TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

Школа инженерная школа ядерных технологий
Направление подготовки 14.03.02 Ядерные физика и технологии
Отделение школы отделение ядерно-топливного цикла

БАКАЛАВРСКАЯ РАБОТА

Тема работы
Влияние приходящей солнечной радиации на гамма-фон

УДК 539.122.16:551.521.1

Студент

Группа	ФИО	Подпись	Дата
0А8А	Субботина Кристина Александровна		

Руководитель ВКР

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

Консультант

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Старший преподаватель	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.	канд. экон. наук		

По разделу «Социальная ответственность»

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

ДОПУСТИТЬ К ЗАЩИТЕ:

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

Томск – 2022 г.

TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

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

BACHELOR THESIS

Topic of research work
Influence of incoming solar radiation on gamma-background

UDC 539.122.16:551.521.1

Student

Group	Full name	Signature	Date
0A8A	Subbotina Kristina Aleksandrovna		

Scientific supervisor

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

Consultant

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

ASVISERS:

Section "Financial Management, Resource Efficiency and Resource Saving"

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Yakimova Tatiana Borisovna	PhD		

Section "Social Responsibility"

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

ADMITTED TO DEFENSE:

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Bychkov Petr Nikolaevich	PhD		

Tomsk – 2022

ПЛАНИРУЕМЫЕ РЕЗУЛЬТАТЫ ОСВОЕНИЯ ООП

Код компетенции	Наименование компетенции
Универсальные компетенции	
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 компетенции	
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	Способностью использовать научно-техническую информацию, отечественный и зарубежный опыт по тематике исследования, современные компьютерные технологии и информационные ресурсы в своей предметной области
ПК(У)-2	Способностью проводить математическое моделирование процессов и объектов атомной отрасли с использованием стандартных методов и компьютерных кодов для проектирования и анализа

ПК(У)-3	Готовностью к проведению физических экспериментов по заданной методике, составлению описания проводимых исследований и анализу полученных экспериментальных данных
ПК(У)-4	Способностью использовать технические средства для измерения основных параметров объектов исследования
ПК(У)-5	Готовностью к составлению отчета по выполненному заданию, к участию во внедрении результатов исследований и разработок
ПК(У)-6	Способностью использовать информационные технологии при разработке новых установок, материалов и приборов, к сбору и анализу исходных данных для проектирования объектов атомной отрасли
ПК(У)-7	Способностью к расчету и проектированию деталей и узлов приборов и установок в соответствии с техническим заданием
ПК(У)-8	Готовностью к разработке проектной и рабочей технической документации, оформлению законченных проектно-конструкторских работ
ПК(У)-9	Способностью к контролю соответствия разрабатываемых проектов и технической документации стандартам, техническим условиям, требованиям безопасности и другим нормативным документам
ПК(У)-10	Готовностью к проведению предварительного технико-экономического обоснования проектных решений при разработке установок и приборов
ПК(У)-11	Способностью к контролю за соблюдением технологической дисциплины и обслуживанию технологического оборудования
ПК(У)-12	Готовностью к эксплуатации современного физического оборудования, приборов и технологий
ПК(У)-13	Способностью 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	Готовностью 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	Способностью 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)

Школа инженерная школа ядерных технологий
Направление подготовки 14.03.02 Ядерные физика и технологии
Отделение школы отделение ядерно-топливного цикла

УТВЕРЖДАЮ:
Руководитель ООП
_______________ Бычков П.Н.
(Подпись) (Дата) (Ф.И.О.)

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

В форме:

бакалаврской работы

Студенту:

Группа	ФИО
0А8А	Субботина Кристина Александровна

Тема работы:

Влияние приходящей солнечной радиации на гамма-фон	
Утверждена приказом директора (дата, номер)	№ 35-84/с от 04.02.2022 г

Срок сдачи студентом выполненной работы:	

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе	Экспериментальные данные по гамма-фону приземной атмосферы, экспериментальные данные по метеорологическим величинам.

Перечень подлежащих исследованию, проектированию и разработке вопросов	- обзор литературных источников; - методы и приборы измерения скорости испарения; - методы и приборы измерения гамма-фона в приземной атмосфере; - методы и приборы измерения солнечной радиации; - корреляционный и регрессионный анализ радиационных и метеорологических величин; - анализ полученных 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
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	Якимова Т.Б.
Социальная ответственность	Передерин Ю.В.

Дата выдачи задания на выполнение выпускной квалификационной работы по линейному графику	25.04.2022

Задание выдал руководитель:

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А8А	Субботина Кристина Александровна		

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

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

APPROVED BY:
Programme Director
_____________ Bychkov P.N.
«____» ____________ 2021

ASSIGNMENT

for the Graduation Thesis completion

In the form:

Bachelor Thesis

For a student:

Group	**Full name**
0A8A	Subbotina Kristina Aleksandrovna

Topic of research work:

Influence of incoming solar radiation on gamma-background	
Approved by the order of the Director of School of Nuclear Science & Engineering (date, number):	№ 35-84/c from 04.02.2022

Deadline for completion of Bachelor Thesis:	

TERMS OF REFERENCE:

Initial date for research work	Experimental data on the gamma background of the surface atmosphere, experimental data on meteorological values.

List of the issues to be investigated, designed and developed	- review of literature sources; - methods and instruments for measuring the evaporation rate; - methods and instruments for measuring gamma background in the surface atmosphere; - methods and instruments for measuring solar radiation; - correlation and regression analysis of radiation and meteorological quantities; - 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**
Financial management, resource efficiency and resource saving	T.B. Yakimova
Social responsibility	Yu. V. Perederin

Date of issuance of the assignment for Bachelor Thesis completion according to the schedule	25.04.2022

Assignment issued by a scientific supervisor / advisor:

Position	**Full name**	**Academic degree, academic status**	**Signature**	**Date**
Professor of NFCF	Yakovleva Valentina Stanislavovna	PhD		
Senior lecturer of NFCF	Poberezhnikov Andrey Dmitrievich	-		

Assignment accepted for execution by a student:

Group	**Full name**	**Signature**	**Date**
0A8A	Subbotina Kristina Aleksandrovna		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

Группа	ФИО
0А8А	Субботиной Кристине Александровне

Школа	ИЯТШ	**Отделение школы (НОЦ)**	ЯТЦ
Уровень образования	Бакалавриат	**Направление/специальность**	14.03.02 Ядерные физика и технологии

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. Стоимость ресурсов научного исследования (НИ): материально-технических, энергетических, финансовых, информационных и человеческих	*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	*- районный коэффициент- 1,3; - коэффициент дополнительной заработной платы - 1,15; - накладные расходы – 16%*
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 НИ с позиции ресурсоэффективности и ресурсосбережения	*Анализ потенциальных потребителей результатов исследования. Исследование конкурентных технических решений. Проведение SWOT-анализа*
2. Планирование и формирование бюджета научных исследований	*Определение трудоемкости работ. Разработка графика проведения научного исследования. Формирование бюджета затрат научно-исследовательского проекта*
3. Определение ресурсной (ресурсосберегающей), финансовой, бюджетной, социальной и экономической эффективности исследования	*Оценка сравнительной эффективности проекта*
Перечень графического материала *(с точным указанием обязательных чертежей)*:	
1. Оценка конкурентоспособности технических решений 2. Матрица SWOT 3. График проведения и бюджет НИ 4. Оценка ресурсной, финансовой и экономической эффективности НИ	

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.	канд экон. наук		15.03.2022

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А8А	Субботина Кристина Александровна		15.03.2022

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

To the student:

Group	Full name
0A8A	Subbotina Kristina Aleksandrovna

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. Resource cost of scientific and technical research (STR): material and technical, energetic, financial and human	*Cost of material resources in accordance with the market prices of Tomsk. Tariff rates of executors in accordance with the staff schedule of NR TPU.*
2. Expenditure rates and expenditure standards for resources	*- regional coefficient - 1.3;* *- coefficient of additional wages - 1.15;* *- overheads - 16%*
3. Current tax system, tax rates, charges rates, discounting rates and interest rates	*The coefficient of contributions to non-budgetary funds - 30.2%.*
The list of subjects to study, design and develop:	
1. Assessment of commercial potential, perspectives and alternatives of research from the position of resource efficiency and resource saving	*Analysis of potential consumers of the research results. Study of competitive technical solutions. Carrying out SWOT-analysis*
2. Planning and budgeting of scientific research	*Determination of the labor intensity of the work. Development of the schedule of scientific research. Formation of the cost budget of the research project*
3. Determination of resource (resource-saving), financial, budgetary, social and economic efficiency of the research	*Assessment of the comparative effectiveness of the project*
A list of graphic material *(with list of mandatory blueprints):*	
1. *Assessment of the competitiveness of technical solutions* 2. *SWOT Matrix* 3. *Schedule and budget of STR* 4. *Assessment of resource, financial and economic efficiency of STR*	

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

Task issued by adviser:

Position	Full name	Scientific degree, rank	Signature	Date
Associate Professor	Yakimova T.B.	PhD		15.03.2022

The task was accepted by the student:

Group	Full name	Signature	Date
0A8A	Subbotina Kristina Aleksandrovna		15.03.2022

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Студенту:

Группа	ФИО
0А8А	Субботина Кристина Александровна

Институт	ИЯТШ	**Отделение (НОЦ)**	ОЯТЦ
Уровень образования	Бакалавриат	**Направление/специальность**	14.03.02 Ядерные физика и технологии

Тема ВКР:

Влияние приходящей солнечной радиации на гамма-фон	
Исходные данные к разделу «Социальная ответственность»:	
1. Характеристика объекта исследования (вещество, материал, прибор, алгоритм, методика, рабочая зона)и области его применения	Объектом исследования является радиационный гамма-фон приземной атмосферы
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. от30.04.2021).
2. Производственная безопасность: – Анализ выявленных вредных и опасныхфакторов – Обоснование мероприятий по снижениювоздействия	- Микроклимат – возможное отклонение в показателе микроклимата - Шум – возможное превышение уровня шума - Освещенность рабочей зоны – возможная отклонение от санитарных норм - Пожароопасность – возможное несоответствие нормам пожарной безопасности - Электробезопасность – возможное несоответствие нормам электробезопасности
3. Безопасность в чрезвычайных ситуациях	- травмирование при падении с высоты собственного роста; - травмирование при падении с лестницы; - удар электрическим током; - пожар.

Дата выдачи задания для раздела по линейному графику	

Задание выдал консультант:

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

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0А8А	Субботина Кристина Александровна		

Task for section
«Social responsibility»

To student:

Group	Full name
0A8A	Subbotina Kristina Aleksandrovna

School	Nuclear Science and Engineering	Division	Nuclear Fuel Cycle
Degree	Bachelor	Educational Program	14.03.02 Nuclear physics and technologies

Topic of research work:

Influence of incoming solar radiation on gamma-background	
Initial data for section «Social Responsibility»:	
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.
List of items to be investigated and to be developed:	
1. Legal and organizational issues to provide safety:	Labor Code of the Russian Federation No. 197-FZ of December 30, 2001 (revised on April 30, 2021).
2. Work Safety: – Analysis of identified harmful and dangerous factors – Justification of measures to reduce probability of harmful and dangerous factors	- Microclimate - possible deviation in the microclimate indicator - Noise - possible exceeding of noise level - Working area illumination - possible deviation from sanitary norms - Fire hazard - possible noncompliance with fire safety standards - Electrical safety - possible noncompliance with electrical safety standards
3. Safety in emergency situations:	- injury from a fall from one's own height; - injury from falling from a ladder; - electric shock; - fire.

