according to the schedule	15.03.2022

Task issued by adviser:

Position	Full name	Academic degree, academic rank	Signature	Date
Professor	Perederin Y.V.	PhD		

The task was accepted by the student:

Group	Full name	Signature	Date
0A8D	Keinih D.D.		

TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

Инженерная школа ядерных технологий
Направление подготовки: 14.03.02 Ядерные физика и технологии
Отделение ядерно-топливного цикла
Период выполнения (осенний / весенний семестр 2021/2022 учебного года)

Форма представления работы:

Бакалаврская работа

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Срок сдачи студентом выполненной работы:	10.06.2022

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
29.04.2022	Формирование целей и задач ВКР, задания на ВКР, плана-графика выполнения ВКР и титульного листа	10
10.05.2022	Обзор литературных источников	10
12.05.2022	Подготовка и калибровка измерительных приборов	10
14.05.2022	Проведение измерений уровня гамма-фона в выбранных локациях города Томска	10
25.05.2022	Анализ и описание результатов	10
3.06.2022	Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	15
3.06.2022	Социальная ответственность	15
7.06.2022	Заключение по работе	10
8.06.2022	Представление итогового варианта пояснительной записки к ВКР	10

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TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Министерство науки и высшего образования Российской Федерации
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School of Nuclear Science & Engineering
Field of training (specialty): 14.03.02 Nuclear Science and Technology
Nuclear Fuel Cycle Division
Period of completion: spring semester 2021/2022 academic year

Form of presenting the work:

Bachelor Thesis

SCHEDULED ASSESSMENT CALENDAR
for the Master Thesis completion

Deadline for completion of Bachelor's Graduation Thesis:	10.06.2022

Assessment date	Title of section (module) / type of work (research)	Maximum score for the section (module)
29.04.2022	Formation of the goals and objectives of the FQP, assignments for the FQP, the schedule for the implementation of the FQP and the title page;	10
10.05.2022	Literature Review and Methodology	10
12.05.2022	Preparation and calibration of measuring instruments	10
14.05.2022	Data collection	10
25.05.2022	Analysis of the obtained experimental data	10
3.06.2022	Financial Management, Resource Efficiency and Resource Saving	15
3.06.2022	Social Responsibility	15
7.06.2022	Conclusion on work	10
8.06.2022	Defense preparation	10

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Position	Full name	Academic degree, academic rank	Signature	Date
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Abstract

Final qualifying work 75 p., 25 figures, 31 tables, 34 sources.

Key words: gamma background, detector, dosimeter, technosphere, radiation, dose rate.

The objective of this study is to investigate changes in gamma background due to Technosphere objects in the urban environment.

A series of measurements were carried out at points located in the immediate vicinity of the objects of the technosphere and at some distance from these objects. The following instruments were used for measurements: wide-range dosimeter DRG – 01T1, dosimeter-radiometer DRBP – 03 and scintillation detector based on a plastic scintillator BC-408.

The highest value of the gamma background level was registered around the stele in memory of the heroes of the Patriotic War. The annual effective dose equivalent at this site equal to 0.1313 mSv/y.

For all the studied objects, the estimated lifetime radiation-induced cancer risk was calculated: 1 – 0.056%, 2 – 0.047%, 3 – 0.037%, 4 – 0.037% and 5 – 0.044%, with a maximum allowable value of 0.029%.

Thus, it is shown that the level of gamma background at the studied sites does not exceed the maximum allowable value, but in some cases exceeds the average value of the gamma background for the territory where there are no infrastructure objects. The estimated lifetime radiation-induced cancer risk during prolonged stay at the studied sites (more than 4.8 hours a day) is a multiple of or equal to the maximum allowable values.

Application areas: Environmental protection, Radiological protection, health physics and construction industry.

Cost-effectiveness/value of the work: The project is feasible and low cost to be undertaken by both Universities and research institutes.

Future plans: to continue research in this area, possibly to cover a wide range of technosphere objects and simulate the results to determine the exact contribution of technosphere objects to the background radiation.

Contents

Introduction

The objective of this work is to verify compliance with radiation safety standards in crowded places, in particular, near monuments and the area next to them, by studying the level of gamma background.

To achieve this objective, the following tasks must be performed:

– Carrying out a series of measurements of the gamm-background level in the crowded places with 3 dosimeters: DRG-01T1, DRBP-03 and a dosimeter based on a scintillation detector;

– Processing the received data and obtaining real data on the state of the gamma background level;

– Comparison of experimental data for different dosimeters;

– Summarizing the results of the study.

Chapter 1. Literature review

1.1. The concept of crowded places

In accordance with paragraph 6 of Article 3 of the Federal Law "On Combating Terrorism", a crowded place means the territory of common use of a settlement or urban district, or a specially designated area outside them, or a place of common use in a building, structure, at another facility where, under certain conditions, more than 50 people can be at the same time [2].

The requirements for ensuring radiation safety of the population apply to regulated natural radiation sources: radon isotopes and their radioactive decay products in indoor air, gamma radiation of natural radionuclides contained in building raw materials, materials and products, natural radionuclides in drinking water, mineral fertilizers and agrochemicals, as well as in products manufactured using mineral raw materials and materials containing natural radionuclides.

The degree of radiation safety of the population is characterized by the following values of effective radiation doses from all major natural radiation sources:

- less than 5 mSv/year – acceptable level of population exposure from natural sources of radiation;
- over 5 to 10 mSv/year – population exposure is increased;
- more than 10 mSv/year – population exposure is high [3].

1.2. Assessment of exposure to ionizing radiation on the population

In [4], to assess the dose load on the population of the city, taking into account the recommendations set out in [5], it was proposed to use the following values: the average value of the measured gamma radiation equivalent dose rate (ADR), the average annual effective dose equivalent (AEDE), estimated lifetime radiation-induced cancer risk (ELCR).

The average annual effective dose equivalent of external exposure to gamma radiation is calculated from the measured values of the equivalent dose rate of gamma radiation in the environment using the correction factor DCF = 0.7 recommended by UNSCEAR and OF = 0.2 for external radiation in accordance with the formula (1.1). The results are based on the assumption that the average person spends about 4.8 hours outdoors.

$$\mathrm{AEDE\ (mSv/yr)} = \mathrm{ADR} \cdot \mathrm{T} \cdot \mathrm{DCF} \cdot \mathrm{OF} \cdot 10^{-3} \tag{1.1}$$

where ADR is the average equivalent dose rate, μSv/h;

T – time in one year in hours.

The probability of radiation-induced cancer and the genetic effects of low-background ionizing radiation are used to assess risks. Radiation-induced cancer is associated with the probability of developing the disease throughout life at a given level of exposure [1], which is estimated by the expression:

$$\mathrm{ELCR} = \mathrm{AEDE} \cdot \mathrm{DL} \cdot \mathrm{RF} \tag{1.2}$$

where AEDE – average annual effective dose equivalent from external gamma radiation;

DL – average life expectancy

RF – risk factor.

Average life expectancy is estimated at 70 years. For stochastic effects, the ICRP uses RF as 0.05 for the population, the global acceptable standard is 0.29 10^{-3} [4]. The calculated average annual effective doses to the population were compared with the recommended safe dose limits and the world average values.

Chapter 2. Equipment and measurement technique.

Measurements of the equivalent dose rate of gamma radiation in the environment were carried out with three different dosimetric devices: DRG - 01T1, DRBP - 03 and a dosimeter based on a scintillation detector. The ADA Cosmo MINI laser rangefinder is used to measure distances to objects and determine the location of measurement points.

2.1. Wide-range portable dosimeter of exposure dose rate DRG-01T1.

DRG-01T1 - a dosimeter designed to measure the exposure dose rate at workplaces, in adjacent premises and on the territory of enterprises using radioactive substances and other sources of ionizing radiation, in the sanitary protection zone and the observation zone. [5]

The dosimeter is a portable, compact monoblock device. The body of the dosimeter DRG-01T1 is made of cast metal. The coating of dosimeters is resistant to detergents. The dosimeter operates from an independent power source. The appearance of the dosimeter is shown in Figure 2.1.

Figure 2.1 – Dosimeter DRG-01T1

The principle of operation of the dosimeter is based on the registration of electric current pulses that occur during the passage of gamma quanta through a gas discharge counter. Current pulses are converted by the input stage into voltage pulses with the amplitude necessary for their registration. Pulses are fed through a frequency divider to a four-digit counter. The accumulated information during the measurement cycle on the counter enters the indicator through a decoder, which converts the BCD information of the counter into a seven-segment positional code of the indicator. The measurement time is set by an adjustable reference frequency generator. By changing the measurement time, the input information from the detectors is scaled to the absolute value of the output parameter (mR/h, R/h). The generator provides several frequencies to control the indicator and control the operation of the dosimeter.

Table 2.1 - Technical characteristics of the DRG-01T1 dosimeter

Parameter	**Gas-discharge meter parameter value**	
	in the "Search" mode	**in the "Measure" mode**
Exposure dose rate measurement range:	100,0 μR/h ÷99,99 R/h	10,0 μR/h ÷9,99 μR/h
Limit of permissible basic relative measurement error:	±30%	±15%
Measurement time, no more	2,5 s	25 s
Energy range of gamma radiation	0,05÷3,0 MeV	
Overall dimensions,	175×90×55 mm	
Weight	0,6 Kg	

2.2. Dosimeter - radiometer DRBP-03

The dosimeter-radiometer DRBP-03 is designed to measure the equivalent dose and equivalent dose rate of ionizing photon radiation, as well as the alpha and beta radiation flux density. The operating principle of the dosimeter is based on the conversion of ionizing radiation energy into electrical impulses using gas-discharge Geiger-Muller counters. Structurally, the dosimeter is made in the form of a control panel in a metal case with built-in detectors and a set of remote detection units. The device is equipped with an extension cord and a battery charger. The appearance of the dosimeter is shown in Figure 2.2.

Figure 2.2 – Dosimeter DRBP-03

The dosimeter DRBP-03 is used for operational dosimetry monitoring of the radiation situation; studies of radiation anomalies; compiling radiation maps of the area; detection of contamination of clothes, walls, floors, etc. [6].

Table 2.2 - Technical characteristics of the dosimeter DRBP-03

Characteristic	Value
Energy range of registered ionizing photon radiation, MeV	0,05–3,0
Energy range of detected α-radiation, MeV	Pu-239
Energy range of detected β-radiation, MeV	0,15–3,5
Measuring range of equivalent dose rate, μSv/h	$0{,}10–3\times10^{6}$
Measuring range of equivalent dose, mSv	$0{,}01–10^{4}$
Measurement range of particle flux density, $s^{-1}cm^{-2}$	0,10–700
Basic relative measurement error, %	±15
Device operating conditions	-20°C …+50°C, 95 % humidity at 35°C
Weight of the complete set, kg	3

2.3. Dosimeter based on scintillation detector

The use of scintillation detectors as receivers of gamma radiation has a number of advantages. Firstly, gamma scintillation counters have a high efficiency of gamma radiation detection from natural radioactive elements. This is due to the fact that flashes that occur in the scintillator when gamma rays are absorbed in it can be collected from its entire thickness, therefore, with sufficient dimensions and density of the scintillator, combined with its high transparency for its own radiation and good optical qualities of the photovoltaic system the average detection efficiency of gamma radiation from a radium source by a scintillation detector can reach 70-80% [7].

Secondly, scintillation counters, being proportional counters, make it possible to estimate the energies of registered gamma quanta. So, for example, in the emission spectrum of the elements of the thorium series there is an intense line with a gamma-quantum energy of 2.62 MeV [8].

Thirdly, high-resolution scintillation counters can be used to create gamma radiometers designed to measure a wide range of detected activity. [9].

There are several types of scintillators on the basis of which a measuring device can be designed. The main ones are BGO scintillator, CsI scintillator, BC-408 plastic scintillator.

The main advantage of the BGO scintillator is its short emission length. This means that for the same volume, a BGO crystal can achieve a much higher photon detection efficiency than either NaI(Tl) or CsI(Tl) crystals. The luminescence spectrum of the BGO scintillator is located slightly to the right, in the region of 480 nm, than the sensitivity peak of the bis-alkali photomultiplier tube photocathode. The refractive index of the BGO crystal ($n = 2.15$) is significantly higher than the refractive index of the photomultiplier tube glass. Both of these factors lead to a decrease in the number of photoelectrons. Another technical difficulty is the formation of air bubbles inside the volume of the crystal during its manufacture. Scattering occurs on the bubbles, which leads to a loss of light flux. The advantages of the BGO scintillator are its good mechanical properties during processing and non-hygroscopicity [10].

The main advantage of CsI scintillators is that CsI(Tl) single crystal is practically non-hygroscopic. Small leaks will not destroy the single crystal, as is the case with the NaI (Tl) scintillator, however, for long-term use, the CsI (Tl) crystal must be isolated in a dry environment. The plastic nature of cesium iodide makes it easy to process. The emission spectrum of the CsI(Tl) scintillator has a maximum at 550 nm and is in poor agreement with the spectral response of a standard bis-alkali photomultiplier tube photocathode. For a CsI(Tl) scintillator, a photocathode with a multilayer photomultiplier is more suitable. [11].

Plastic scintillators are usually two or three component mixtures of polymer-based organic scintillation molecules. Primary fluorescence centers are excited due to the loss of energy by the incident particles, and when these excited states decay, light is emitted in the ultraviolet wavelength range. The absorption length of this ultraviolet is very short because the fluorescence centers are opaque to their own emitted light; so the light is extracted by adding a second component to the scintillator which absorbs the initially emitted light and re-emits it isotropically at long wavelengths. They have transparency and the ability to provide high detection efficiency due to their large volume and almost any configuration at relatively low cost and high temperature stability of the luminous flux, as well as ease of processing. The main disadvantage of plastic scintillators is their lower energy resolution compared to inorganic scintillators. The maximum dimensions of plastic scintillators are limited by the attenuation length of their own radiation, up to 5 m. All plastic scintillators are sensitive to x-rays, gamma rays, fast neutrons and charged particles [12].

One of the main characteristics of scintillation detectors is the decay time. This is the time during which the energy absorbed in the scintillator and excited by the passage of a fast charged particle is converted into light radiation. For inorganic scintillators, the decay time ranges from hundreds of nanoseconds to tens of microseconds. Organic scintillators (plastic and liquid) light up within nanoseconds.

The dosimeter used in this work is based on a scintillation detector based on a BC-408 plastic scintillator. Pulses from the detector are registered by a counting system based on the Arduino platform, displayed on the screen and recorded in the internal memory of the device. The device also includes a stabilized high voltage source with a voltage divider to power the PMT and a battery.

The appearance of the dosimeter is shown in Figure 2.3.

Figure 2.3 – Dosimeter based on a scintillation detector

2.4. Conclusions by section

When using a detector of the DRG-01T1 type to measure background values of the dose rate, the value of the relative error can grow up to 60%, which will adversely affect the measurement results.

Summarizing the characteristics of scintillation detectors and considering economic efficiency, reliability and best overall properties, the plastic scintillator BC-408 based on polyvinyltoluene was chosen from their set of scintillation detectors.

To draw a conclusion about the efficiency of measurements of detectors of the DRG-01T1 type and a plastic scintillator BC-408, the third device, the DRBP-03 dosimeter-radiometer, was chosen.

Chapter 3. Experimental results and their analysis

2.1. Experiment planning

Radiation reconnaissance of objects and territories in order to determine the effect of the level of gamma radiation on the population of the city of Tomsk was carried out for the following places: Stele in memory of the heroes of the Patriotic War of 1812 (Figure 3.1), the area near the Drama Theater and the site near the decorative construction "Khachkar" (fig. 3.2), a stele in memory of the fallen in local wars (fig. 3.3) and a monument to the fallen in the battles for the Motherland (fig. 3.4). In each zone, control areas were selected, in each area, control measurement points were selected, shown in the corresponding figures by arrows and numbers. The measurements at each control point were carried out using a wide-range dosimeter DRG-01T1, a dosimeter-radiometer DRBP-03 and a scintillation detector based on a plastic scintillator BC-408.

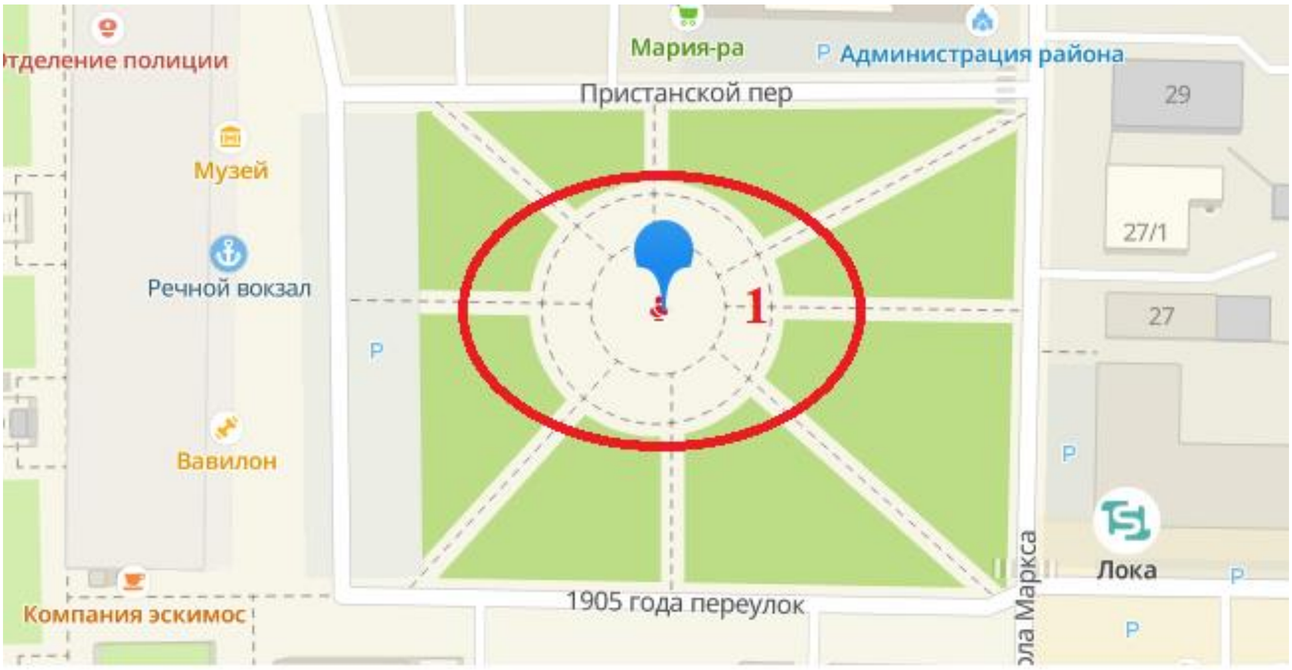

Figure 3.1 – Stele in memory of the heroes of the Patriotic War of 1812

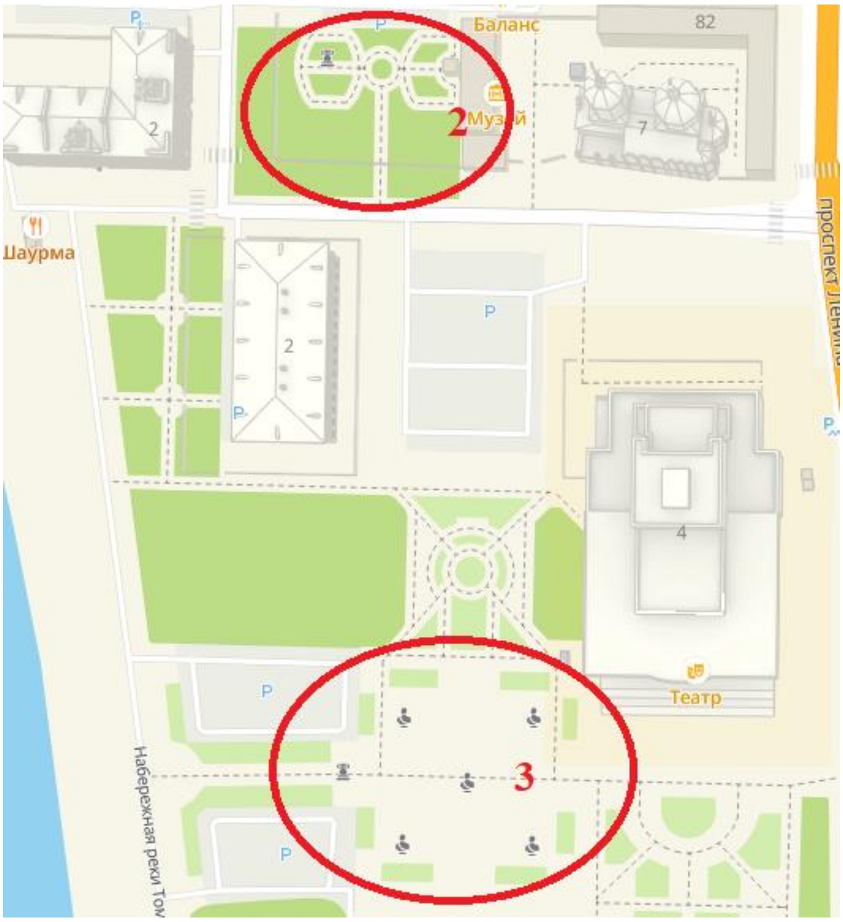

Figure 3.2 – Site near the decorative construction "Khachkar" (2) and the area near the Drama Theater (3)

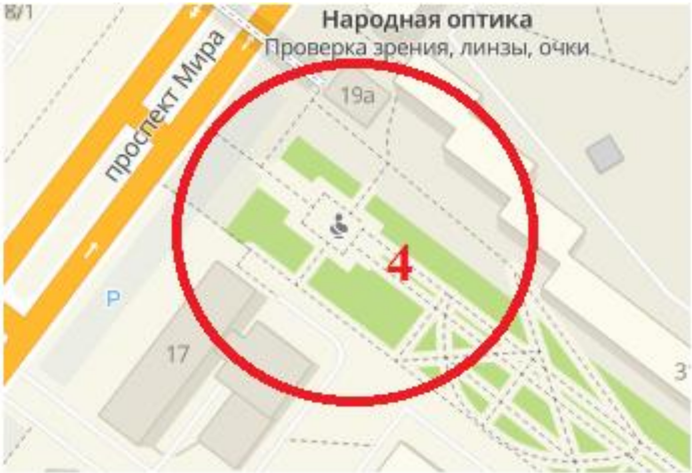

Figure 3.3 – Stele of memory of the fallen in local wars

Figure 3.4 - Monument to the fallen in the battles for the Motherland

2.2. Assessment of the radiation situation

2.2.1. Stele in memory of the heroes of the Patriotic War of 1812

The control points were located at various distances from the monument (starting from a distance of 5 cm) and were distributed over the area lined with granite around it. At each of the 10 presented points (Fig. 3.5), a series of measurements was carried out. The measurement results are shown in the graph in fig. 3.6.

Figure 3.5 – Place of measurements

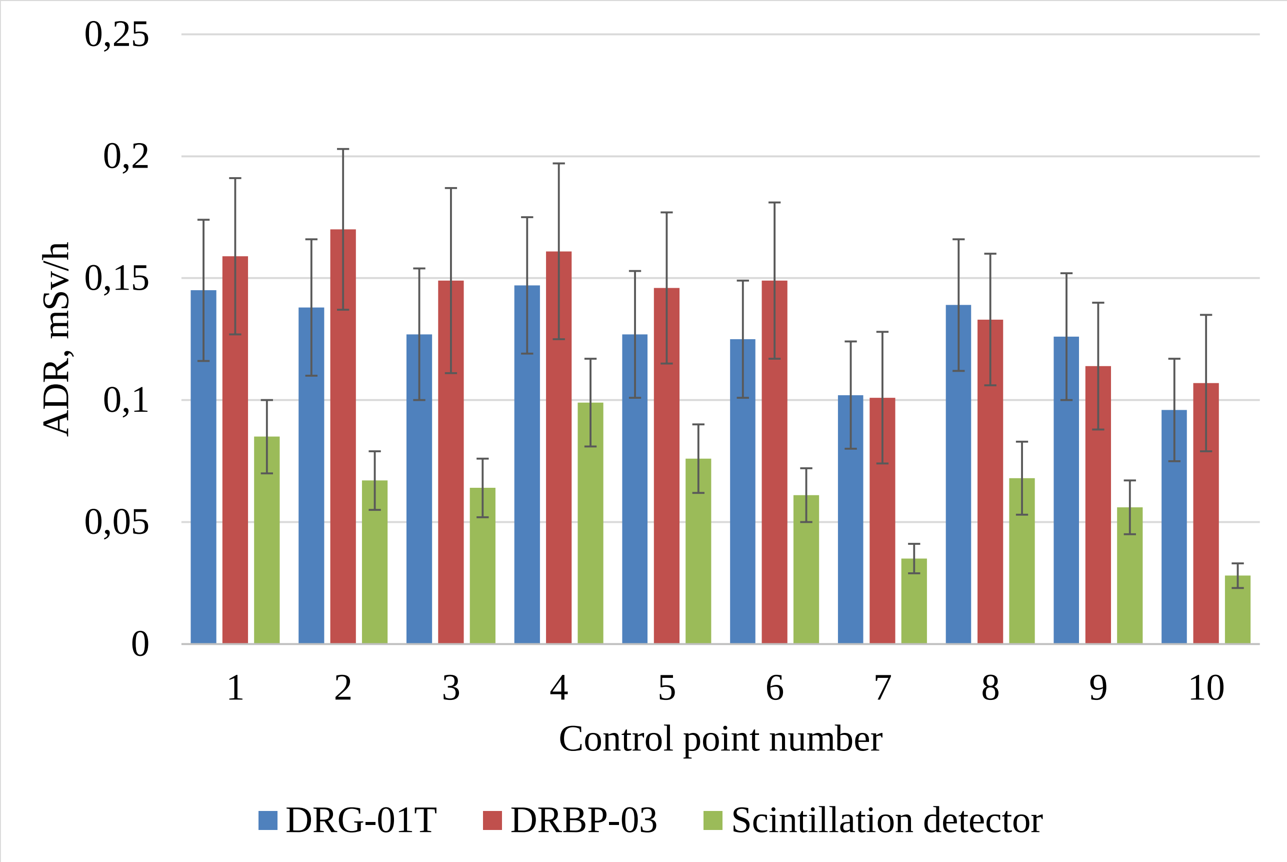

Figure 3.6 – Average value of the measured ambient equivalent dose rate of gamma radiation

Since the values of the equivalent dose rate for the three dosimeters are within the margin of error, an average value can be found for each point under study.

Table 3.1 – Average equivalent dose rate

point №	1	2	3	4	5	6	7	8	9	10
ADR, µSv/h	0,13	0,125	0,113	0,136	0,116	0,111	0,079	0,113	0,077	0,11

From Table 3.1, the following conclusion can be drawn: the values of the average equivalent dose rate in different points of the site vary from 0.077 µSv/h to 0.136 µSv/h. The average value of average equivalent dose rate on this site in total is 0.11 µSv/h. The basic sanitary rules for ensuring radiation safety [25] set the maximum allowable value ша equivalent dose rate equal to 0.3 µSv/h.