Assignment date for section according to schedule	

The task was issued by consultant:

Position	Full name	Scientific degree, rank	Signature	Date
Assistant professor	Yu. V. Perederin	PhD		

The task was accepted by the student:

Group	Full name	Signature	Date
0A8A	Subbotina Kristina Aleksandrovna		

TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

Школа инженерная школа ядерных технологий
Направление подготовки 14.03.02 Ядерные физика и технологии
Уровень образования бакалавриат
Отделение школы отделение ядерно-топливного цикла
Период выполнения весенний семестр 2021 /2022 учебного года

Форма представления работы:

бакалаврская работа

КАЛЕНДАРНЫЙ РЕЙТИНГ-ПЛАН
выполнения выпускной квалификационной работы

Срок сдачи студентом выполненной работы:	

Дата контроля	Название раздела (модуля) / вид работы (исследования)	Максимальный балл раздела (модуля)
14.02.2022	Формирование целей и задач ВКР, задания на ВКР, плана-графика выполнения ВКР и титульного листа;	10
28.02.2022	Обзор литературных источников;	10
14.03.2022	Обьекты и методы исследования;	10
31.03.2022	Получение экспериментальных данных;	10
21.04.2022	Корреляционный и регрессионный анализ радиационных и метеорологических величин;	10
04.05.2022	Финансовый менеджмент, ресурсоэффективность и ресурсосбережение;	15
11.05.2022	Социальная ответственность;	15
18.05.2022	Заключение по работе	10
02.06.2022	Представление итогового варианта пояснительной записки к ВКР	10

СОСТАВИЛ:
Руководитель ВКР

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

СОГЛАСОВАНО:
Руководитель ООП

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

TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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«Национальный исследовательский Томский политехнический университет» (ТПУ)

School School of Nuclear Science and Engineering
Field of training (specialty) 14.03.02 Nuclear Physics and Technology
Level of education Bachelor degree programme
Department 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 Bachelor Thesis completion

Deadline for completion of Bachelor's Graduation Thesis:	

Assessment date	Title of section (module) / type of work (research)	Maximum score for the section (module)
14.02.2022	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
28.02.2022	Review of literary sources;	10
14.03.2022	Objects and research methods;	10
31.03.2022	Obtaining experimental data;	10
21.04.2022	Correlation and regression analysis of radiation and meteorological quantities;	10
04.05.2022	Financial management, resource efficiency and resource conservation;	15
11.05.2022	Social responsibility;	15
18.05.2022	Conclusion on work	10
10.06.2022	Presentation of the final version of the explanatory FQP Notes	10

COMPILED BY:
Scientific supervisor:

Position	Full name	Academic degree, academic status	Signature	Date
Professor	V.S. Yakovleva	PhD		

AGREED BY:

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

Abstract

Final qualifying work 91 p., 26 figures, 21 tables, 39 sources, 1 app.

Key words: gamma background, evaporation, evapotranspiration, incoming solar radiation, surface atmosphere, relative humidity, dynamics, precipitation, meteorological parameters, regression analysis, correlation analysis.

The object of the study is the, incoming solar radiation, gamma background and relative humidity of the surface atmosphere of the city of Tomsk.

The objective of the work is to study the effect of incoming solar radiation on the gamma background.

In the course of the research, the dependencies of the dynamics of the gamma background, incoming solar radiation and relative humidity drawn up. In addition, a correlation and regression relationship carried out between the gamma background and meteorological parameters.

The result of the study is the regression dependences of the gamma background, incoming solar radiation and relative humidity with the corresponding regression and correlation coefficients.

Implementation degree: high, the project can used to continue research.

Applications: meteorology, agronomy, geophysics, radiation ecology.

Economic efficiency / value of work is high.

In the future planned: the obtained results will used to create a methodology for calculating the rate of evaporation of moisture from the soil surface, using the dynamics of changes in the gamma background of the surface atmosphere as one of the main parameters, which will significantly reduce the number of meteorological parameters, whose measurement is necessary to determine the rate of evaporation at the moment.

Оглавление

Introduction

Evaporation is an important part of the complex process of the water cycle on Earth and is of great importance in water and energy exchange, since the evaporation process accompanied by heat consumption. The theory of the issue of moisture evaporation from the soil surface is of great scientific and practical importance [1].

Evaporation is one of the most important parameters in the study of water and heat exchange in the soil-water-atmosphere system. The value of evaporation together with precipitation is the input information for most hydrological and water balance models.

Due to the technical difficulties of direct measurement, a number of evaporation methods developed, including empirical methods, simulations and methods based on remote sensing. However, these methods have regional limitations and require the data of a large number of meteorological parameters measured only at a small number of large weather stations.

The level of the gamma background near the earth's surface, as a parameter that depends, among other things, on the properties of the soil that attenuate gamma radiation, can be used to replace meteorological parameters that are difficult to measure and automatically collect information.

The subject of this study was the relationship between the gamma background and incoming solar radiation, as incoming solar radiation is a factor initiating the processes of heat transfer and evaporation.

The object of the work is to study the effect of incoming solar radiation on the gamma background.

To achieve the object of the study, it is necessary to solve the following tasks:

1. Review and analysis of literature on this topic;
2. Measure the parameters of the external environment necessary for the study for 2021;
3. Carry out correlation and regression analysis of experimental data;

1 Literature review

1.1 Evaporation and evaporation rate

Evaporation is the process by which a substance changes from a liquid or solid state to a vapor state. The process by which moisture evaporates from the soil surface covered with vegetation called evapotranspiration. It divided into the evaporation of water from plants, called transpiration, and the evaporation that occurs directly from the soil.

One of the physical quantities characterizing the evaporation process is the evaporation rate - the mass of water evaporated from a unit surface per unit time. In practice, millimeters are used as a unit for measuring the rate of evaporation (the height of a layer of water that has evaporated over a certain period).

Potential evaporation - the maximum possible evaporation from excessively moist soil or from the surface of the water under the existing meteorological conditions of a particular area. It also expressed in millimeters of the evaporated water layer per unit of time.

Evaporation from the soil surface is of interest to many specialists from a scientific and practical point of view in a wide variety of fields, including meteorology and agronomy. Information about evaporation also helps in the study of water and heat balances of various natural objects.

To date, many maps of isolines of average long-term evaporation have been developed for the entire territory of the country. However, the evaporation values taken from these maps often do not reflect the actual evaporation in the area of interest, since they do not take into account the whole variety of climatic and physical-geographical factors, as well as local conditions affecting evaporation [2].

1.1.1 Factors affecting evaporation rate

The rate of evaporation depends on many factors. Among meteorological factors, the most significant are temperature, precipitation, wind speed, air humidity and solar radiation flux. For example, with an increase in soil moisture, the amount of evaporation also increases. According to Dalton's law, the rate of evaporation is directly proportional to the difference between the saturated vapor pressure, calculated from the temperature of the evaporating surface, and the partial pressure of water vapor in the air, and inversely proportional to atmospheric pressure. The dependence of the evaporation rate on the wind speed is associated with turbulent vapor diffusion, which becomes more intense as the wind increases [3].

The type and properties of the soil itself also affect evaporation. For example, sandy soils evaporate less than clay soils, and dark soils heat up more than light soils and therefore evaporate more moisture. From an uneven soil surface (plowed field), evaporation is more intense than from a flat one, since turbulent air mixing is more developed over a rough surface. The depth of groundwater can also have an impact - the closer they are to the surface, the greater the amount of evaporation [1].

1.1.2 Methods for determining the evaporation rate

There are many different methods to determine evaporation from the soil surface. All these methods can be divided into instrumental, where the measurement of evaporation is carried out using instruments, and calculated. In this case, the evapotranspiration is most often estimated, since the separation into evaporation from the soil surface and transpiration is difficult to implement and the evaporation of different types is carried out simultaneously.

The measurement of evaporation with the help of instruments referred to as an experimental method for its study. It also called the evaporator method. Observations carried out at hydrological stations located in the most typical natural and climatic zones of the country.

In Russia and the CIS countries, to measure the total evaporation from the surface of the soil covered with vegetation, it carried out with the help of weight soil evaporators GGI-500-50 and GGI-500-100, a hydraulic soil evaporator of a small model and a lysimeter GR-80. This method of measurement is relatively simple, but has a number of disadvantages: the soil in the evaporator is isolated, the metal wall of the device distorts heat exchange with the surrounding soil, and soil structure of the monolith is disturbed during the charging of the evaporator [2].

However, at agrometeorological stations, direct measurement of evapotranspiration using soil evaporators is quite rare. Also, observational data on evaporators often contain systematic errors. Therefore, calculation methods for determining evaporation are more widely used, which selected based on local conditions and the original data set [4].

To calculate evaporation from both the bare soil surface and with covered vegetation, the following four methods mainly used water and heat balances, turbulent diffusion, and empirical formulas.

When determining evapotranspiration by the water balance method, data on soil moisture and precipitation are used.

Heat balance methods are based on the use of heat balance equations for the soil surface, taking into account heat and water exchange in the surface layer of the atmosphere. Among foreign researchers, the Penman-Monteith methods [5,6] are widely used, which use such indicators as air density and heat capacity, vapor pressure deficit, illumination, latent heat of vaporization, the slope of the saturated vapor pressure curve, and the Priestley-Taylor radiation method [7,8], in which evaporation (transfer of the latent heat flux) is calculated taking into account solar radiation and heat flux in the soil. These methods take into account many factors that affect evaporation, but not all of these quantities are always measured at meteorological stations.

A detailed description of calculations by the heat balance method can be found in the "Guide to gradient observations and determination of heat balance components" [9]. The range of meteorological conditions under which the heat balance method can be used to determine evaporation is somewhat limited. It gives inaccurate results for the morning and evening hours, as well as for the daytime when the weather is cloudy.

It is possible to determine the hourly, daily, monthly and annual values of evaporation from the soil by using the turbulent diffusion method. To calculate the amount of evaporation used data from gradient measurements: wind speed, temperature and air humidity [9, 10].

Empirical formulas for calculating evaporation are derived based on the analysis of the found relationship between meteorological parameters and measured evaporation. Empirical models tend to use fewer variables, which simplifies calculations. The disadvantage of these methods is their limited application. For one region, such models may produce accurate results, while for another they may not work [1, 3, 10]. Application conditions are described in the Recommendations for the calculation of evaporation from the land surface [11]. The use of one method or another for the calculation depends on the availability of initial data and the accuracy of the results obtained.

With the development of methods and systems for remote sensing of the Earth, new possibilities arise for estimating evaporation from the soil surface, taking into account the detailed geophysical information obtained in this way. In [12] methods for estimating evaporation in large regions are considered. The temperatures of the earth's surface, necessary for the calculations, obtained using remote sensing systems.

Information received from satellites makes it possible to develop new methods for calculating land and environmental parameters and, in particular, evaporation from the soil surface. In [13] a physical and mathematical model of the interaction of the land surface with the atmosphere RSBLSM is described (Remote Sensing Based Land Surface Model), designed to calculate the components of the water and heat balance of territories on a regional scale, which uses satellite data on the characteristics of soil and snow cover.

In [14] the issues of satellite data processing and their use in the existing evaporation model GLEAM (Global Land Evaporation Amsterdam Model) are considered. This model uses the Priestley-Taylor method using satellite meteorological data.

1.2 Solar radiation

Many calculation methods for finding evaporation use parameters such as radiation balance and solar radiation [7-11, 14].

Solar radiation is the energy emitted by the Sun. When it reaches Earth, most of the solar radiation converted into heat. When it reaches the surface, it partly reflected and partly absorbed by the Earth. The Earth also has radiation that is absorbed by the atmosphere along with some of the solar radiation. The radiation balance is the difference between the radiation coming to the soil surface and the radiation leaving it. It includes direct and diffuse radiation, reflected radiation, as well as radiation from the atmosphere and the earth's surface. With a positive radiation balance, the earth's surface heats up, and with a negative one, on the contrary, it cools down [15].