On fig. 3.7 shows a comparison of the measurement results, the gamma background and the maximum allowable value at each of the points on the site.

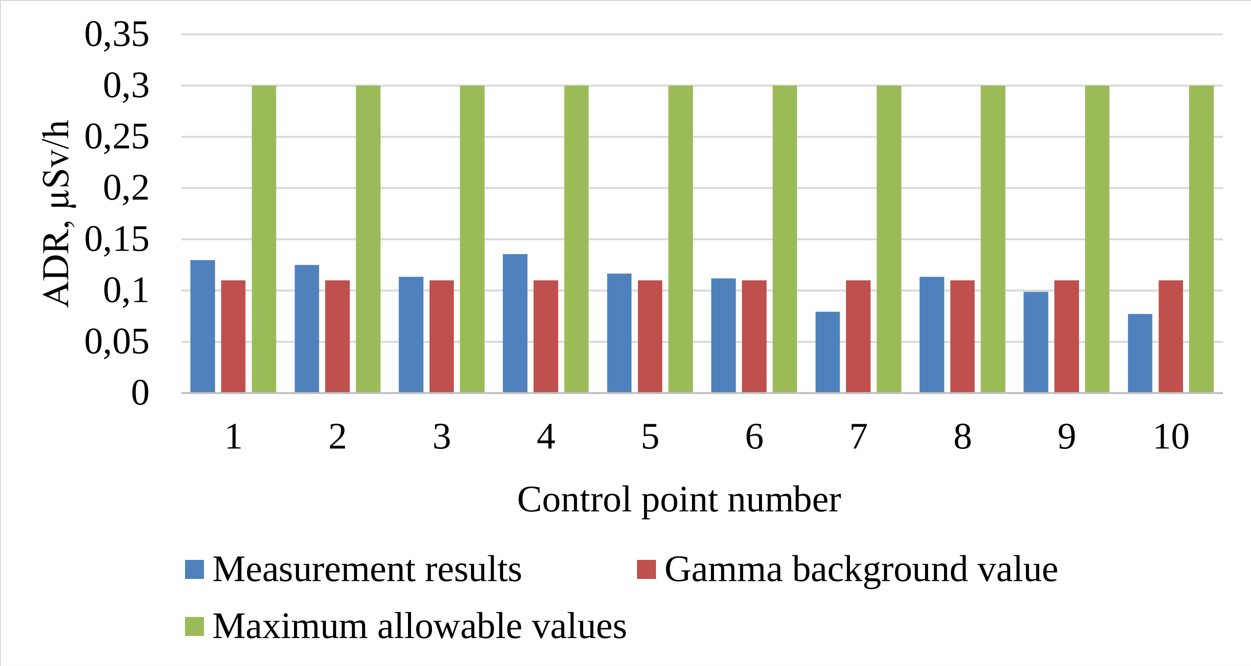

Figure 3.7 – Comparison of the measurement results, the gamma background and the maximum allowable value

Using formulas (1.1, 1.2), the following values were calculated: average annual effective dose equivalent and estimated lifetime radiation-induced cancer risk. Taking into account that all the readings of the detectors are within the limits of the statistical error, the average value of the readings of all three detectors can be considered reliable.

Table 3.2 – Calculated AEDE and ELCR

point №	1	2	3	4	5	6	7	8	9	10
AEDE, mSv/y	0,159	0,153	0,139	0,166	0,143	0,137	0,097	0,139	0,121	0,094
ELCR, %	0,056	0,054	0,049	0,058	0,05	0,048	0,034	0,049	0,033	0,047

From Table 3.2, the following conclusion can be drawn: the values of the average annual effective dose equivalent in different points of the site vary from 0.094 µSv/y to 0.166 µSv/y, the values of the estimated lifetime radiation-induced cancer risk in different points of the site vary from 0.033% to 0.058%. The average values of average equivalent dose rate and estimated lifetime radiation-induced cancer risk on this site in total is 0.135 μSv/y and 0.047% respectively, with a maximum recommended value of the probability of cancer risk of 0.029%.

2.2.2. Decorative construction "Khachkar"

Figure 3.8 shows the measurement scheme for the second area. Control points 1, 2, 3, 4, 5, 6, 7 they provide data on the average dose received by the population when visiting a decorative structure and a park nearby. Control points 8, 9, 10 allow you to determine the dose rate outside the park next to the parking lot and the wall of the house lined with granite.

Figure 3.8 – Scheme of measurement near the decorative construction "Khachkar"

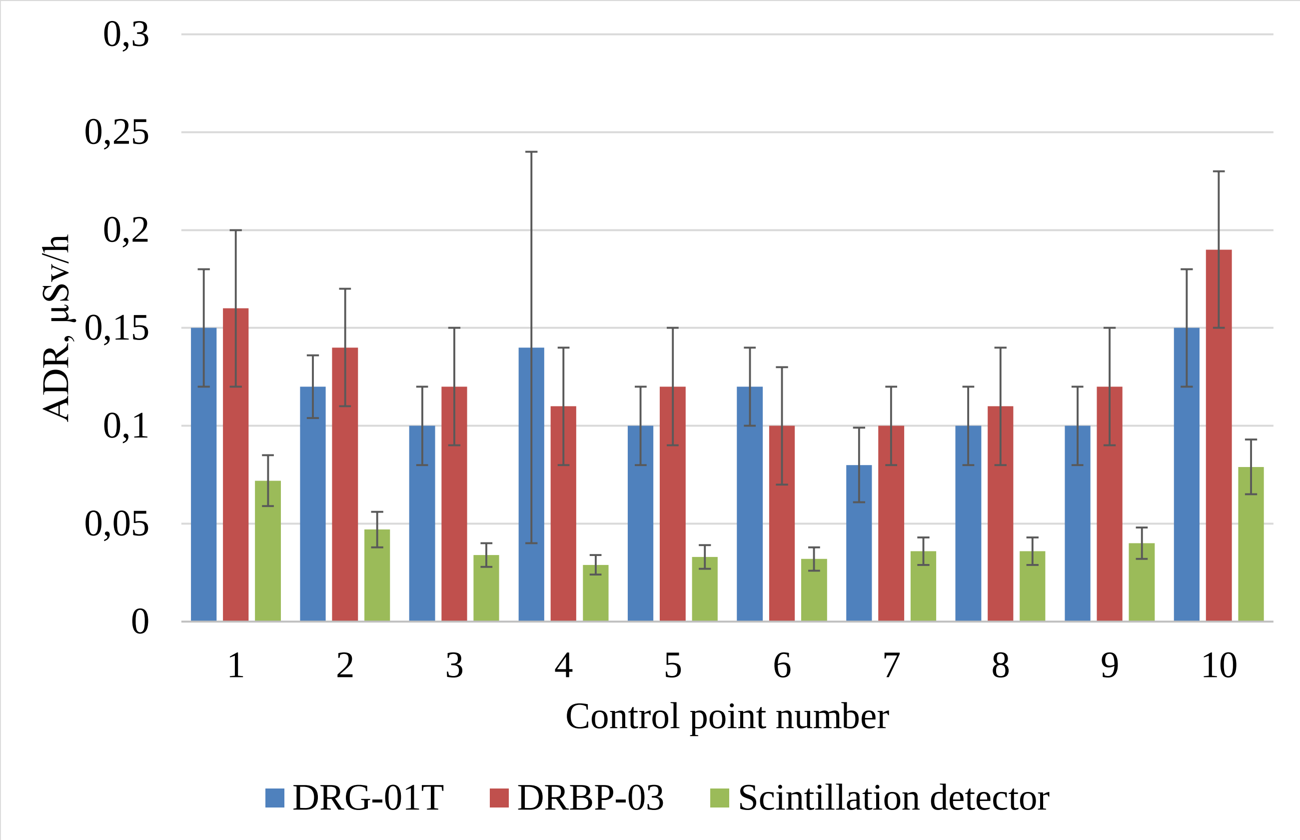

Figure 3.9 – Average value of the measured ambient equivalent dose rate of gamma radiation

Table 3.3 – Average equivalent dose rate

point №	1	2	3	4	5	6	7	8	9	10
ADR, µSv/h	0,127	0,102	0,085	0,093	0,084	0,084	0,072	0,082	0,087	0,14

From Table 3.3, the following conclusion can be drawn: the values of the average equivalent dose rate in different points of the site vary from 0.072 µSv/h to 0.127 µSv/h. The average value of average equivalent dose rate on this site in total is 0.0956 µSv/h. The basic sanitary rules for ensuring radiation safety [25] set the maximum allowable value ща equivalent dose rate equal to 0.3 µSv/h.

On fig. 3.10 shows a comparison of the measurement results, the gamma background and the maximum allowable value at each of the points on the site.

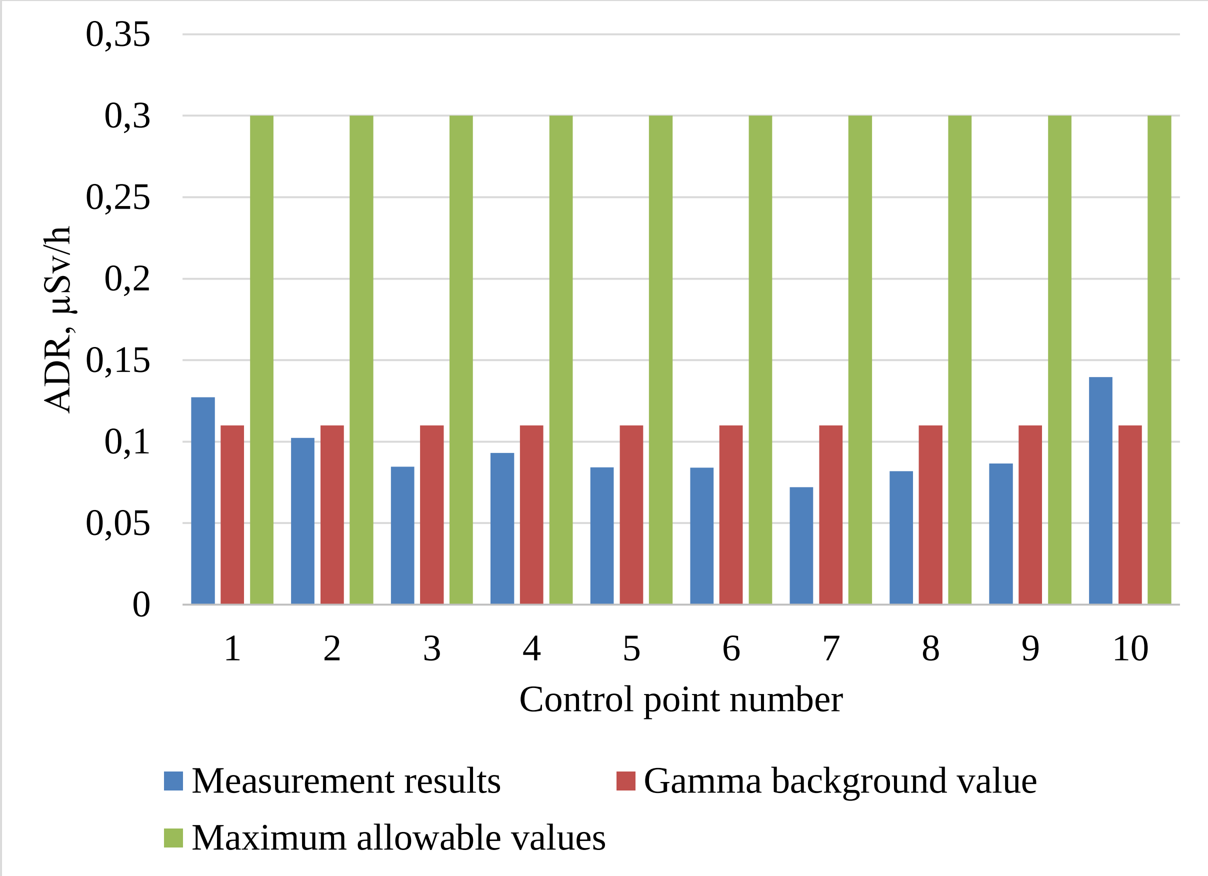

Figure 3.10 – Comparison of the measurement results, the gamma background and the maximum allowable value

Table 3.4 – Calculated AEDE and ELCR

point №	1	2	3	4	5	6	7	8	9	10
AEDE, μSv/y	0,156	0,126	0,104	0,114	0,103	0,103	0,088	0,101	0,106	0,171
ELCR, %	0,055	0,044	0,036	0,04	0,036	0,036	0,031	0,035	0,037	0,059

From Table 3.4, the following conclusion can be drawn: the values of the average annual effective dose equivalent in different points of the site vary from 0.088 μSv/y to 0.171 μSv/y, the values of the estimated lifetime radiation-induced cancer risk in different points of the site vary from 0.031% to 0.059%. The average values of average equivalent dose rate and estimated lifetime radiation-induced cancer risk on this site in total is 0.117 μSv/y and 0.041% respectively, with a maximum recommended value of the probability of cancer risk of 0.029%.

2.2.3. The area near the Drama Theater

Figure 3.11 shows the location of control points in the area near the Drama Theater (site 3).