Direct solar radiation is radiation that reaches the place of observation directly from the Sun. Accordingly; scattered solar radiation is radiation from the Sun that has scattered in the atmosphere. The sum of direct and scattered radiation called total radiation and is the main component of the radiation balance. The amount of total radiation can vary depending on the presence of clouds, the height of the Sun, and the composition of the atmosphere. In addition, part of the total radiation coming to the soil surface reflected from it [16].

1.3 Radiation background

The natural radiation background is formed by cosmic radiation and radiation created by radionuclides scattered in nature contained in the earth's crust, surface air, soil, water, plants, and food products, in animal and human organisms. The man-made background radiation is mainly associated with the processing and movement of rocks, the combustion of coal, oil, gas and other fossil fuels, as well as with nuclear weapons testing and nuclear energy.

The level of radiation background is a non-constant value and changes both in space and in time.

1.3.1 Fluctuations of the gamma background of the surface atmosphere

Sources of natural gamma background on the ground are natural radionuclides contained in the soil and (or) building materials and structures, secondary cosmic photon radiation.

Studies show that the change in the dose rate of gamma radiation near the earth's surface is influenced by many meteorological factors: atmospheric pressure, air humidity, temperature, wind speed and direction, etc. As is known, changes in the intensity of the radiation field are associated with two groups of factors: terrestrial (migration of radionuclides under the influence of changing wind directions, sea currents, etc.) and extraterrestrial (changes in the intensity of cosmic radiation reaching the surface; the emergence of secondary radiation due to the formation of radionuclides in the process of interaction of cosmic radiation with elements of soil, sea water, etc.) [17,18].

An analysis of data on changes in the intensity of the radiation field depending on various meteorological parameters, carried out by researchers, shows that, as a first approximation, it can be considered that the gamma background increases with increasing temperature and decreases with increasing humidity and pressure. However, a more detailed analysis shows that the dependence of the gamma background on a certain environmental parameter changes at different times of the year [18].

Also in 2009 - 2010, a group of scientists from the Polar Geophysical Institute of the KSC RAS investigated the increase in the intensity of the gamma background in the surface layer of the atmosphere during precipitation in Apatity and Svalbard. A clear relationship found between an increase in the intensity of gamma radiation and rain (snow) cloudiness. The study made it possible to consider the main reason for the increase in gamma radiation during precipitation to be the X-ray bremsstrahlung of energetic electrons accelerated by electric fields inside rain (snow) clouds [19].

Tomsk Polytechnic University, in collaboration with the Institute for Monitoring Climatic and Ecological Systems, also conducted a study of the dependence of the gamma background level on precipitation. The following aspects analyzed the total duration of the recorded bursts, the duration of the rises and falls of the bursts, their shape, and the dependence of the magnitude at the height of the detector. The results of the study showed that most bursts of β-radiation dose rate and γ-radiation flux density coincide with periods of precipitation. However, the magnitude of bursts does not always correlate with the intensity of precipitation [20].

1.4 Chapter Conclusion

There are many methods for determining evaporation from the soil surface, many of which use parameters such as radiation balance and solar radiation.

The main contribution to the radiation background of the surface layer of the atmosphere is made by the natural background, which includes soil and atmospheric radionuclides.

Various meteorological parameters, such as pressure, temperature, wind speed, precipitation, etc., can affect changes in the magnitude of the gamma background of the surface atmosphere.

2 Measurement methods and instruments

2.1 Instruments for measuring gamma radiation

Gamma radiation dosimeters mainly based on gas discharge counters and designed to detect gamma radiation with energies in the range from 0.05 to 3.0 MeV. One example of dosimeters of this type is the dosimeter-radiometer DRBP-03 (Fig. 1) with a detection unit BDG-01.

Figure 1 – Dosimeter DRBP-03 [21]

Dosimeter DRBP-03 is used for operational dosimetric monitoring of the radiation situation; studies of radiation anomalies; compiling radiation maps of the area; detection of dirt on clothes, walls, floors, etc. [21].

Table 1 – Technical characteristics of the dosimeter DRBP-03

Characteristic	**Value**
The energy range of the registered ionizing photon radiation, MeV	0,05 – 3,0
Energy range of registered α-radiation	Pu-239
β-radiation, MeV	0,15 – 3,5
Measuring range of equivalent dose rate, μSv/h	0,10 – 3×10^6

Continuation of Table 1

Measuring range of equivalent dose, mSv	0,01 – 104
Measurement range of particle flux density, $s^{-1}cm^{-2}$	0,10 – 700
Basic relative measurement error, %	±15
Operating conditions of the instrument	-20°C …+50°C, 95 % humidity at 35°C
Weight of the complete set, kg	3

In addition, dosimeters and sensors based on scintillation detectors used to measure gamma radiation. Scintillators divided into two main classes: organic and inorganic.

Dosimeters based on organic scintillators, whose atomic numbers are close to the atomic number of human tissue, used to measure the ambient dose equivalent rate and the ambient dose equivalent of low-energy photons. Of the inorganic scintillators, single crystals of sodium iodide activated by thallium, single crystals of cesium and potassium iodide, also activated by thallium, are mainly used to detect gamma radiation [21].

There is a category of dosimeters (or dosimeters-radiometers) that classified as search devices. These devices measure either the equivalent dose rate of gamma radiation or the gamma radiation flux density from the surface under study and recommended for use to search for radiation sources. For example, such search devices include ISP-RM1401M, ISP-RM1401 K-01 and others. In these devices, a CsI(Tl) scintillator is used to detect gamma radiation [21].

In this work, the gamma background was measured using a BDKG-03 gamma radiation detection unit (Fig. 2) based on a scintillator NaI(Tl). This detection unit has a high sensitivity, which is a necessary condition for measuring the magnitude of the gamma background. The detection unit designed to search, quickly detect and localize sources of gamma radiation, as well as to measure the ambient equivalent dose rate and the dose of gamma radiation in the energy range of 50 keV-3 MeV.

Figure 2 – Gamma radiation detection unit BDKG-03

Table 2 – Technical characteristics of the detection unit BDKG-03

Detector	NaI(Tl) d = 25 x 40 mm
Range of ambient equivalent dose rate of gamma radiation	0,03 – 300 μSv/h
Range of ambient equivalent dose of gamma radiation	0,03 μSv – 10 mSv
Range of exposure dose rate of gamma radiation	3 μR/h – 30 mR/h
Range of exposure dose of gamma radiation	3 μR – 100 mR
Energy range	50 keV – 3 MeV
Basic measurement error, no more	±20 %
Energy dependence of sensitivity	±20 %
Sensitivity to ^{137}Cs	350 imp·s^{-1}/ μSv·h^{-1}
Dimensions	d = 60 x 295 mm
Weight, no more	0,6 kg

2.2 Instruments for measuring solar radiation

Various devices used to measure solar radiation: a thermoelectric actinometer that measures direct radiation; balance meter used to measure the radiation balance; pyranometer used in the measurement of total and scattered radiation and others.

At meteorological stations, as well as in scientific and engineering research, pyranometers often used to measure solar radiation.

The total energy flux of solar radiation measured by a pyranometer installed in a horizontal plane. The thermocouple sensor protected from external influences by one or two glass hemispherical caps, which also set the spectral sensitivity of the device. I also use the second pyranometer to measure the scattered solar radiation.

The flux of direct solar radiation measured using a pyrheliometer. The pyrheliometer is a thermocouple battery-based radiometer with a 5° field of view and a flat eyepiece.

The incoming solar radiation measured using a CM-11 pyranometer manufactured by Kipp&Zonen (рис. 3). The device is designed to measure the total and scattered radiation coming from both the Sun and the surface.

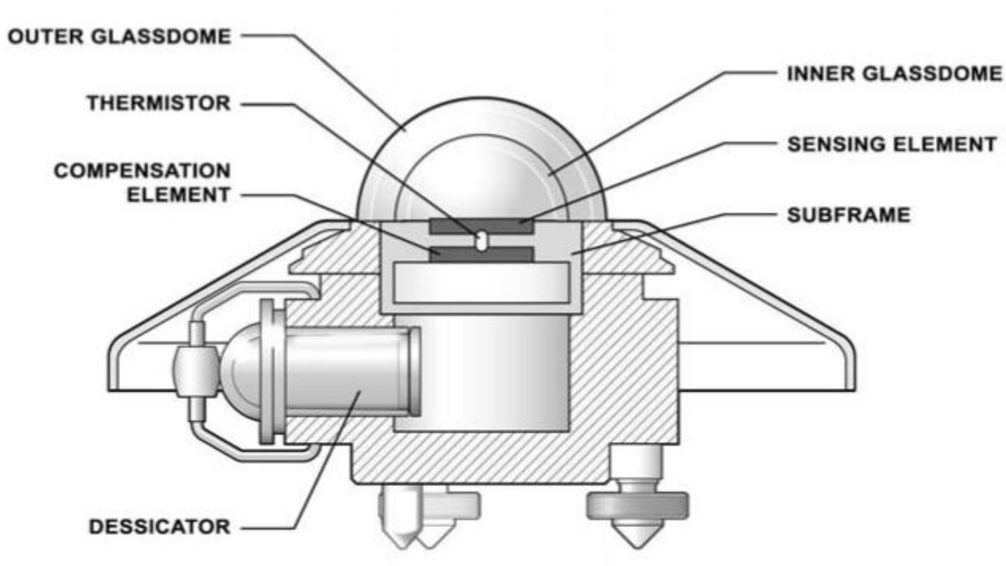


Figure 3 – Schematic representation of the design of the pyranometer CM 11

2.3 Experimental site

Measurements of natural gamma radiation were carried out at the experimental site (Fig. 4), owned by the Institute for Monitoring Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences (IMKES SB RAS) and located in Akademgorodok area of the city of Tomsk, during the summer period of 2021.

From 2009 to the present, NR TPU together with IMCES SB RAS has been studying the influence of various meteorological values of meteorological parameters on the dynamics of the radiation background, taking into account regional studies. Radiometric and dosimetric measurements of ionizing radiation, including α-, β-, γ-, neutron and X-ray radiation, in the surface layer at heights from 10 cm to 30 m and in the ground to a depth of 5 m, as well as monitoring of the characteristics of radon fields are made using measuring complexes of Tomsk Polytechnic University in continuous mode.

Figure 4 – Experimental site of the IMCES SB RAS

The gamma background was measured using dosimetric measuring equipment, including a dosimeter-radiometer DRBP-03 with a built-in γ-radiation detector and remote detectors of γ-radiation BDG-01 and α- and β-radiation BDBA-02 and a dosimetric measuring complex with sensors γ -radiation BDKG-03 based on a scintillator NaI(Tl).

Incoming solar radiation is measured using a pyranometer Kipp & Zonen CM-11 and photometer NILU-UV-6T.

3 Investigation of the relationship between the gamma background of the surface atmosphere and meteorological quantities

After studying the meteorological situation in Tomsk for 2021, the summer period chosen as the most favorable for studying the relationship between the gamma background, incoming solar radiation and relative air humidity. From this period, the month with the least amount of liquid atmospheric precipitation chosen, since they have a significant impact on the dynamics of the gamma background, causing sharp bursts. Figure 5 shows the dynamics of the total amount of liquid precipitation for three months of the summer period. The resulting graph shows that in August the least amount of precipitation fell.

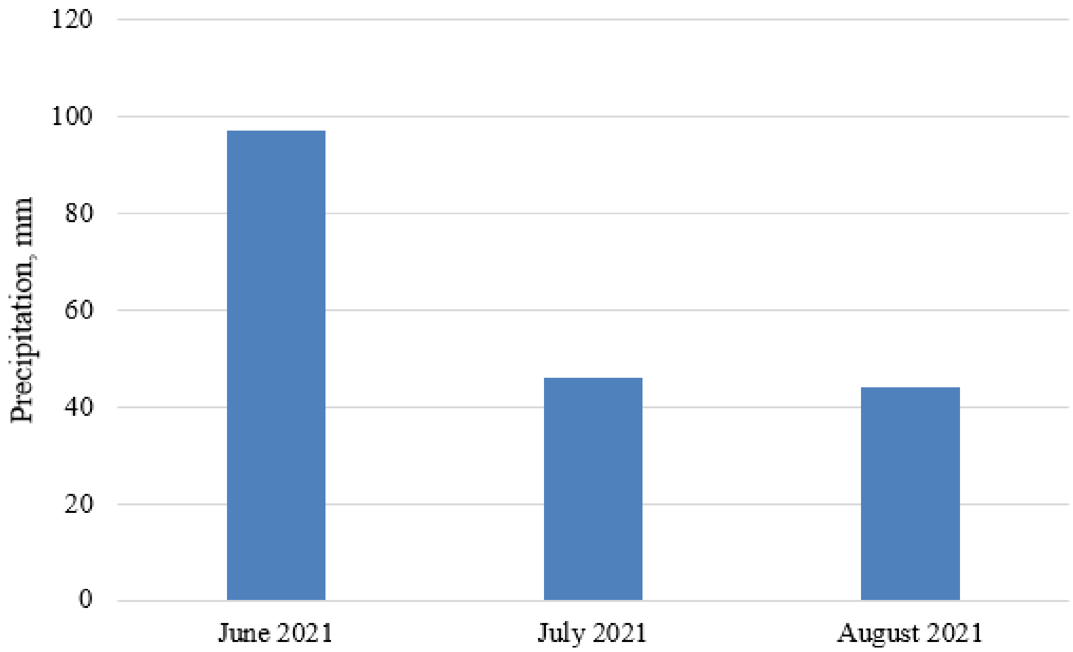


Figure 5 – The total amount of liquid precipitation by months

Data for August 2021 on incoming solar radiation, gamma background and relative air humidity were obtained as a result of measurements carried out on the territory of the IMCES SB RAS. Based on the data obtained, graphs were constructed, and correlation and regression analyzes were carried out. For statistical analysis and graphical presentation of the data, the program Microsoft Excel was used.

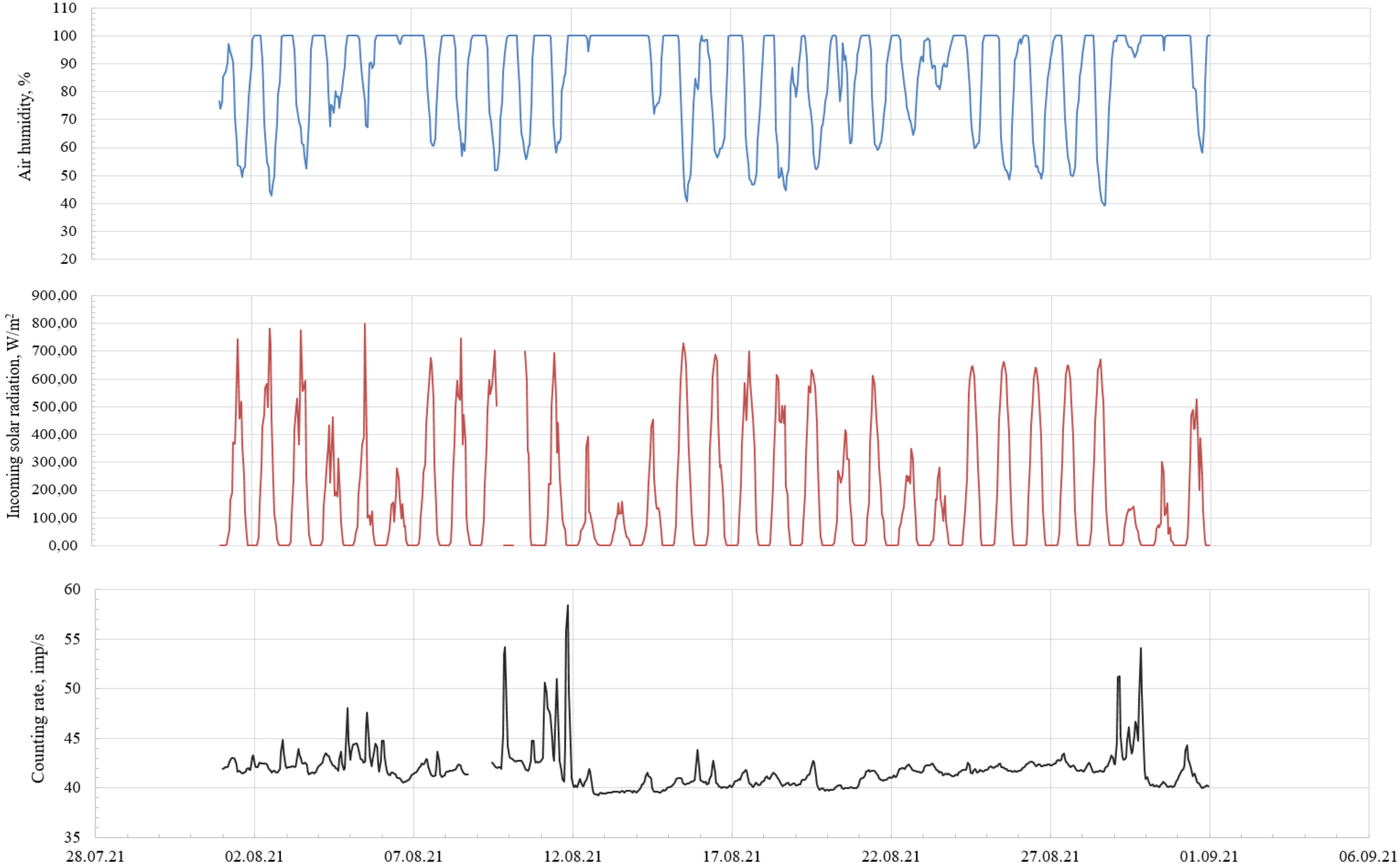


Figure 6 – Variations in the gamma background, solar radiation and air humidity for August 2021

A graph of the dynamics of the gamma background, as well as solar radiation and relative air humidity built (Fig. 6). On the graph presented in fig. 6, you can see the relationship between the studied parameters. However, the obtained correlation coefficient between the gamma background and incoming solar radiation for the selected period is insignificant and equals 0.01. Therefore, for a more detailed study, this time period was divided into several shorter ones.

3.1 Investigation of the relationship between the gamma background of the surface atmosphere and incoming solar radiation

A graph of the amount of liquid precipitation by day for August 2021 is shown in Figure 7.

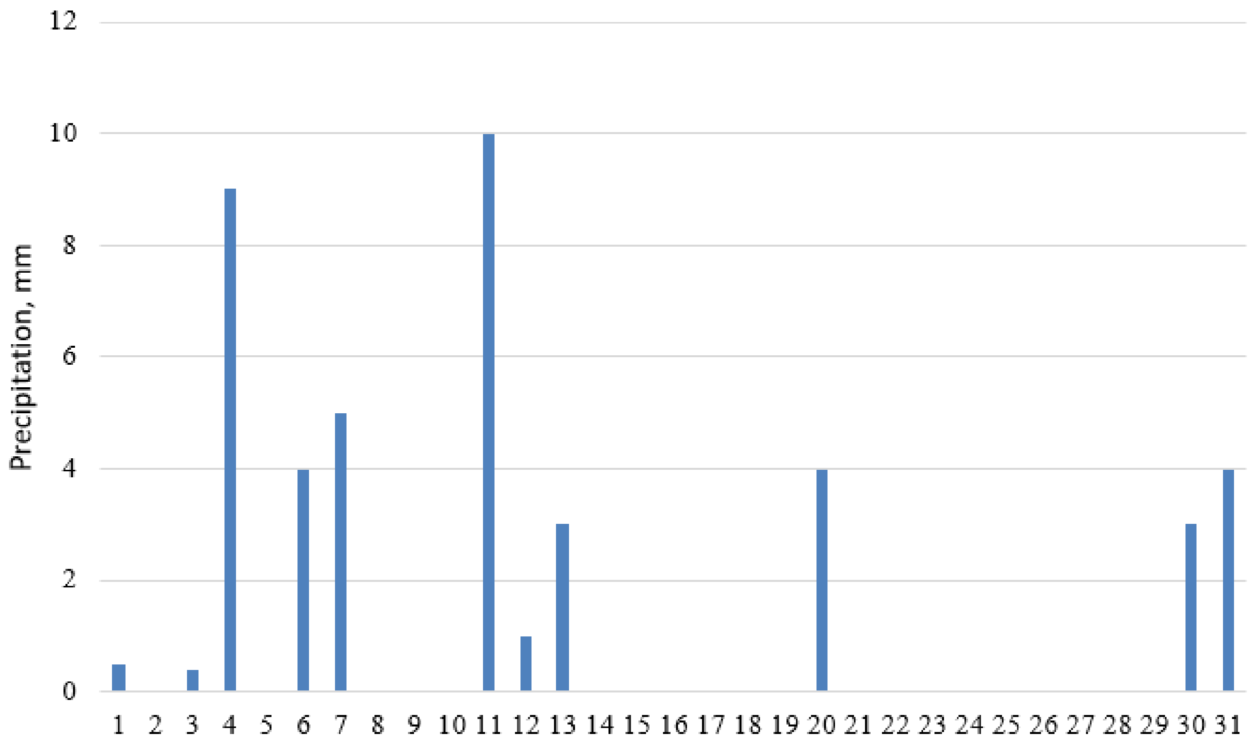


Figure 7 – Dynamics of the intensity of liquid precipitation for August 2021

For the study, days with precipitation and in their absence were selected. As can be seen from the graphs, an increase in the gamma-background count rate often coincides with an increase in the level of incoming solar radiation (Fig. 8). However, the correlation coefficient for the three selected days is 0.1.

Figure 8 – Variations in the gamma background and the magnitude of incoming solar radiation in the period from 03.08.2021 to 05.08.2021

When considering each day separately (Fig. 9-11), higher values of the correlation coefficients were obtained (Table 3). At the same time, higher correlation coefficients obtained on days with little or no precipitation.