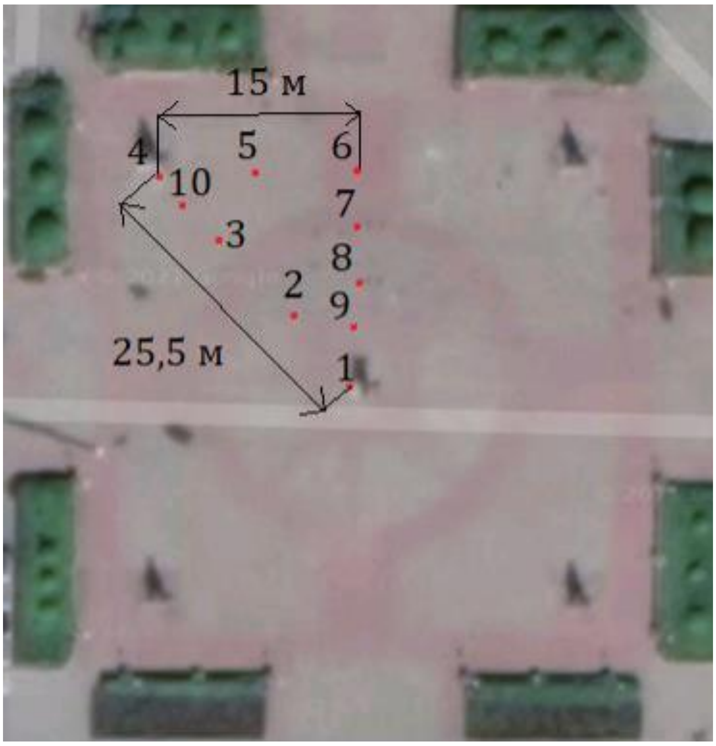

Figure 3.11 – Control points on the area near the Drama Theater

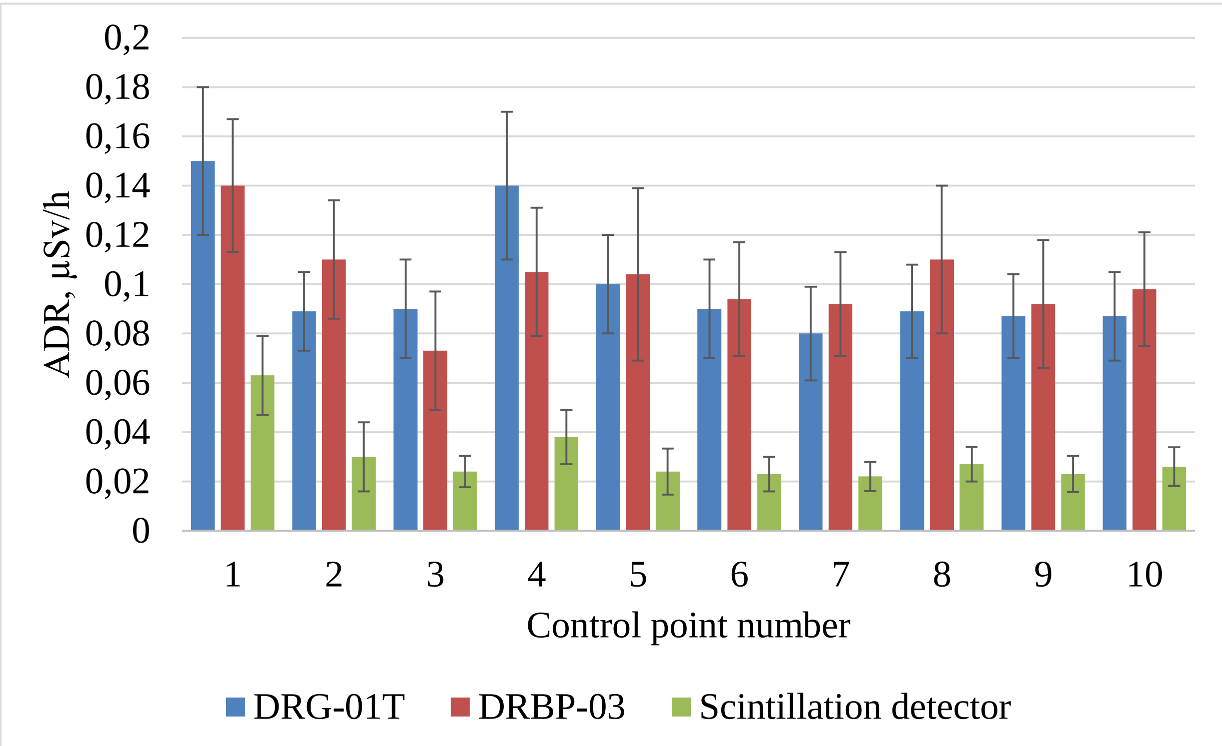

Figure 3.12 – Average value of the measured ambient equivalent dose rate of gamma radiation

Table 3.5 – Average equivalent dose rate

point №	1	2	3	4	5	6	7	8	9	10
ADR, µSv/h	0,118	0,076	0,062	0,094	0,076	0,069	0,065	0,075	0,067	0,07

From Table 3.5, the following conclusion can be drawn: the values of the average equivalent dose rate in different points of the site vary from 0.062 µSv/h to 0.118 µSv/h. The average value of average equivalent dose rate on this site in total is 0.077 µSv/h. The basic sanitary rules for ensuring radiation safety [25] set the maximum allowable value ща equivalent dose rate equal to 0.3 µSv/h.

On fig. 3.13 shows a comparison of the measurement results, the gamma background and the maximum allowable value at each of the points on the site.

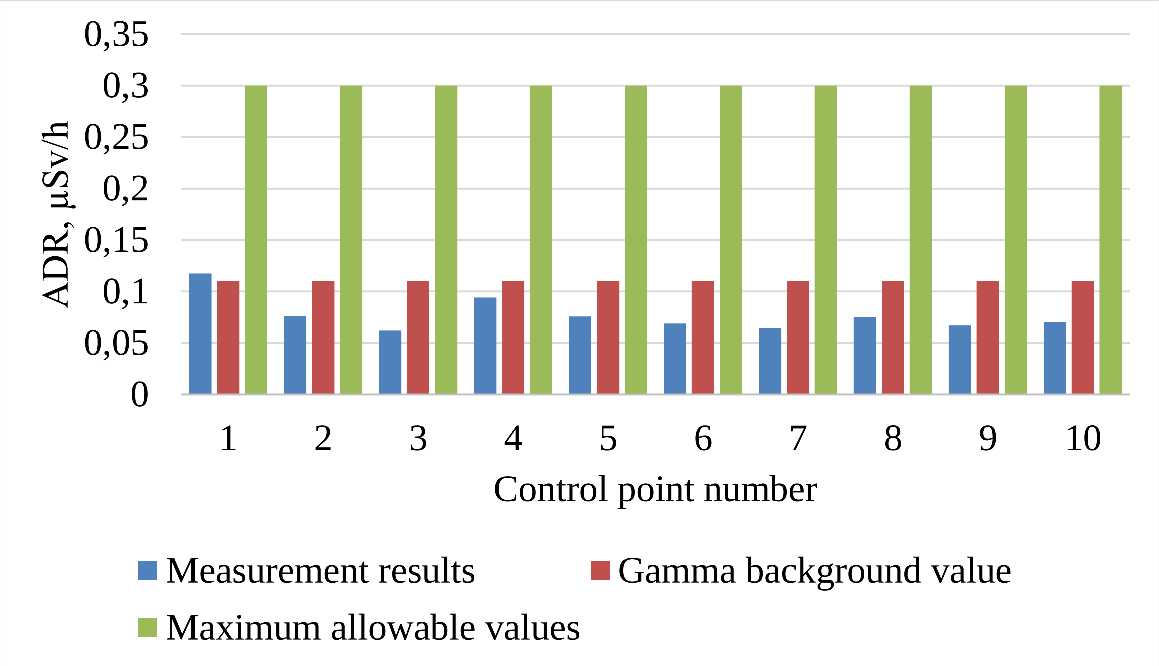

Figure 3.13 – Comparison of the measurement results, the gamma background and the maximum allowable value

Table 3.6 – Calculated AEDE and ELCR

point №	1	2	3	4	5	6	7	8	9	10
AEDE, µSv/y	0,144	0,094	0,076	0,116	0,093	0,085	0,079	0,092	0,083	0,086
ELCR, %	0,051	0,033	0,027	0,04	0,033	0,03	0,028	0,032	0,029	0,03

From Table 3.6, the following conclusion can be drawn: the values of the average annual effective dose equivalent in different points of the site vary from 0.076 μSv/y to 0.144 μSv/y, the values of the estimated lifetime radiation-induced cancer risk in different points of the site vary from 0.027% to 0.051%. The average values of average equivalent dose rate and estimated lifetime radiation-induced cancer risk on this site in total is 0.095 μSv/y and 0.033% respectively, with a maximum recommended value of the probability of cancer risk of 0.029%.

2.2.4. Stele of memory of the fallen in local wars

Figure 3.14 shows the location of control points on the site № 4.

Figure 3.14 - Control points on the site around stele of memory of the fallen in local wars

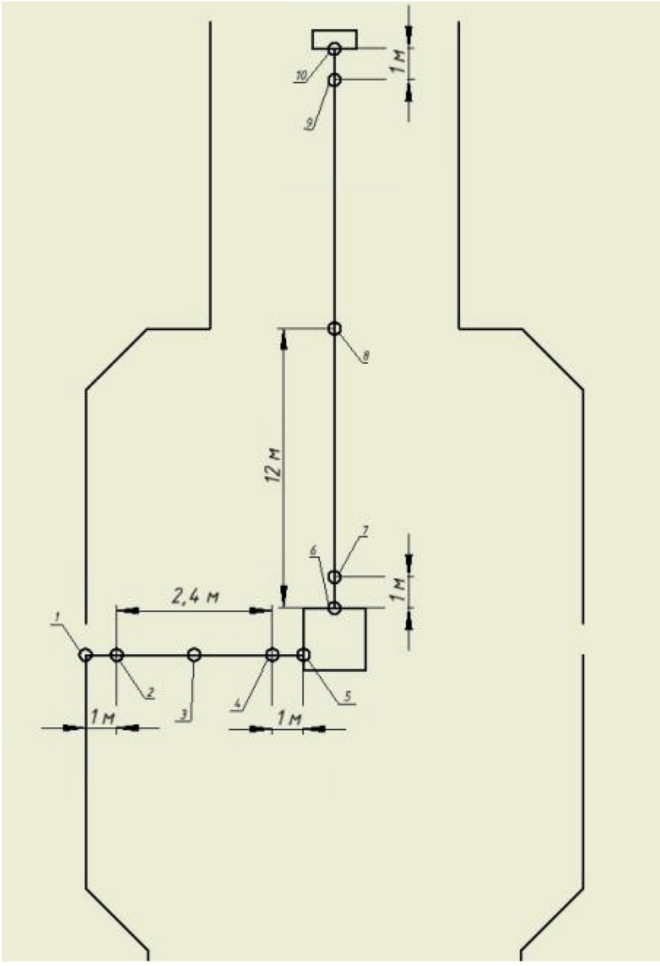

Figure 3.15 - Dose scheme for site 4

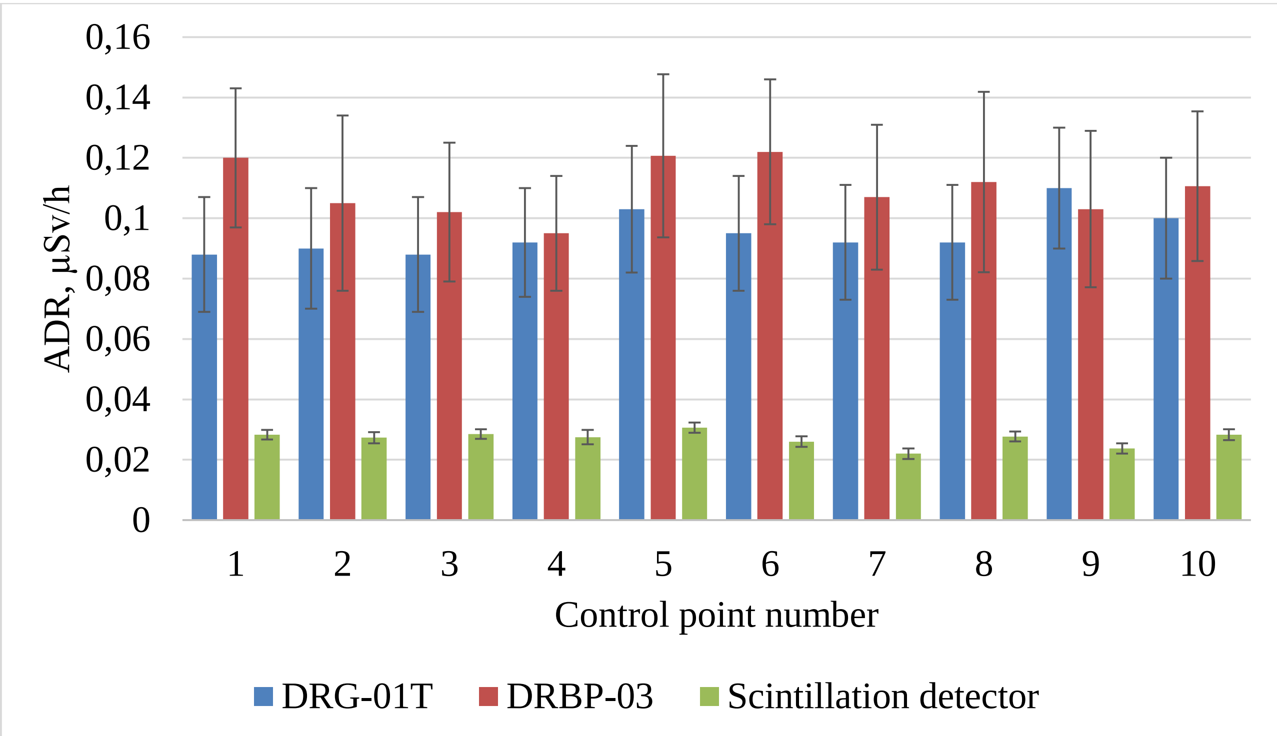

Figure 3.16 – Average value of the measured ambient equivalent dose rate of gamma radiation

Table 3.7 – Average equivalent dose rate

point №	1	2	3	4	5	6	7	8	9	10
ADR, μSv/h	0,079	0,074	0,073	0,072	0,085	0,081	0,74	0,077	0,079	0,08

From Table 3.7, the following conclusion can be drawn: the values of the average equivalent dose rate in different points of the site vary from 0.072 μSv/h to 0.085 μSv/h. The average value of average equivalent dose rate on this site in total is 0.077 μSv/h. The basic sanitary rules for ensuring radiation safety [25] set the maximum allowable value ща equivalent dose rate equal to 0.3 μSv/h.