Table 3 – Correlation coefficients for the counting rate and incoming solar radiation in the period from 3 to 5 August 2021

Date	Correlation coefficient
03.08.2021	0,55
04.08.2021	-0,31
05.08.2021	0,54

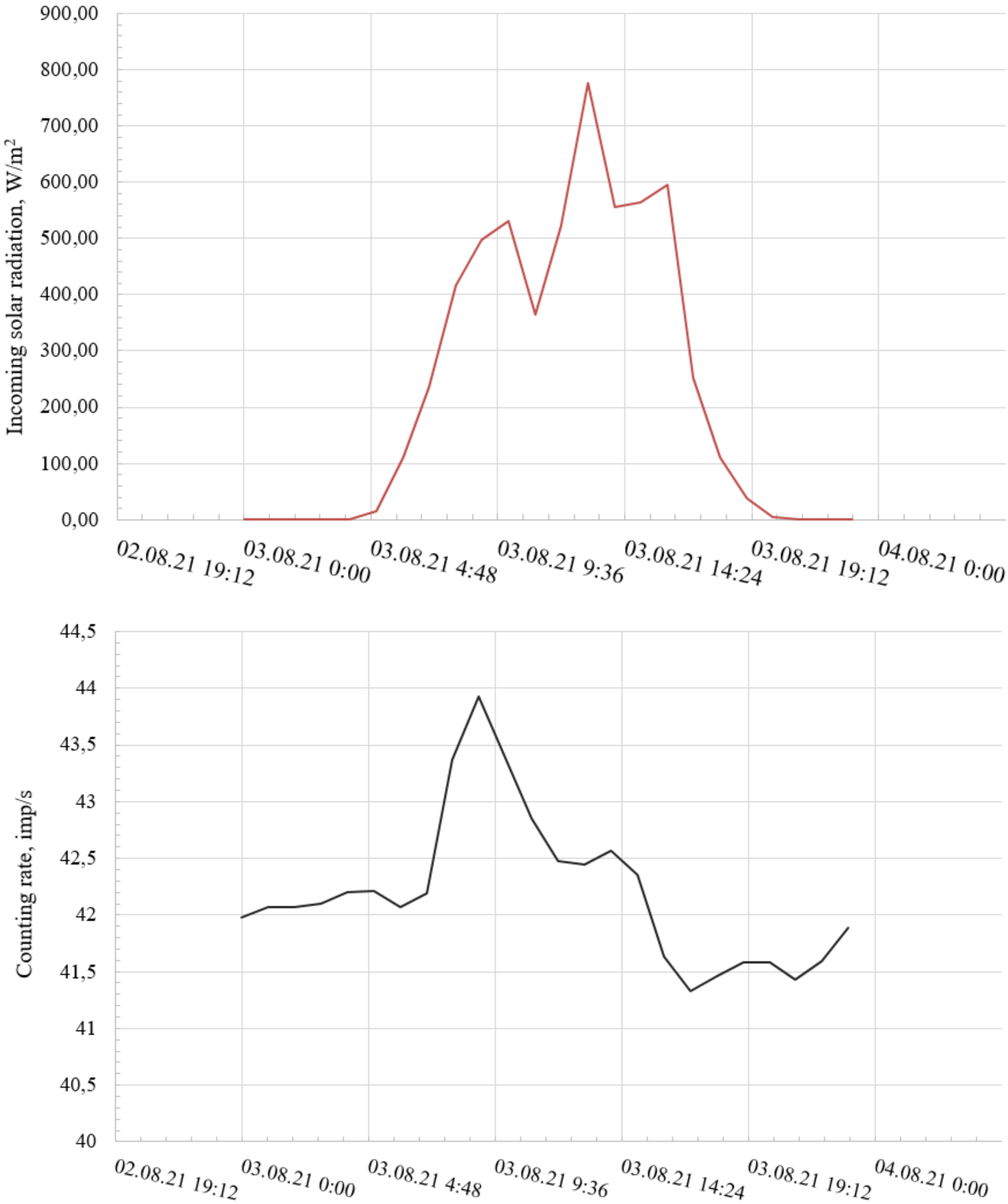


Figure 9 – Daily dynamics of the gamma background and the magnitude of incoming solar radiation (03.08.202)

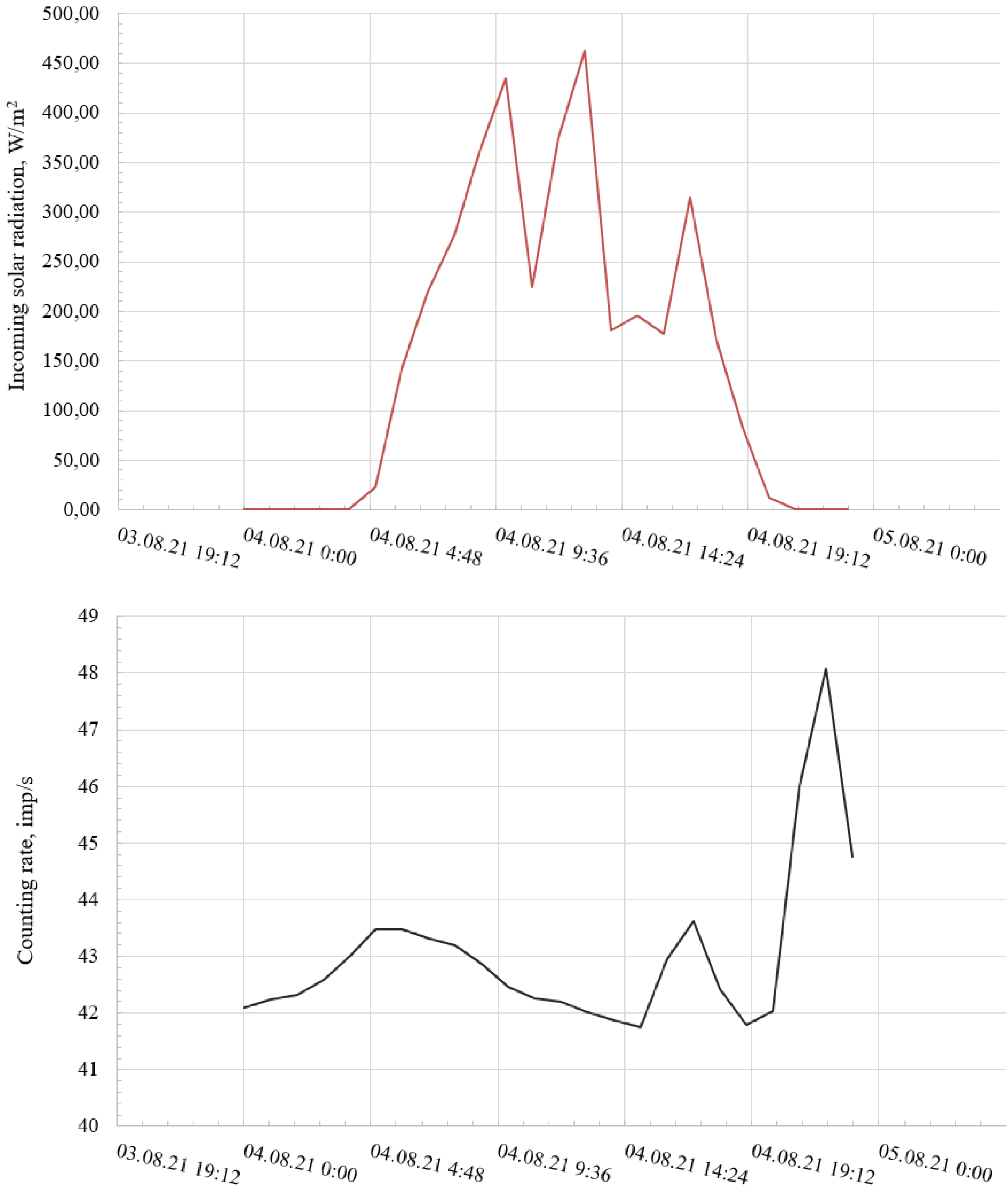


Figure 10 – Daily dynamics of the gamma background and the magnitude of incoming solar radiation (04.08.2021)

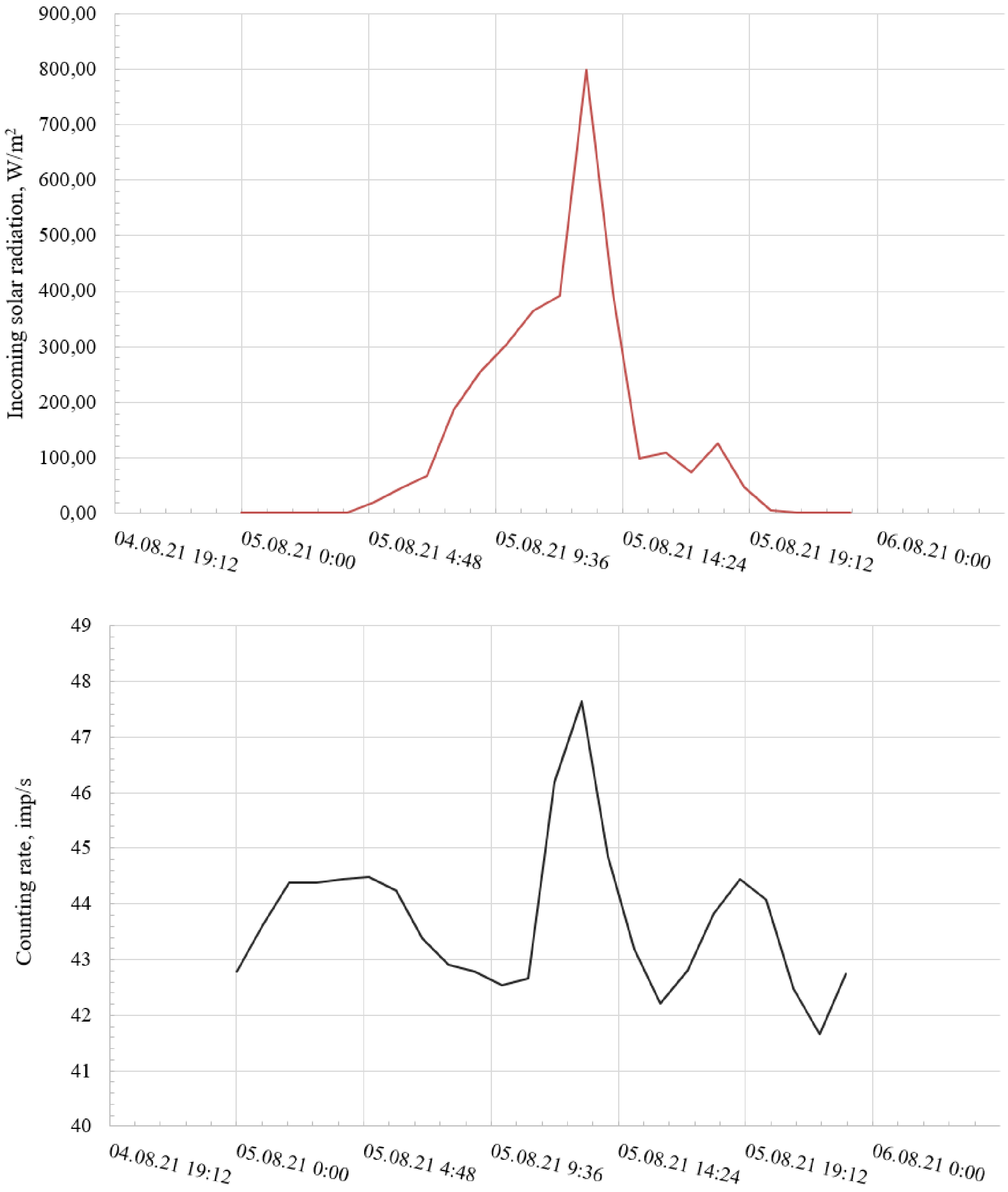


Figure 11 – Daily dynamics of the gamma background and the magnitude of incoming solar radiation (05.08.2021)