On fig. 3.17 shows a comparison of the measurement results, the gamma background and the maximum allowable value at each of the points on the site.

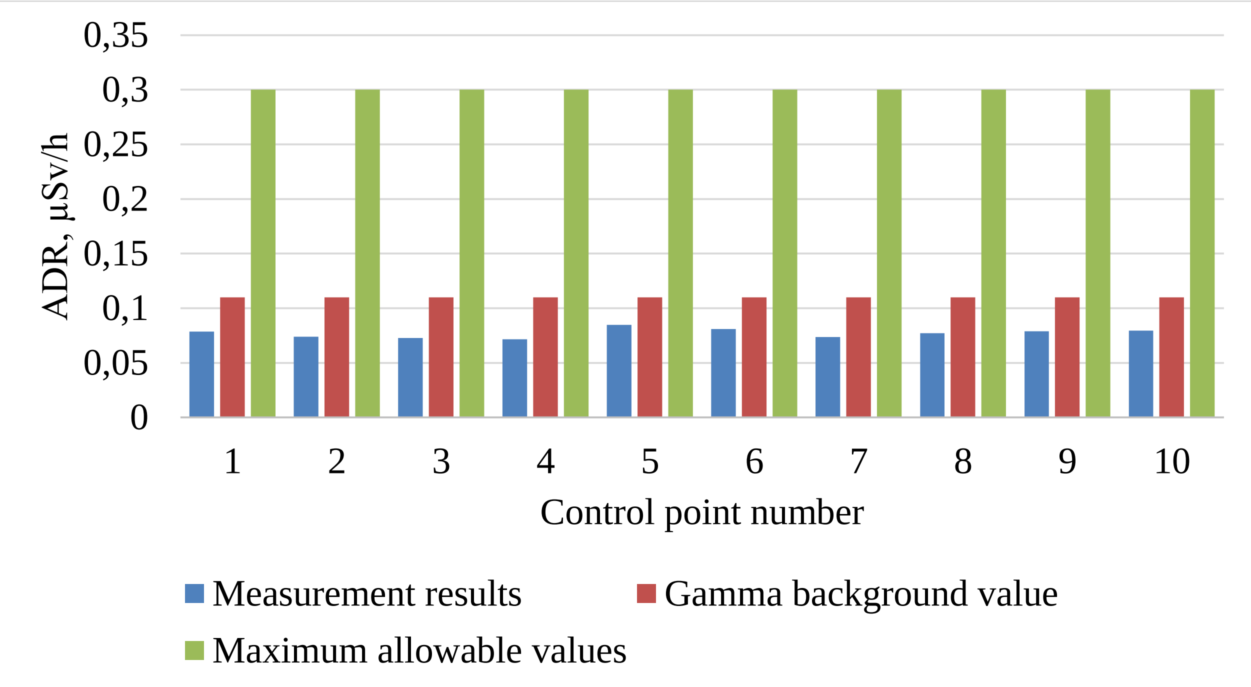

Figure 3.17 – Comparison of the measurement results, the gamma background and the maximum allowable value

Table 3.8 – Calculated AEDE and ELCR

point №	1	2	3	4	5	6	7	8	9	10
AEDE, μSv/y	0,097	0,091	0,089	0,088	0,104	0,099	0,09	0,095	0,097	0,098
ELCR, %	0,034	0,032	0,031	0,031	0,036	0,035	0,032	0,033	0,034	0,034

From Table 3.8, the following conclusion can be drawn: the values of the average annual effective dose equivalent in different points of the site vary from 0.088 μSv/y to 0.104 μSv/y, the values of the estimated lifetime radiation-induced cancer risk in different points of the site vary from 0.031% to 0.036%. The average values of average equivalent dose rate and estimated lifetime radiation-induced cancer risk on this site in total is 0.095 μSv/y and 0.033% respectively, with a maximum recommended value of the probability of cancer risk of 0.029%.

2.2.5. Monument to the fallen in the battles for the Motherland

Figure 3.18 shows the location of control points on the site № 5.

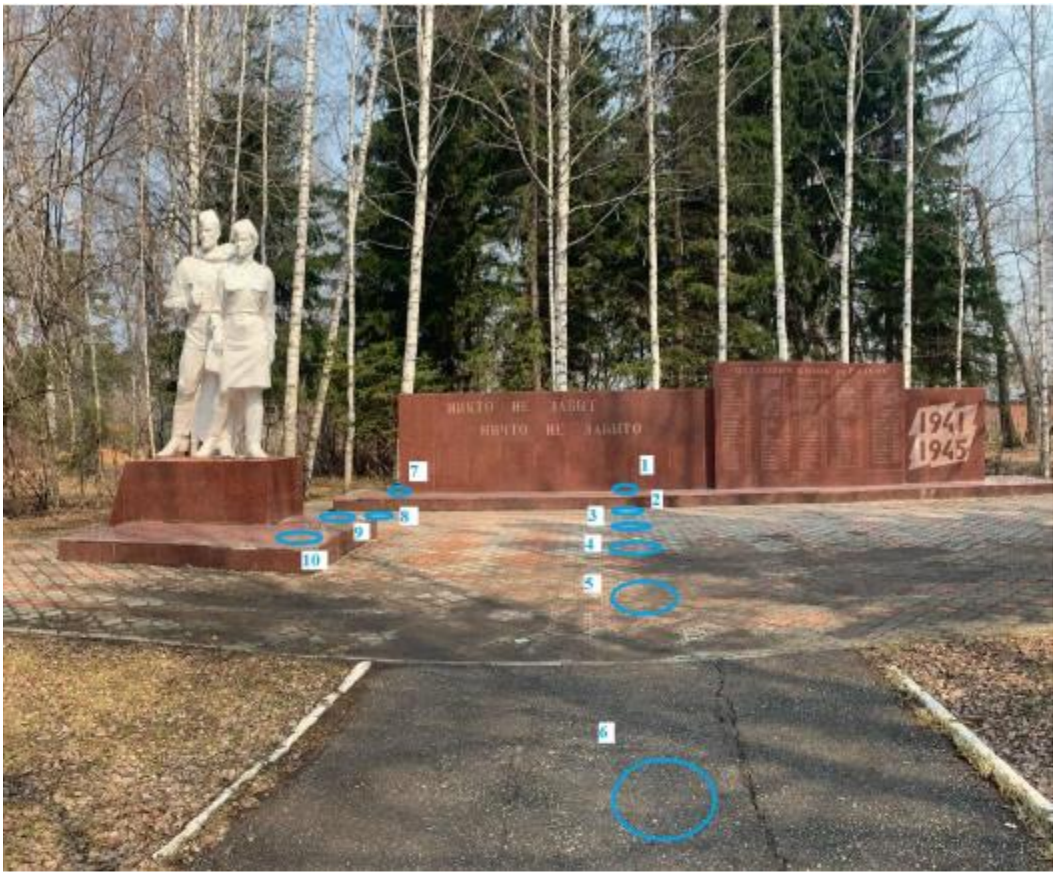

Figure 3.18 – Control points on the site close to monument to the fallen in the battles for the Motherland

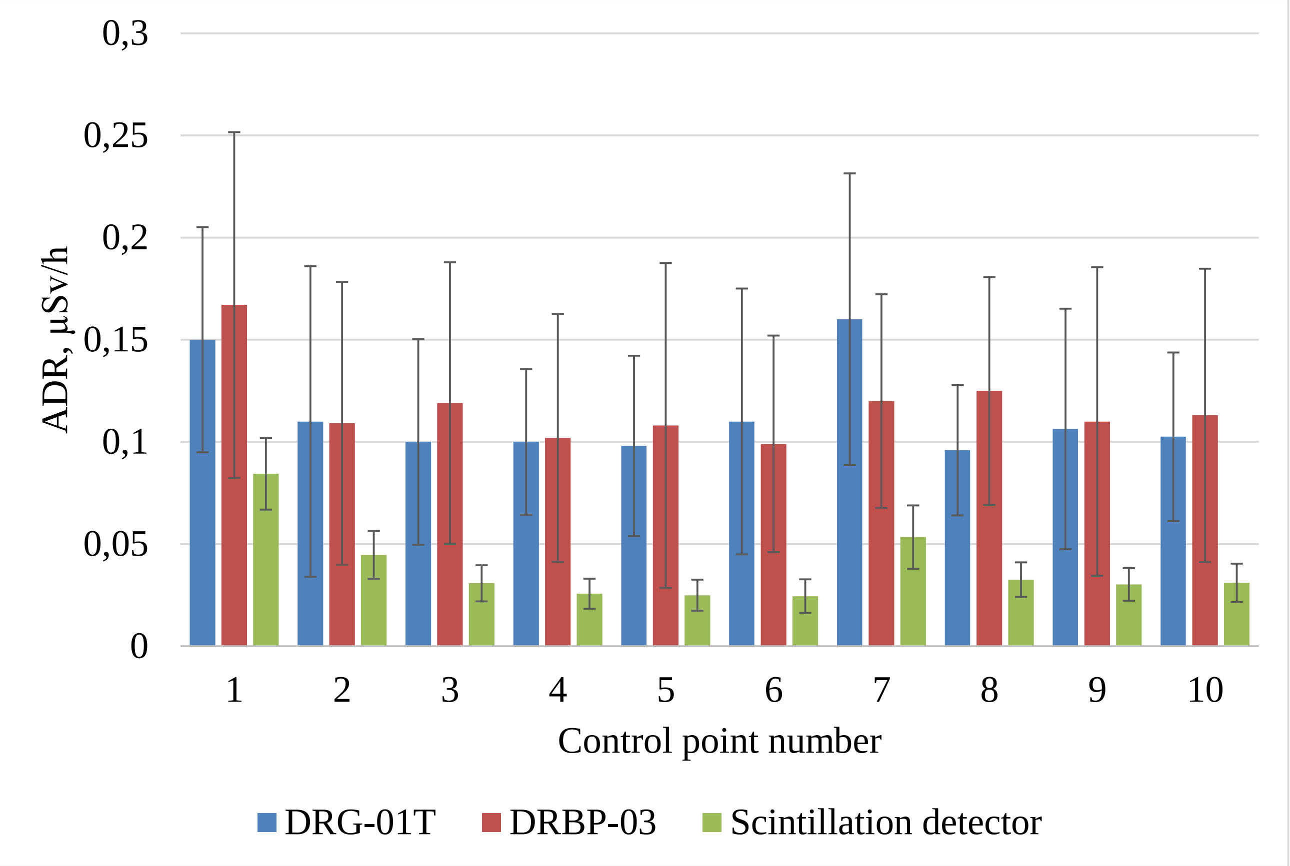

Figure 3.19 – Average value of the measured ambient equivalent dose rate of gamma radiation

Table 3.9 – Average equivalent dose rate

point №	1	2	3	4	5	6	7	8	9	10
ADR, µSv/h	0,13	0,088	0,083	0,076	0,077	0,078	0,011	0,085	0,082	0,082

From Table 3.9, the following conclusion can be drawn: the values of the average equivalent dose rate in different points of the site vary from 0.076 µSv/h to 0.13 µSv/h. The average value of average equivalent dose rate on this site in total is 0.09 µSv/h. The basic sanitary rules for ensuring radiation safety [25] set the maximum allowable value ща equivalent dose rate equal to 0.3 µSv/h.

On fig. 3.20 shows a comparison of the measurement results, the gamma background and the maximum allowable value at each of the points on the site.

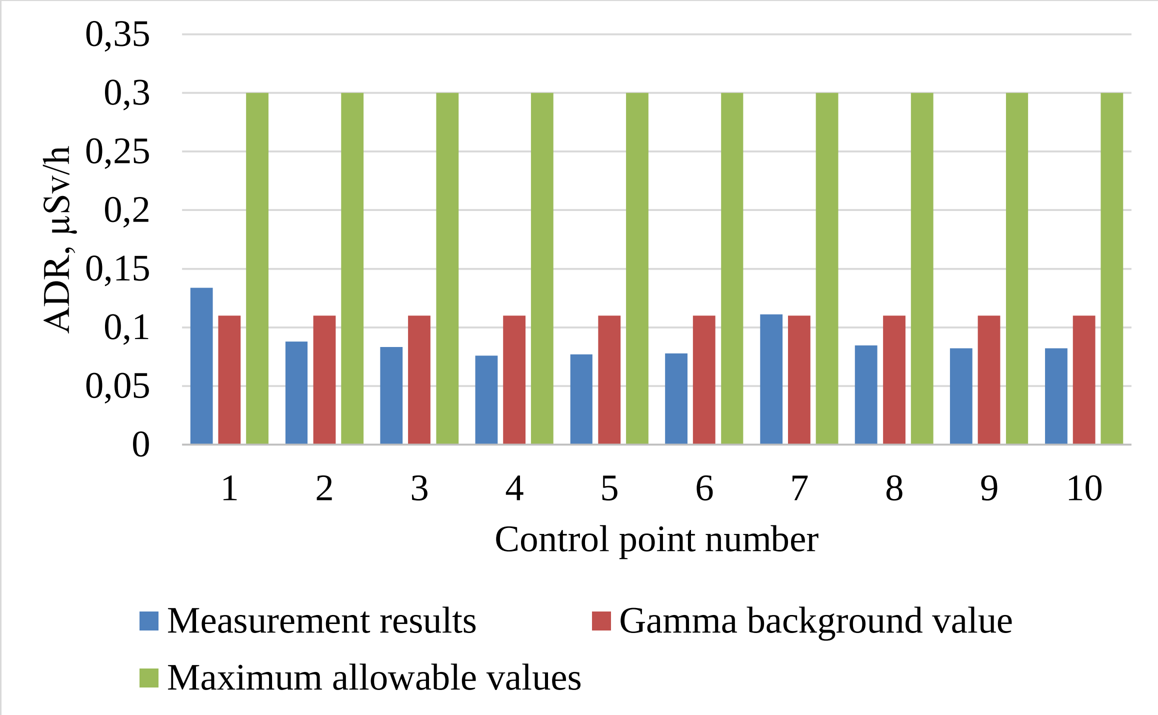

Figure 3.20 – Comparison of the measurement results, the gamma background and the maximum allowable value

Table 3.10 – Calculated AEDE and ELCR

point №	1	2	3	4	5	6	7	8	9	10
AEDE, μSv/y	0,164	0,108	0,102	0,093	0,094	0,095	0,136	0,104	0,101	0,101
ELCR, %	0,057	0,038	0,036	0,033	0,033	0,033	0,048	0,036	0,035	0,035

From Table 3.10, the following conclusion can be drawn: the values of the average annual effective dose equivalent in different points of the site vary from 0.093 μSv/y to 0.164 μSv/y, the values of the estimated lifetime radiation-induced cancer risk in different points of the site vary from 0.033% to 0.057%. The average values of average equivalent dose rate and estimated lifetime radiation-induced cancer risk on this site in total is 0.11 μSv/y and 0.038% respectively, with a maximum recommended value of the probability of cancer risk of 0.029%.

Chapter 4. Financial management

4.1. Potential consumers of research results

The purpose of the project work - to investigate gamma background in different atmospheric objects with potentially high radiation hazard. These facilities have people all year round who can receive high doses of radiation, in turn, these doses increase the risk of developing cancer.

In order to find out in which direction to conduct research, a consumer analysis was carried out. Various research institutes and operational radiological services may show interest in the project.

Table 4.1 – Project stakeholders

Project stakeholders	Stakeholder expectations
Research institutes	Obtaining data on the operation of several types of dosimeters in the field and research methods for other cities
Operational radiological services	Obtaining up-to-date information about the radiological situation around several socially significant objects of the technosphere

Table 4.2 – Purpose and results of the project

Objectives of the project:	The goal is to radiation survey area to determine the effect level of gamma radiation on the population of the city of Tomsk.
Expected results of the project:	1. Carrying out a series of measurements using dosimeters of different types 2. Comparison of the experimental results for different detectors, conclusions about the effectiveness of their work and generalization of the research results.
Acceptance criteria of the project result:	1. Correctness of data array processing 2. Availability of graphs with their description and analysis.
Requirements for the project result:	1. The project must be completed by May 31, 2021. 2. The results obtained must meet the criteria for the acceptance of the project result. 3. The presence of a conclusion about the radiological situation in the central part of the city of Tomsk

Project constraints and assumptions:

1. Funding source: government funding.
2. Project completion date: until 31.05.2021.
3. Time limit for TPU employees.

4.2. Analysis of competitive technical solutions

To analyze competitive technical solutions, experimental measurements were taken with detectors. The position of the development and competitors is assessed for each indicator by an expert way on a five-point scale, where 1 is the weakest position, and 5 is the strongest. The weights of the indicators, determined by expert, should add up to one.

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

$$K = \Sigma B_i \cdot Б_i \qquad (4.1)$$

where K – competitiveness of a scientific development or a competitor;

B_i – indicator weight (in fractions of a unit);

$Б_i$ – weighted average of the i-th indicator;

$Б_{Ki}$ – detector measurements.

Table 4.3 – Scorecard for comparing competitive technical solutions (developments)

Criteria for evaluation	**Criterion weight**	**Points**	**Competitiveness**	
		$Б_{K1}$	$K_{ф}$	$K_{к1}$
Technical criteria for assessing resource efficiency				
1. Reliability of the received data	0,3	4	1,2	1,2
2. No influence of atmospheric conditions on the experiment	0,15	3	0,75	0,45
3. Experiment safety	0,1	3	0,4	0,3
4. Ease of experimenting	0,12	4	0,6	0,48
5. Time of data production	0,1	3	0,3	0,3
6. Availability of expensive equipment	0,05	3	0,25	0,15
Economic criteria for assessing efficiency				
1. Funding for scientific development	0,05	2	0,25	0,1
2. Cost of materials	0,1	2	0,5	0,2
3. Competitiveness	0,03	4	0,12	0,12
Total	1	40	4,37	3,3

During the analysis of competitive technical solutions, a table was compiled (a scorecard for comparing competitive technical solutions).

4.3. SWOT analysis

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

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

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

Table 4.4 – SWOT anlysis

	Strengths of the research project: −S1. Reliability of the received data; −S2. The importance of measurements for the life and health of citizens; −S3. The lack of similar studies; –S4. Security of conducting research.	Weaknesses of the research project: − W1. Lack of funding; − W2. Long term for processing results; −W3. Limited human resources make it impossible to survey vast territories.
Capabilities: – C1. Using the innovative infrastructure of TPU. – C2. The novelty of the research will lead to the emergence of stakeholders	Results of the analysis of the interactive matrix of the project fields "Strengths and Capabilities": 1. Growth in demand for this type of research due to the spread among various organizations and universities. 2. Priority to this research in comparison with competitors due to the implementation of proper reliability and safety	Results of the analysis of the interactive matrix of the project fields "Weaknesses and Capabilities": 1. Lack of a large number of orders for research. 2. Improvement of γ-detectors will lead to a decrease in the measurement error
Threats: − T1. High competition due to modernization of other devices; − T2. Lack of funding from both the university and third-party enterprises	Results of the analysis of the interactive matrix of the project fields "Strengths and Threats": 1. High reliability coupled with low data cost significantly increases competitiveness; 2. Advantage over competitors due to the novelty of the idea.	Results of the analysis of the interactive matrix of the project fields " Weaknesses and Threats": 1. Research stagnation due to lack of funding; 2. A decrease in the cost of γ-detectors will allow the purchase of an additional number of detectors to expand the area of dose rate measurement, which will lead to an increase in demand for this technique.

To identify the degree of need for strategic changes, an interactive matrix was built, presented in Table 4.5.

Table 4.5 – Interactive matrix

Strengths of the research project					
Capabilities		S1	S2	S3	S4
	C1	+	+	0	+
	C2	-	+	+	-

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

4.4. Research planning

Таблица 4.6 – Список этапов, работ и распределение исполнителей

Main stages	**№**	**Content of work**	**Duration days**	**Position of the performer**
Development of technical specifications	1	Preparation and approval of technical specifications	5	Scientific supervisor, consultant of FM, SR, bachelor
Choosing a direction of research	2	Development of a research methodology	3	Supervisor, bachelor
	3	Choosing a direction of research	20	Supervisor, bachelor
	4	Scheduling of works by topics	7	Supervisor, bachelor
Theoretical and experimental research	5	Analysis of literary sources	10	Bachelor
	6	Practical calculation	12	Bachelor
Summarizing and Evaluating Results	7	Evaluation of the effectiveness of the results obtained	6	Supervisor, bachelor
	8	Determination of the feasibility of holding a FQP	3	Supervisor, bachelor
Carrying out the FQP				
Development of technical documentation and design	9	Calculations and their analysis	30	Bachelor
	10	Evaluation of production efficiency and development application	9	Bachelor, FM Consultan
	11	Developing social responsibility on the topic	8	Bachelor, SR consultant

Registration of a set of documentation for FQP	12	Drawing up an explanatory note	25	Bachelor
Total: 138 days				

Draw up a Gantt chart based on the project schedule (Figure 4.1).

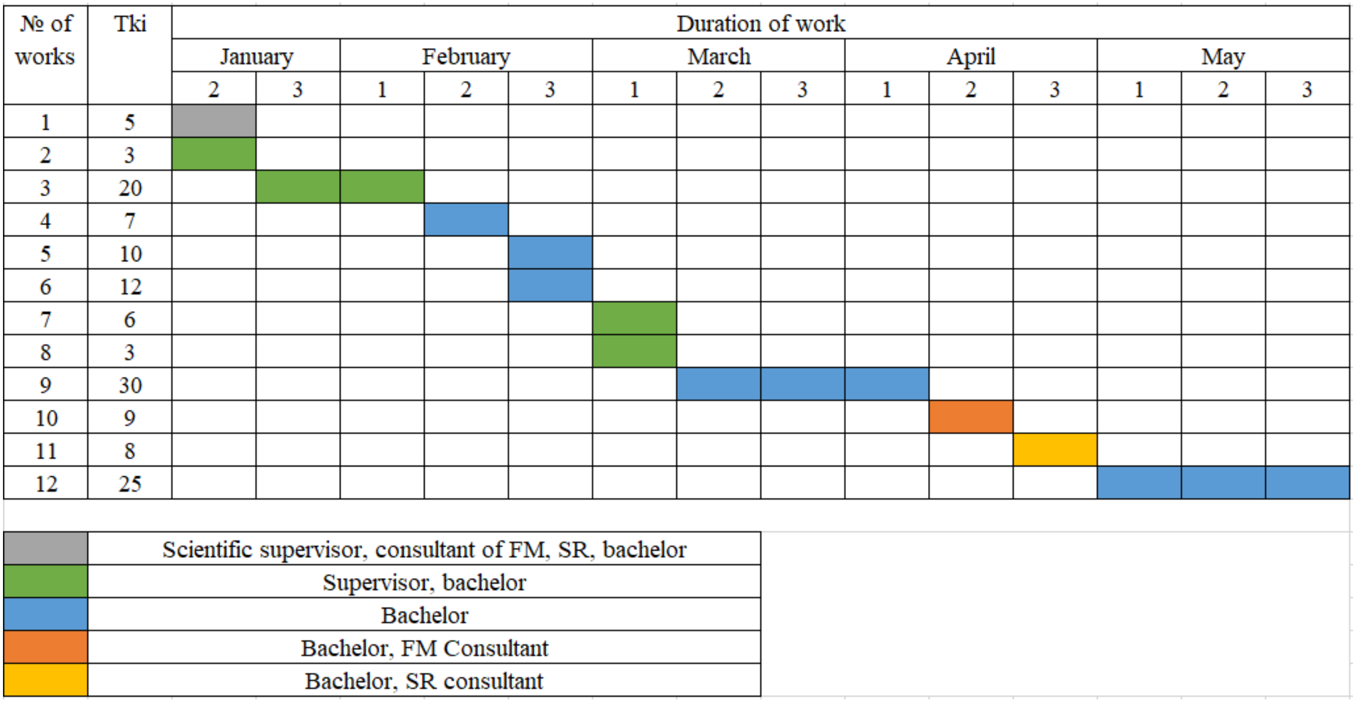

Figure 4.1 – Gantt chart

4.5. Project budget

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

1. Materials;
2. The cost of wages of employees;
3. Contributions to extrabudgetary funds;
4. Works performed by third parties;
5. Special equipment for scientific and experimental work;
6. Other direct costs;
7. Overhead costs.

Groups 1-6 relate to direct costs, the amount of direct costs, as a rule, should be determined by direct account, these are costs associated directly with the implementation of a specific scientific and technical research, the remaining costs are calculated indirectly, these are the costs of maintaining the administrative apparatus, general technical and general economic services, they are grouped together in the Overhead group.

4.5.1. Material cost

To perform measurements, it is necessary to design a special detector based on a plastic scintillator.

Table 4.7 – Calculation of costs for the item "Development of equipment"

№	Name of components	Cost, rubles
1	Scintillator BC-408	2500
2	Arduino Nano PCB	500
3	Photomultiplier FEU-82	5000
4	Other components (voltage divider, wire capacitors, etc.)	1000
	Total	**9000**

The special equipment required for carrying out experimental work includes a laptop.

Laptop cost: 40,000 rubles. Service life: 5 years.

Depreciation deductions for the duration of the project:

$$A = \frac{40000 \cdot 138}{1825} = 3025\, rub. \tag{4.2}$$

Table 4.8 – Calculation of costs for the item "Special equipment for scientific work"

№	Equipment	Days of operation	Life time	Cost	Depreciation deductions
1	Laptop	138	5 yers	40000	3025 rub.
	Total				**3025 rub.**

4.5.2. Basic salary

The amount of wage costs is determined based on the labor intensity of the work performed and the current remuneration system. The basic salary includes a bonus paid monthly from the payroll (the amount is determined by the Regulations on Labor Remuneration).

The salary of the project performer is calculated by the formula:

$$С_{зп} = З_{осн} + З_{доп} \tag{4.3}$$

where $З_{осн}$ – basic salary;

$З_{доп}$ – additional wages.

Basic salary ($З_{осн}$) of the project performer is calculated by the following formula:

$$З_{осн} = З_{дн} \cdot Т_{раб} \tag{4.4}$$

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

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

Average daily wages are calculated using the formula

$$З_{дн} = \frac{З_м \cdot М}{F_д} \tag{4.5}$$

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

М – the number of months of work without vacation during the year: with a vacation of 48 work. days М = 10.4 months, 6-day week;

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

Table 4.9 – Balance of working hours

Working time indicators	**Scientific adviser**	**Student**
Calendar number of days	365	365
Number of non-working days - weekends - holidays	 19 6	 19 6
Lost working time - vacation - sick absence	48	48
Valid annual working time fund	251	251

Employee's monthly salary:

$$З_м = З_б \cdot (1 + k_{пр} + k_д) \cdot k_р \tag{4.6}$$

where $З_б$ – base salary, rub.;

$k_{пр}$ – premium coefficient equal to 0,3;

$k_д$ – the coefficient of surcharges and allowances is approximately 0,2 – 0,5; (the calculations are accepted $k_д$ = 0,2);

$k_р$ – regional coefficient equal to 1.3 (for Tomsk).