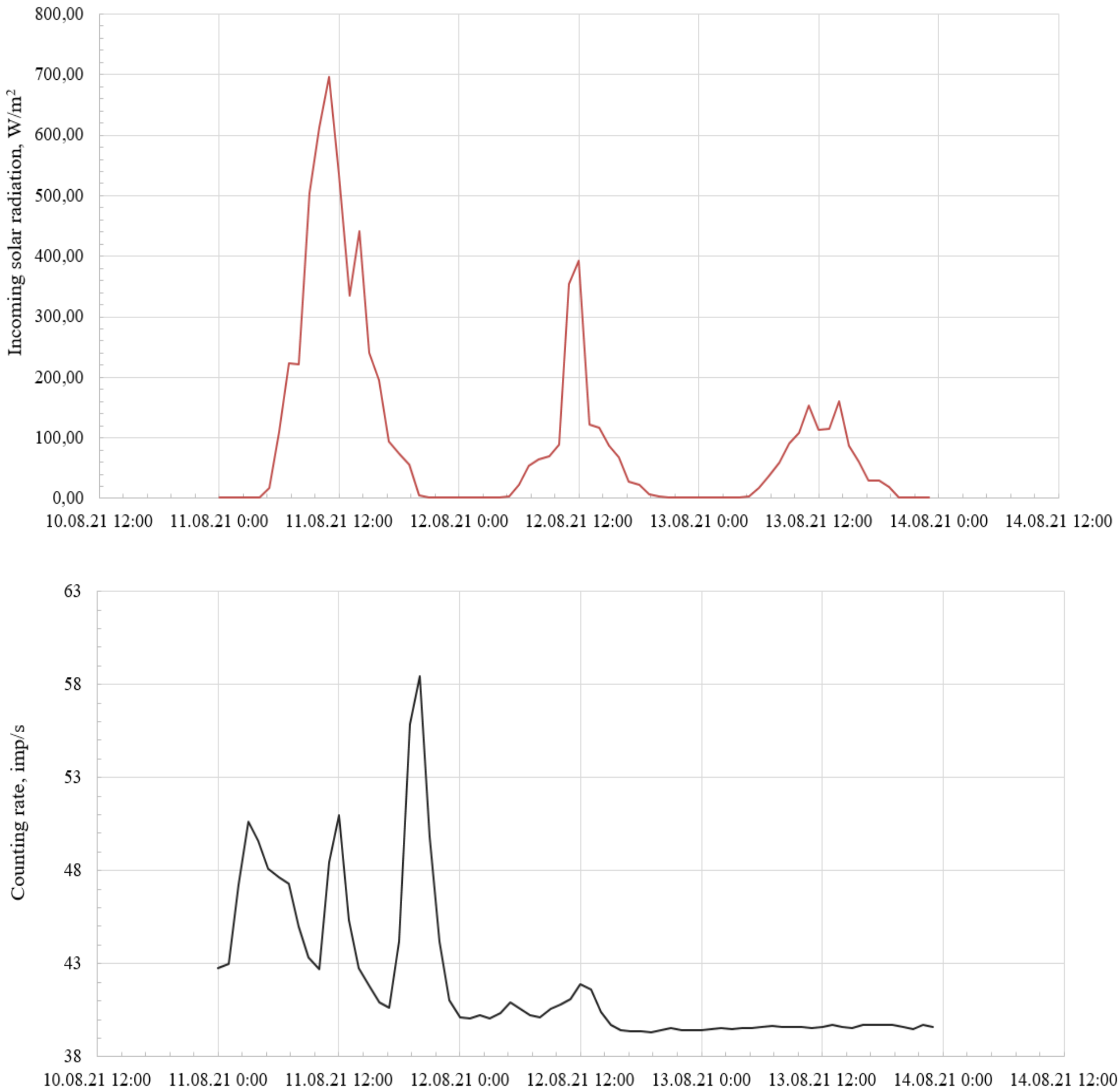


Figure 12 – Variations in the gamma background and the magnitude of incoming solar radiation in the period from 11.08.2021 to 13.08.2021

Also, during the month there are days when the gamma background variations do not coincide with the change in solar radiation, for example, on August 11 and 13 (Fig. 12, 13). At the same time, the highest correlation coefficient (0.67) is observed on the day with the least amount of precipitation.

Table 4 – Correlation coefficients for the counting rate and incoming solar radiation in the period from 11 to 13 August 2021

Data	Correlation coefficient
11.08.2021	-0,16
12.08.2021	0,67
13.08.2021	0,19

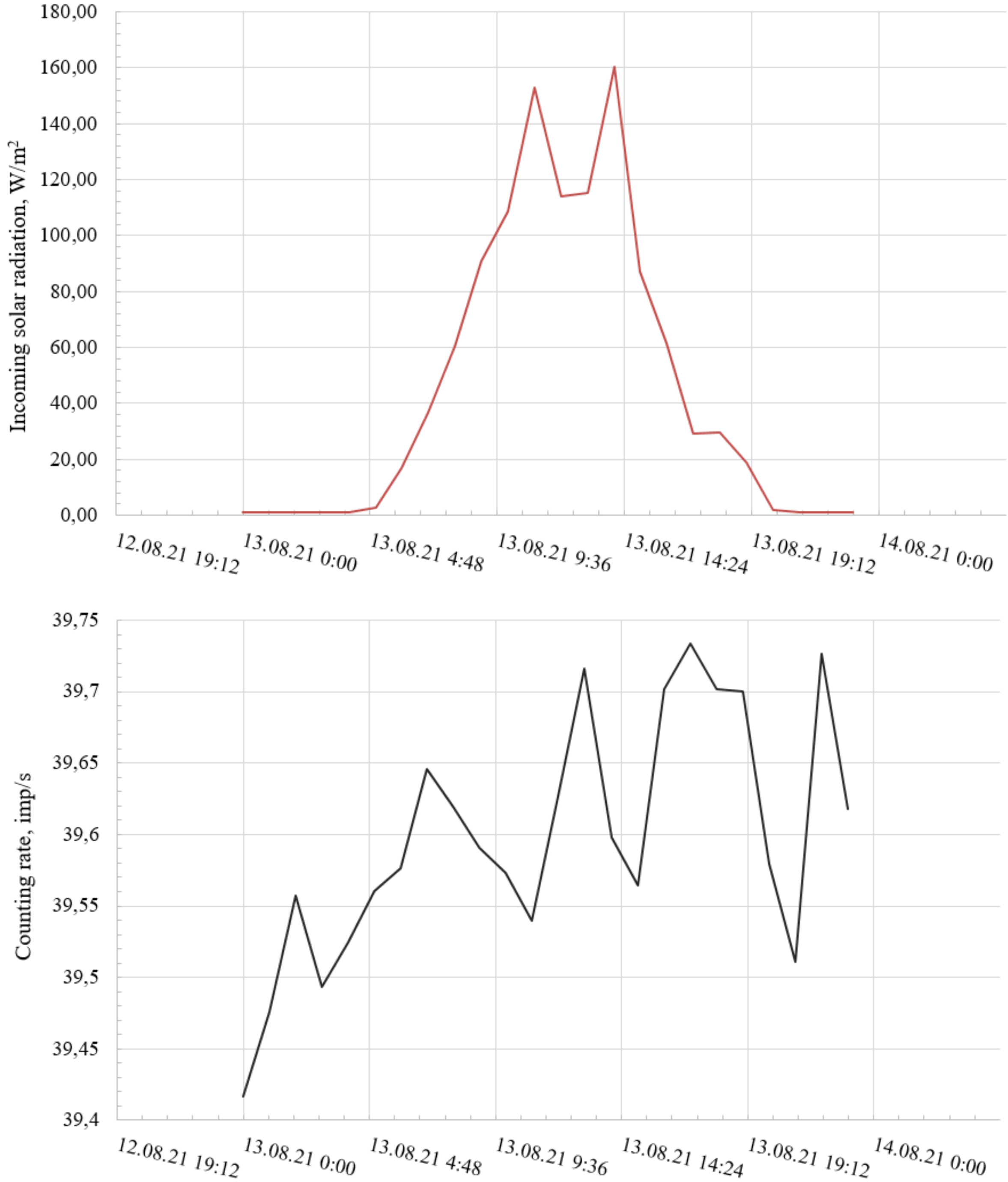
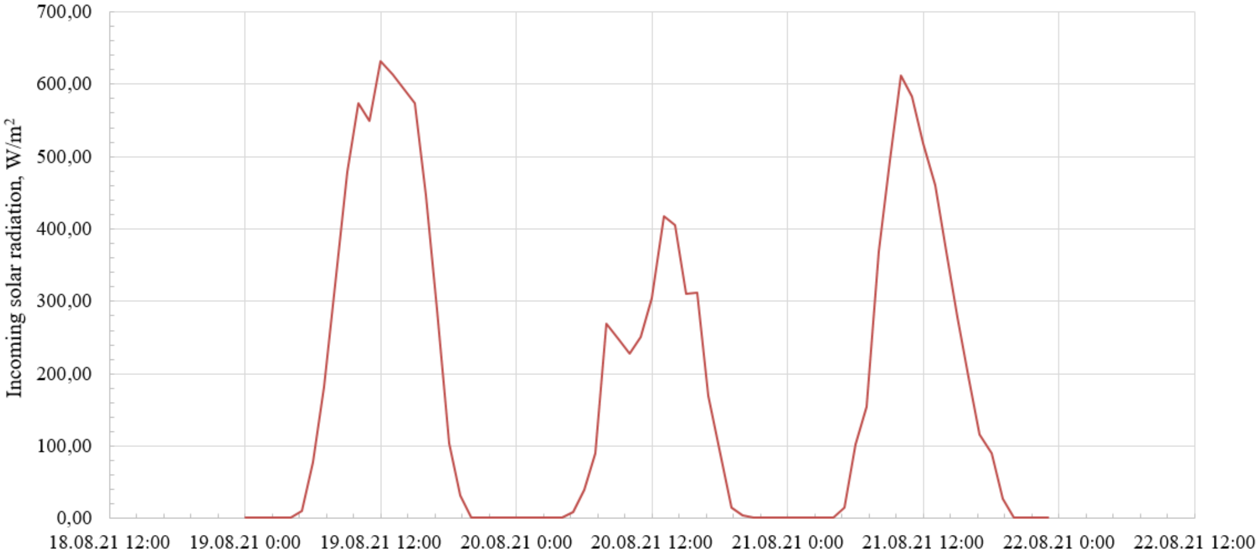


Figure 13 – Daily dynamics of the gamma background and the magnitude of incoming solar radiation (13.08.2021)



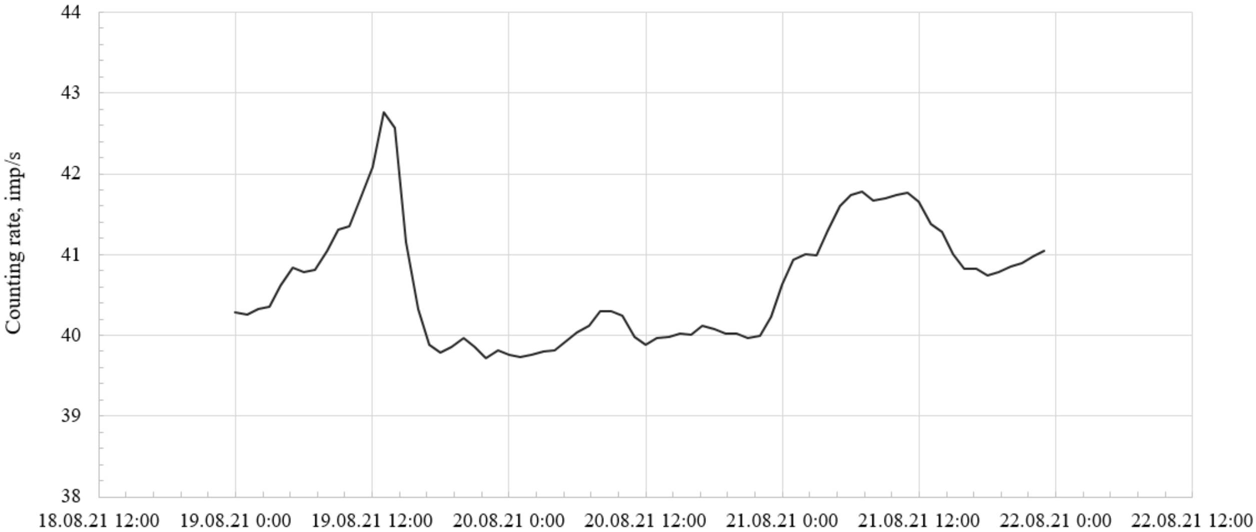


Figure 14 – Variations in the gamma background and the magnitude of incoming solar radiation in the period from 19.08.2021 to 21.08.2021

The correlation analysis carried out for the selected dates showed that there is a relationship between incoming solar radiation and the gamma background of the surface atmosphere. On some days, a particularly pronounced relationship between these parameters observed, for example, on August 19 (Fig. 15) and August 21 (Fig. 16), when there is no liquid precipitation. On other days, the correlation coefficient becomes negative (Tables 3, 4). Such variations in the dependence of the gamma background on solar radiation may occur due to the fact that many other meteorological factors can influence its value. In addition, this paper did not consider the processes of changing the gamma background at night, when the amount of incoming solar radiation is zero.

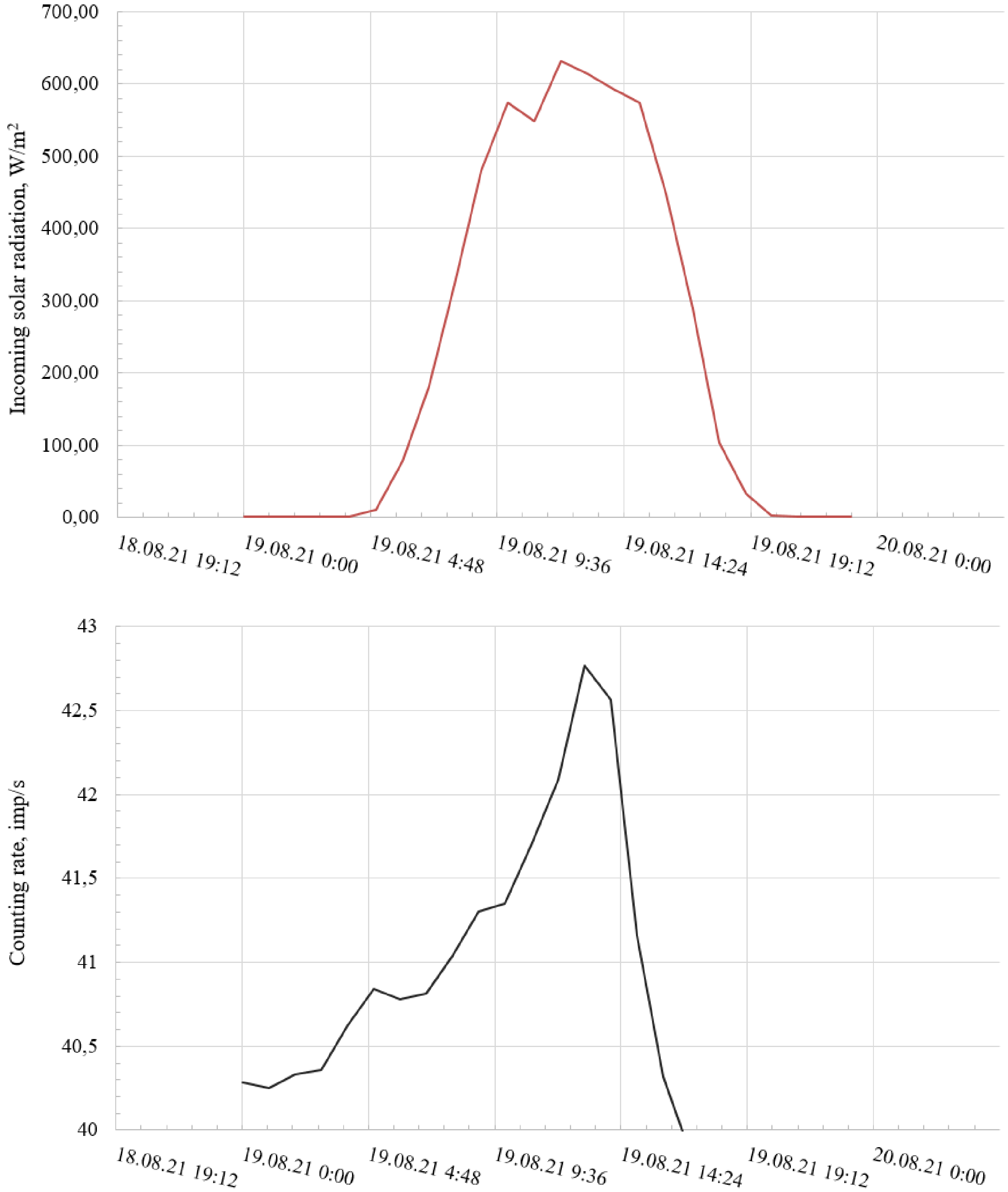


Figure 15 – Daily dynamics of the gamma background and the magnitude of incoming solar radiation (19.08.2021)

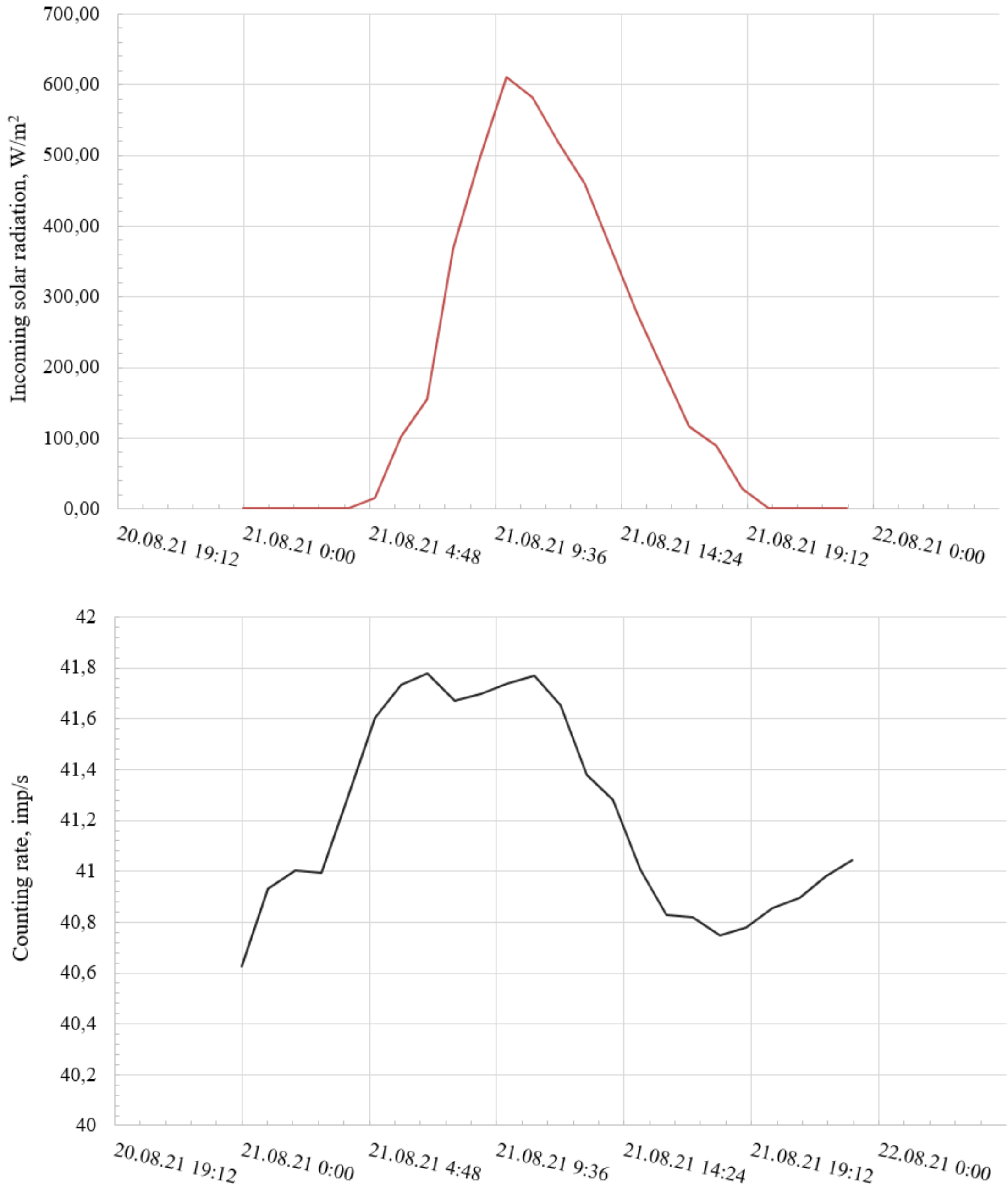
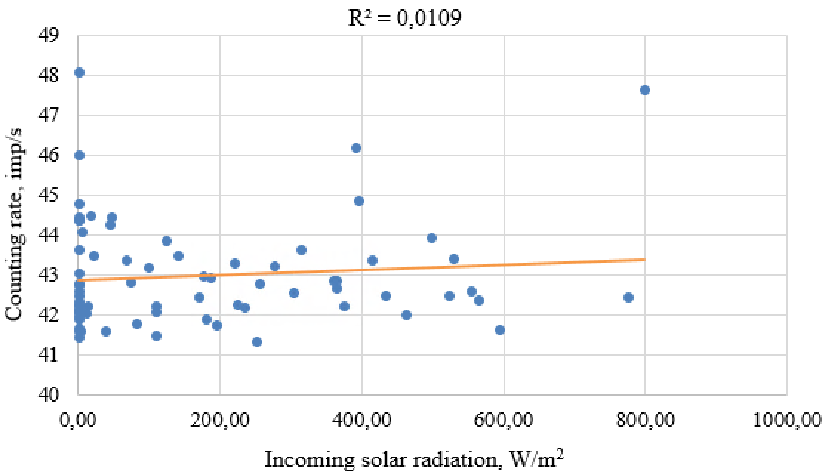


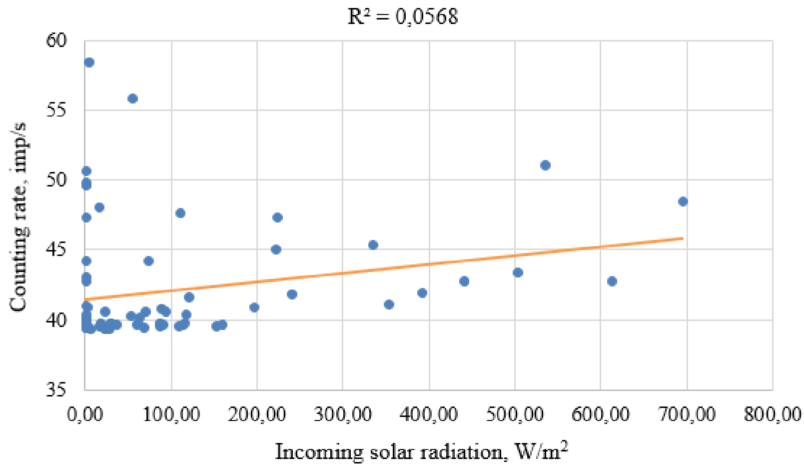
Figure 16 – Daily dynamics of the gamma background and the magnitude of incoming solar radiation (21.08.2021)

Table 5 – Correlation coefficients for the counting rate and incoming solar radiation in the period from 19 to 21 August 2021