Table 4.10 – The calculation of the basic salary

Performers	**Salary, rub**	$k_р$	$З_м$, **rub.**	$З_{дн}$, **rub.**	$Т_р$, **working days**	$З_{осн}$, **rub.**
Scientific adviser	30847	1,3	60151,65	1662	86	214341,18
Student (engineer)	17890		34885,5	964	136	196581,88
Total:						**410923,06**

4.5.3. Additional salary

This group includes the amount of payments provided for by labor legislation, for example, payment of regular and additional vacations; payment of time associated with the performance of state and public duties; payment of remuneration for seniority, etc. (on average - 12% of the basic salary).

Additional salary is calculated on the basis of 10-15% of the basic salary of employees directly involved in the performing of threads:

$$З_{доп} = k_{доп} \cdot З_{осн} \quad (4.7)$$

where $k_{доп}$ – additional salary coefficient equal to 0,12;

$З_{осн}$ – basic salary, rub.

Table 4.11 – Salaries of project performers

Salary	**Scientific adviser**	**Student**
Basic salary, rub.	214341,18	196581,88
Additional salary, rub.	25720,9	23589,82
Total, rub:	**460233,78**	

4.5.4. Contributions to extrabudgetary funds

This group reflects the obligatory deductions according to the norms established by the legislation of the Russian Federation to the state social insurance bodies (FSS), the pension fund (PF) and medical insurance (FFOMS) from the costs of salary of employees.

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

$$З_{внеб} = k_{внеб} \cdot (З_{осн} + З_{доп}) \quad (4.8)$$

where $k_{внеб}$ – coefficient of deductions for payment to extra-budgetary funds equal to 30,2%.

$$З_{внеб} = 0{,}302 \cdot 460233{,}78 = 147274{,}8 \text{ руб.} \quad (4.9)$$

4.5.5. Overheads

This group includes management and maintenance costs. In addition, this includes the costs of maintaining, operating and repairing equipment, production tools and inventory, buildings, structures, etc.

Overhead costs are 30% of the amount of basic and additional salary of employees directly involved in the implementation of scientific research.

$$З_{накл} = k_{накл} \cdot (З_{осн} + З_{доп}) = 0{,}3 \cdot 460233{,}78 = 138070{,}1 \text{ rub.} \quad (4.10)$$

4.5.6. Other direct costs

In this part of the costs, the costs of electricity consumed by the equipment are considered, which are calculated according to the formula:

$$З_э = T_{эл} \cdot P \cdot t_{об} \quad (4.11)$$

where $T_{эл}$ – electricity tariff (5.8 rubles per 1 kWh);

P – equipment power, kW;

$t_{об}$ – time of equipment use, h.

Table 4.12 – Calculation of other direct costs

Equipment	**Working time, h**	**Power consumption of electricity, kW**	**Price for 1 kW, rub.**	**Electricity costs (Зэ), rub.**
Computer	276	0,5	5,8	348
Total:				**348**

The calculated amount of research costs is the basis for the formation of the project cost budget. Determination of the cost budget for a research project for each implementation option is shown in the table 4.13.

Table 4.13 – Project cost budget

Article title	Amount,rub.
Equipment development costs	9000
Special equipment costs	3025
Costs for the basic salary of performer	410923,06
Costs of additional salaries of performers	49310,72
Contributions to extrabudgetary funds	147274,8
Overheads	138070,1
Other direct costs	348
Project cost budget	**757951,68**

The planned cost of the project is 757951,68 rubles.

4.6. Determination of the resource (resource-saving), financial, budgetary, social and economic efficiency of the research

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

The integral financial development indicator is defined as:

$$I_{\text{фин}}^{\text{исп}i} = \frac{\Phi_{pi}}{\Phi_{max}} \quad (4.12)$$

where Φ_{pi} – cost of the i-th version;

Φ_{max} – maximum cost of performing of a research project (including analogues).

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

Since the development has one version, then:

$$I_{\text{фин}}^{\text{исп}} = 1 \quad (4.13)$$

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

$$I_{\text{p}i} = \Sigma \text{a}_i \cdot b_i \quad (4.14)$$

where $I_{\text{p}i}$ – integral indicator of resource efficiency for the i-th;

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

b_i – the point estimate of the i-th variant of the development, is established by an expert according to the selected rating scale.

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

Table 4.14 – Оценка характеристик выполнения проекта

Criteria	Parameter weighting factor	Evaluation
1. Promotes increased user productivity	0,23	5
2. Ease of use	0,10	5
3. Interference immunity	0,20	4
4. Energy saving	0,20	3
5. Reliability	0,12	4
6. Material consumption	0,15	4
Total	**1**	

$$I_{\text{p}} = 5 \cdot 0{,}23 + 5 \cdot 0{,}1 + 4 \cdot 0{,}2 + 3 \cdot 0{,}2 + 4 \cdot 0{,}12 + 4 \cdot 0{,}15 = 4{,}13 \quad (4.15)$$

Integral indicator of the effectiveness of development options (Iиспi) is determined on the basis of the integral indicator of resource efficiency and the integral financial indicator according to the formula:

$$I_{\text{исп}i} = \frac{I_{p-\text{исп}i}}{I_{\text{фин}}^{\text{исп}i}} \quad (4.16)$$

Comparative project effectiveness:

$$\text{Э}_{\text{ср}} = \frac{I_{\text{исп}1}}{I_{\text{исп}2}} \quad (4.17)$$

Table 4.15 – Development efficiency

№	Indicators	Evaluation
1	Integral financial development indicator	1
2	Integral indicator of resource efficiency	4,13
3	Integral efficiency indicator	0,24

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

4.7. Conclusions by section

As a result of fulfilling the objectives of the section, the following conclusions can be drawn:

– the market in which the provided service is in demand has been determined;

– an analysis of competitors was carried out;

– in the course of planning, a schedule for the implementation of the work stage was developed for the manager and the engineer, which allows you to estimate and plan the working hours of the performers. The days from the schedule are determined, when and how much the manager and engineer work;

– to estimate the costs of the project, a project budget has been developed, which is 757951,68 rub;

– based on the data obtained and the analysis of efficiency, it can be concluded that the selected version of the execution is the most effective from the standpoint of resource efficiency.

In the completed final qualifying work, economic and technical criteria of efficiency were achieved due to the functional capabilities of the development, as well as social ones due to the demand for such technology on the market.

Chapter 5. Social responsibility

As part of the final qualifying work, the dependence between the gamma background of the surface atmosphere and incoming solar radiation was investigated. The main part of the work was performed on a PC located in the laboratory auditorium № 244 of the 10th TPU building.

The work consisted in conducting statistical analysis and searching for dependencies between the obtained data on the gamma background near the soil surface and incoming solar radiation.

5.1. Organization of the workplace of the PC operator

The rational layout of the workplace provides for a clear order and constancy of the placement of objects, tools and documentation. What is required to perform the work should more often be located in the zone of easy reach of the workspace (Figure. 5.1) [14].

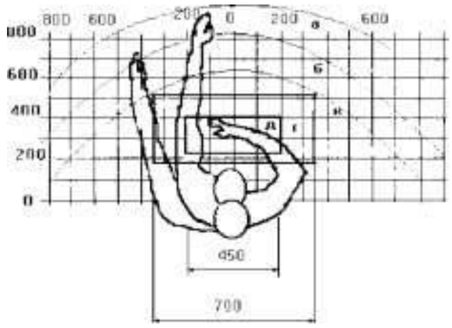

Рисунок 5.1 – Zones of reach of the hands in the horizontal plane: а – the zone of maximum reach of the hands; б – the zone of reach of the fingers with the outstretched hand; в – the zone of easy reach of the palm; г – the optimal space for rough handwork; д – the optimal space for fine handwork

Optimal placement of labor items and documentation in the areas of hand reach: the display is located in zone а (in the center); the keyboard is located in zone г, д; the system unit is located in zone б (left); the printer is located in zone а (right); documentation: in the area of easy palm reach – в (left) – literature and documentation necessary for work; in the drawers of the desk – literature that is not used constantly.

When choosing a workplace, namely a desk, the following requirements should be taken into account:

– the height of the working surface should not exceed 680 – 800 mm;

– the height of the working surface for the keyboard should not be more than 650 mm.

– the width of the desktop should not be less than 700 mm, and its length should not be less than 1400 mm, respectively;

– there should be legroom under the table, at least 600 mm long, at least 500 mm wide, the depth of the space at knee level should be at least 450 mm, and at the level of the extended legs – at least 650 mm.

The work chair should be able to adjust the height and tilt angles of the seat and backrest. The recommended seat height from the floor level should not exceed 450 – 550 mm. Due to the special design of the work chair, it should provide a depth and width of the seat surface of 400 mm, with the possibility of deepening the front edge.

The computer monitor should be located at the operator's eye level at a distance of 500 to 600 mm. The choice of the monitor should be made taking into account the possibility of adjusting the brightness and contrast of the image on the screen. It should also be possible to adjust the monitor screen:

– in height +3 cm;

– tilt relative to the vertical 10-20 degrees;

– in the left and right directions.

For comfortable work behind the keyboard, it should be placed at a distance of 100 to 300 mm from the edge of the work surface. The position of the keyboard should be provided in such a way that it is located at the level of the operator's elbow and has an angle of inclination to the horizontal surface of 15 degrees. To ensure maximum comfort during operation, the design of the keys should have a quadrangular shape with rounded corners, and the surfaces should have a concave shape. Also, the design of the keys should provide the operator with a click sensation when pressed, mechanical keyboards are best suited for this. The color of the keys must match the color of the working panel.

If the operator's work involves monotonous mental work that requires considerable nervous tension and a lot of concentration, it is best to choose soft, low-contrast color shades (slightly saturated shades of cold blue or green) that do not weaken attention. If the work requires a lot of mental and physical tension, then warmer shades should be used, which help to increase concentration [14].

5.2. Assessment of harmful and dangerous factors

This paragraph contains an analysis of all harmful and dangerous factors that may occur when working in the laboratory. All harmful and dangerous factors characteristic of the laboratory environment are presented in Table 5.1.

Table 5.1 – Possible harmful and dangerous factors

Factors (GOST 12.0.003-2015 [2])	Regulatory documents
1. Microclimate	GOST 30494-96. Residential and public buildings. Indoor microclimate parameters [16]
2. Noise	GOST 12.1.003-83. The system of Occupational Safety Standards (SSBT). Noise. General safety requirements (with Change N 1) [17]
3. Illumination of the working area	SNiP 23-05-95*. Natural and artificial lighting (with Change N 1) [18]
4. Fire and explosion hazard	SP 12.13130.2009. Definition of categories of premises, buildings and outdoor installations for explosion and fire hazards (as amended by the ed. of the Ministry of Emergency Situations of Russia No. 643 dated 09.12.2010) [19] GOST 12.1.004-91 System of occupational safety standards. Fire safety. General requirements [20]
5. Electrical safety	GOST 12.1.009-76 System of Occupational Safety Standards (SSBT) [21] GOST 12.1.019-2017 SSBT Electrical safety [22]

	GOST R IEC 61140-2000 Protection against electric shock. General provisions on safety provided by electrical equipment and electrical installations in their interrelation [10]

5.2.1. Deviation of microclimate parameters

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

Auxiliary equipment, PCs, as well as lighting devices emit heat during operation. High temperature contributes to rapid fatigue and overheating of the body when in close proximity to heat sources.

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

When rationing meteorological conditions in industrial premises, the time of year, the physical severity of the work performed, as well as the amount of excess heat in the room are taken into account. Optimal meteorological conditions of temperature and humidity are set according to [25] and are given in Table 5.2.

For the convenience of working indoors, it is necessary to normalize the parameters of the microclimate, that is, it is necessary to take measures to control methods and means of protection against high and low temperatures, heating systems, ventilation and air conditioning, etc.

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

Period of the year	Category of works according to the level of energy consumption, W	Air temperature, °C	Surface temperature, °C	Relative humidity of the air, %	Air velocity, m/s

Cold	Ia (up to 139)	22-24	21-25	60-40	Not more than 0.1
Warm	Ia (up to 139)	23-25	22-26	60-40	Not more than 0.1

To maintain these norms of microclimate parameters, it is sufficient to have a natural unorganized ventilation of the room and a local air conditioner of a full air conditioning installation that ensures the constancy of temperature, relative humidity, speed of movement and air purity. To ensure the circulation of air masses in the laboratory room, a fan can be used. To calculate the multiplicity of fan air exchange in the laboratory, the volume of which is V = 90,3 m^3 (S = 25,8 m^2, h = 3,5 m), let's use the formula [26]:

$$W = V \cdot k \tag{5.1}$$

where *k* – normalized multiplicity of air exchange (for laboratories k = 3), 1/h.

Substituting the data into formula (1), we obtain a characteristic of the multiplicity of fan air exchange:

$$W = 90{,}3 \cdot 3 = 270{,}9\ \frac{\mathrm{m}^3}{\mathrm{h}}.$$

Based on the obtained parameters, a SHUFT CFs 100S round duct fan with maximum performance is designed for the audience 271 m^3/h [24].

In winter, a central heating system is needed that provides a set temperature level according to [27]. It must provide sufficient, constant and uniform heating of the air. A water heating system is used to maintain the required temperature. This system is reliable in operation and provides the possibility of temperature control over a wide range. When installing a ventilation and air conditioning system in a laboratory room, it is necessary to comply with certain fire safety requirements. In rooms with high requirements for air cleanliness, water heating should be used.

In room № 244 of the 10-building, the microclimate parameters correspond to the established norms [25-27].

5.2.2. Noise

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

To assess the noise environment, it is allowed to use a numerical characteristic called the sound level (measured in dB). In accordance with [28], the permissible noise level for work requiring concentration, work with increased requirements for the processes of monitoring and remote control of production cycles at workplaces in rooms with noisy equipment is 75 dB. Zones with a sound level of 80 dB should be marked with safety signs according to [29].

In Auditorium No. 244, the main sources of noise are computers (cooling inside the system unit, optical DVD-ROM drives).

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

During the period under consideration, additional sound insulation is not required, since the maximum value of the noise level is not reached.

In order to bring the noise level up to sanitary standards when organizing work in the room, preventive maintenance of computer system units should be carried out in a timely manner (dust removal and lubrication of moving parts of cooling units, replacement of excessively noisy components).

Protection against increased noise levels is carried out by methods of reducing it in the source of formation and on the path of propagation, by the device of screens and sound-absorbing facings, by personal protective equipment according to [28, 129].

In auditorium № 244, the noise level does not exceed the set parameters according to [28].

5.2.3. Lack of natural and artificial lighting

Insufficient illumination of the working area is also considered one of the factors affecting human performance. The reasons for the insufficiency of natural and artificial lighting are the remoteness of the workplace from lighting sources, insufficient power and poor quality of lighting sources, inappropriate weather factors or time of day.

For industrial enterprises, optimal illumination of the territory and premises is an important and difficult technical task, the solution of which ensures normal hygienic conditions for working personnel. Properly selected light sources and their design create conditions for industrial work, the correctness of technological operations, compliance with rules and safety regulations.

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

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

A common name is lighting, the lamps of which illuminate the entire area of the room, both occupied by equipment or workplaces, and auxiliary. Depending on the location of the lamps, uniform and localized general lighting is distinguished. With a general uniform illumination, the lamps are located evenly in the upper area of the room, thereby ensuring the same illumination of the entire room. It is used, as a rule, when the location of the working areas in the design

unknown or with a flexible layout. With general localized lighting, the lamps are placed taking into account the location of the technological equipment, creating the required level of illumination on individual surfaces [33].

The combined lighting system consists of general and local lighting. General lighting is designed to illuminate passages and areas where work is not carried out, as well as to equalize the brightness in the field of view of workers. Local lighting is provided by lamps located directly at the workplace. It should be preferred if different visual tasks are to be solved in several working areas of the room and therefore different levels of illumination are required for them. It is also necessary when workplaces are geographically remote from each other. At the same time, it should be borne in mind that the device of only local lighting is unacceptable, since it creates a large difference in the illumination of the working surfaces and the surrounding space, which adversely affects vision [18].

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

For general lighting, gas-discharge lamps are used: daytime (LD), cold-white (LCB), warm-white (LTB) and white color (LB).

We will determine the required number of light sources to fully illuminate the classroom with working computers with fluorescent ceiling lights.

Luminous flux for fluorescent lamps, 56 W:

$$F = Ra \cdot P \tag{5.2}$$

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

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

The required number of lamps to illuminate the laboratory audience:

$$N = \frac{E \cdot s \cdot z \cdot k}{K \cdot F \cdot n} \tag{5.3}$$

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

K – transition coefficient, 4,5;

n – the coefficient of use of the luminous flux of the lighting system, 45 %;

k – stock ratio, 4,5;

S – the area of the illuminated room, 25,8 m^2;

z – correction factor that takes into account uneven lighting, 0,9.

$$N = \frac{300 \cdot 25{,}8 \cdot 0{,}9 \cdot 4{,}5}{4{,}5 \cdot 4480 \cdot 0{,}45} = 3{,}46.$$

The calculated value of the number of lamps is rounded up to an integer. We get that 4 lamps are needed for proper lighting of the audience.

To protect against insufficient illumination of the working area, natural lighting is the most acceptable in its spectrum, but it is not always enough. This is largely due to the mode of operation. It is usually recommended to use general and combined lighting. The illumination standards of the workplace in auditorium № 244 correspond to [18].

5.2.4. Electrical safety

The sources of the dangerous factor are conductive cables, elements of electrical equipment. The danger of electric shock is aggravated by the fact that a person is unable to detect voltage remotely without special devices. Electric current passing through a living organism has thermal (burns, heating and damage to blood vessels, overheating of the heart, brain and other organs), electrolytic (decomposition of organic fluid, including blood, which causes a significant violation of its composition, as well as tissue as a whole) and biological effects (violation of internal bioelectric processes, characteristic of a normally functioning organism and closely related to its vital functions).

The operator works with electrical appliances: a computer (display, system unit, etc.) and peripheral devices. The risk of electric shock exists in the following cases [21, 22]:

– when directly touching live parts during repair;
– when touching non-current-carrying parts that are energized (in case of violation of the insulation of current-carrying parts);
– when touching the floor, walls that are energized;
– in case of a short circuit in high-voltage units: the power supply unit and the display scan unit.

Electric current passing through the human body has thermal, chemical and biological effects.

The thermal (thermal) effect manifests itself in the form of burns of a skin area, overheating of various organs, as well as ruptures of blood vessels and nerve fibers resulting from overheating.

Chemical (electrolytic) action leads to the electrolysis of blood and other solutions contained in the human body, which leads to a change in their physicochemical compositions, and hence to a violation of the normal functioning of the body.

Measures to ensure electrical safety of electrical installations:

– disconnecting the voltage from the live parts on which or near which the work will be carried out, and taking measures to ensure that it is impossible to supply voltage to the place of work;
– posting posters indicating the place of work;
– grounding of the housings of all installations through the zero wire;
– coating of metal surfaces of tools with reliable insulation;
– unavailability of current-carrying parts of the equipment (enclosure of electric-reflecting elements, enclosure of current-carrying parts) [21, 22].

The room in which the work took place is suitable for Class 1 rooms in which the operating voltages do not exceed 1000 V [22].

Also, the computer carries the danger not only of electric current, but also the harmful factor of electromagnetic radiation.

The main sources of electromagnetic radiation in workrooms are computer and mobile device displays, electrical wiring network, system unit, power supplies, displays of dosimetric devices. Exposure to electromagnetic radiation can lead to disruption of the functions of the cardiovascular, respiratory and nervous systems, as well as the digestive tract, and changes in blood composition. Table 5.3 shows the permissible levels of parameters of electromagnetic fields [17].

Table 5.3 – Temporary permissible levels of electromagnetic fields generated by a PC

Name of parameters		The value of the permissible level
Electric field strength	In the frequency range of 5 Hz - 2 kHz	25 V/m
	In the frequency range 2 kHz - 400 kHz	2,5 V/m
Magnetic flux density	In the frequency range of 5 Hz - 2 kHz	250 nTl
	In the frequency range 2 kHz - 400 kHz	25 nTl
Electrostatic potential of the video monitor screen		500 V

The propagation of the electromagnetic field occurs with the help of electromagnetic waves, which in turn emit charged particles, molecules and atoms. The harm of electromagnetic radiation has been officially proven and confirmed by relevant studies of scientists, therefore, as far as possible, it is necessary to limit its effect on the human body.

The intensity of the electromagnetic field at a distance of 50 cm around the screen according to the electrical component should correspond to [32].

An increased level of electromagnetic radiation can negatively affect the human body, namely, lead to nervous disorders, sleep disorders, significant deterioration of visual activity, weakening of the immune system, disorders of the cardiovascular system.

There are the following ways to protect against electromagnetic fields:

– increasing the distance from the source (the screen must be at least 50 cm away from the user);

– the use of on-screen filters, special screens and other personal protective equipment.

In auditorium № 244, the radiation corresponds to the norms [30, 31].

5.2.5. Fire and explosion safety

Depending on the characteristics of the substances and materials in the room, according to the explosion and fire hazard, the premises are divided into categories А, Б, В, Г and Д in accordance with [19].

The room in question belongs to category В, since it contains solid combustible substances in a cold state. Possible causes of fire:

– working with open electrical equipment;

– short circuits in power supplies;

– non-compliance with fire safety rules.

In order to reduce the risk of fire and minimize possible damage, preventive measures are carried out, which are divided into organizational, technical, operational and regime. Organizational and technical measures consist in conducting regular briefings of employees responsible for fire safety, training employees in the proper operation of equipment and necessary actions in the event of a fire, certification of substances, materials and products in terms of fire safety, manufacture and use of visual agitation tools to ensure fire safety [20]. Maintenance measures include preventive inspections of equipment. Routine measures include the establishment of rules for the organization of work and compliance with fire protection measures. To prevent the occurrence of a fire, the following fire safety rules must be observed:

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

In a room with electrical equipment, in order to avoid electric shock, it is advisable to use carbon dioxide or powder fire extinguishers. These fire extinguishers are designed to extinguish fires of various substances and materials, electrical installations under voltage up to 1000 V, flammable liquids. Chemical and foam fire extinguishers are not allowed. Fire extinguishers should be placed on the protected object in accordance with the requirements in such a way that they are protected from direct sunlight, heat flows, mechanical influences and other adverse factors (vibration, aggressive environment, high humidity, etc.). They should be clearly visible and easily accessible in case of fire. It is preferable to place fire extinguishers near the places where a fire is most likely to occur, along the passage paths, as well as near the exit from the room. Fire extinguishers should not prevent the evacuation of people during a fire. According to the fire safety requirements [6, 7], there are 2 fire extinguishers on the floor, portable powder fire extinguishers, staircases are equipped with hydrants, there is a fire alarm button.

5.3. Emergency situations

The dangers of an accident include a sudden and uncontrolled source of energy: a moving object, uncontrolled movement or energy.

Let's consider possible emergency situations in the auditorium № 244 of the TPU educational building 10, namely:

– occurrence of fire;
– electric shock;
– falling from the height of your own growth;
– falling down the stairs.

Measures to prevent and eliminate the consequences of the above-mentioned emergencies are presented in table 5.4.

Table 5.4 – Examples of emergency situations and measures to prevent and eliminate them in the workplace

№	Emergency situation	Prevention measures	Measures to eliminate the consequences of an emergency
1	Occurrence of fire	1. Timely briefing. 2. Installation of automatic fire extinguishing equipment in the premises. 3. Installation of smoke and fire sensors. 4. Providing escape routes and maintaining them in proper condition. 4. Control of electrical appliances.	1. Call 112; 2. De-energize the room, stop the air supply; 3. Immediately report the fire to the person on duty or to the security post; 4. If possible, take measures to evacuate people, extinguish a fire and save material assets.
2	Electric shock	1. Grounding of all electrical installations. 2. Limitation of the workspace. 3. Ensuring the unavailability of live parts of the equipment. 4. Timely briefing.	1. Quickly release the victim from the action of electric current [10]; 2. Call an ambulance (112); 3. If the victim has lost consciousness, but his breathing has been preserved, he should be comfortably laid down, unbutton the restraining clothes, create an influx of fresh air and ensure complete rest; 4. The victim should be given ammonia to smell, sprinkle his face with water, rub and warm the body;

			5. In the absence of breathing, artificial respiration and heart massage should be performed immediately.
3	Falling from the height of your own growth	1. Maintenance of the premises in proper order. 2. Limitation of the workspace. 3. Timely briefing.	1. Examine or interview the victim; 2. If necessary, call an ambulance (112); 3. Stop the bleeding, if there is any; 4. If there is a suspicion that the victim's spine is broken (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.
4	Falling down the stairs	1. Installation of handrails on the stairs. 2. Covering the stairs with an anti-slip coating. 3. Timely briefing.	1. If necessary, call an ambulance (112); 2. Stop the bleeding, if there is any; 3. If there is a suspicion that the victim's spine is broken (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical care is provided.

5.4. Conclusions by section

Harmful and dangerous factors in the auditorium № 244 of the 10 TPU building are considered:

– microclimate [16];
– noise [17];
– illumination of the working area [18];
– fire and explosion hazard [19-20];
– electrical safety [21-23].

Room № 244 is assigned:

– to electrical safety to hazard class 1 [22];
– to fire and explosion safety to category B [19].

Emergency situations that are possible in auditorium № 244, as well as measures to prevent emergencies and measures to eliminate the consequences of emergencies are considered.

Conclusion

A series of measurements of the gamma background was carried out at points located at different distances from objects, presumably containing an increased concentration of natural radioactive isotopes, located in a number of crowded places of the city of Tomsk (stele in memory of the heroes of the Patriotic War of 1812, the decorative construction "Khachkar", the territory near the Drama Theater, the stele in memory of the fallen in local wars and the monument to the fallen in the battles for the Motherland). The following instruments were used for measurements: a wide-range dosimeter DRG-01T1, a dosimeter-radiometer DRBP-03 and a scintillation dosimeter based on a plastic scintillator BC-408.

The level of gamma background at all studied sites is within the acceptable range (does not exceed 0.3 μSv/h). The highest value of the gamma background level was registered around the stele in memory of the heroes of the Patriotic War. The annual effective dose equivalent at this site equal to 0.1313 mSv/y.

For all the studied objects, the estimated lifetime radiation-induced cancer risk was calculated: 1 – 0.056%, 2 – 0.047%, 3 – 0.037%, 4 – 0.037% and 5 – 0.044%, with a maximum allowable value of 0.029%.

Thus, it is shown that the level of gamma background at the studied sites does not exceed the maximum allowable value, but in some cases exceeds the average value of the gamma background for the territory where there are no infrastructure objects. The estimated lifetime radiation-induced cancer risk during prolonged stay at the studied sites (more than 4.8 hours a day) is a multiple of or equal to the maximum allowable values.

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Application A