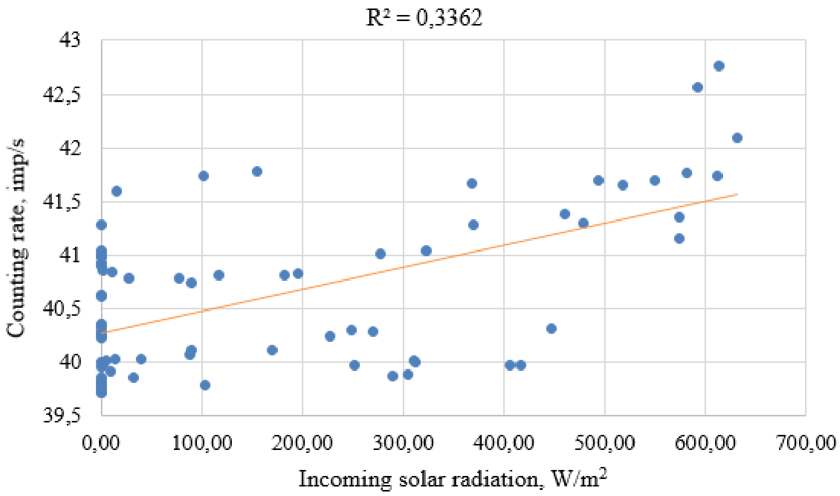
Date	Correlation coefficient
19.08.2021	0,81
20.08.2021	0,34
21.08.2021	0,66



a)



b)



c)

Figure 17 – Regression dependencies between the gamma background and incoming solar radiation: a) the period from 03.08.2021 to 05.08.2021; b) the period from 11.08.2021 to 13.08.2021; c) the period from 19.08.2021 to 21.08.2021

Along with the correlation analysis, a linear regression analysis also carried out for three selected time intervals. The results of the analysis are presented in fig. 17. The maximum value of the coefficient of determination among the selected time periods is 33.6%.

Since precipitation has a significant impact on the results of correlation and regression analyses, it decided to select a number of days before and after precipitation in the form of rain for further research. The average daily dynamics of changes in the gamma background and incoming solar radiation built for the periods from 14 to 19 August (Fig. 18) and from 21 to 28 August (Fig. 19).

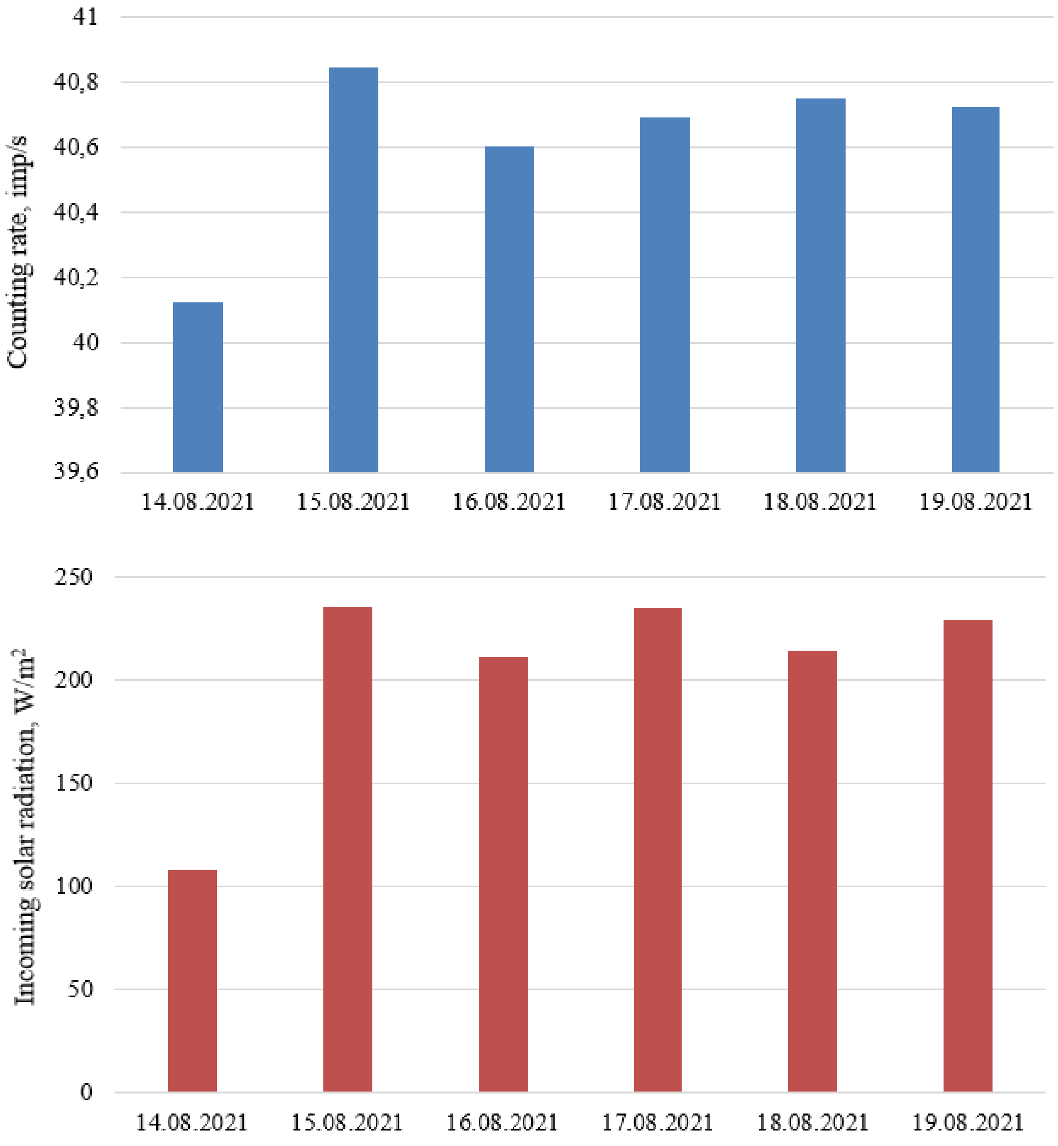


Figure 18 – Average daily dynamics of the gamma background and incoming solar radiation in the period from 14.08.2021 to 19.08.2021

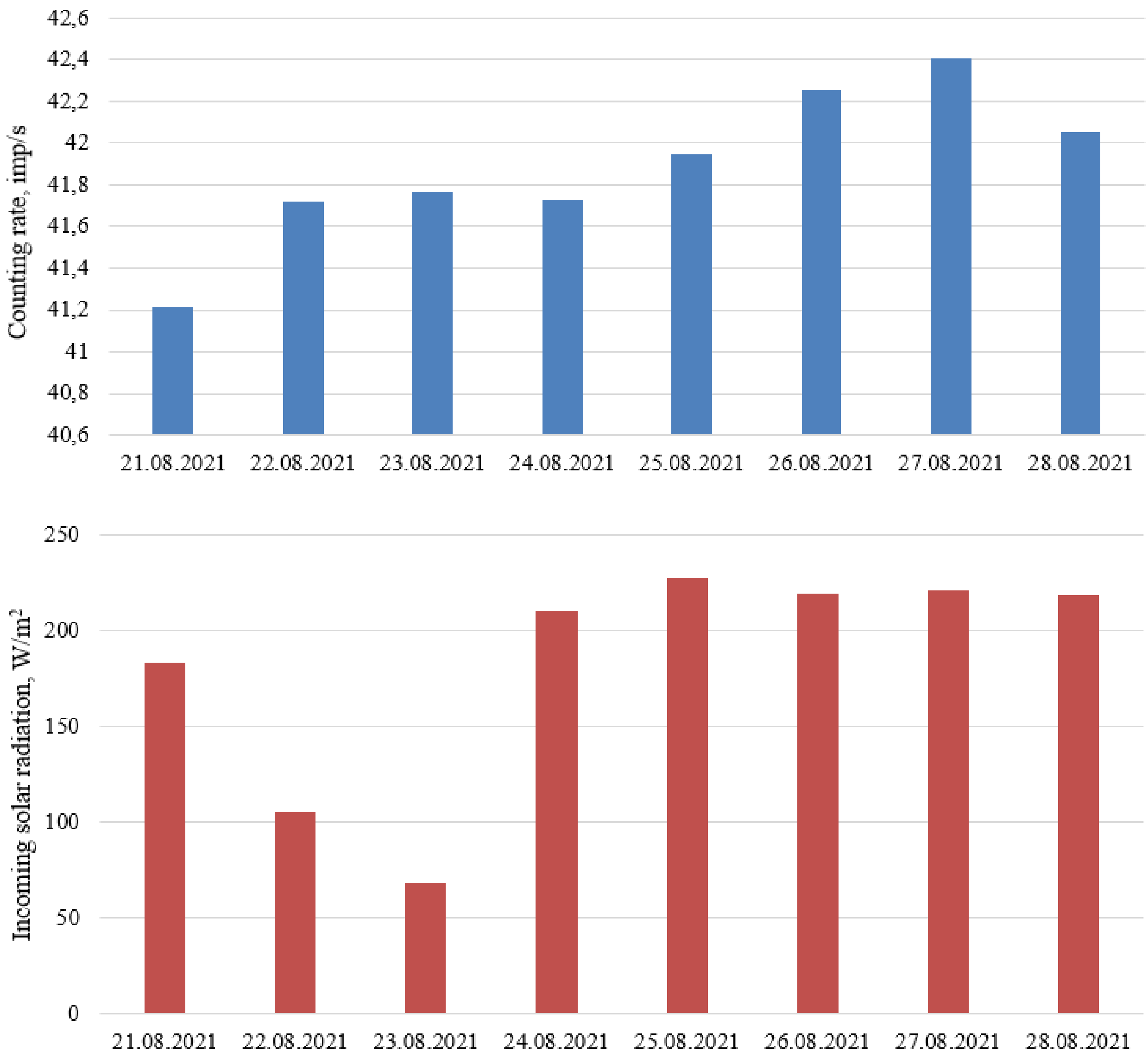
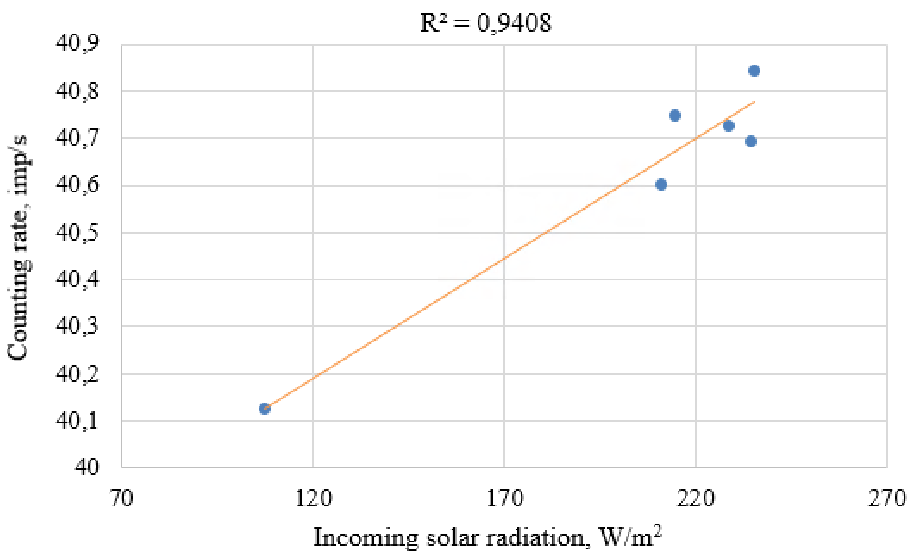
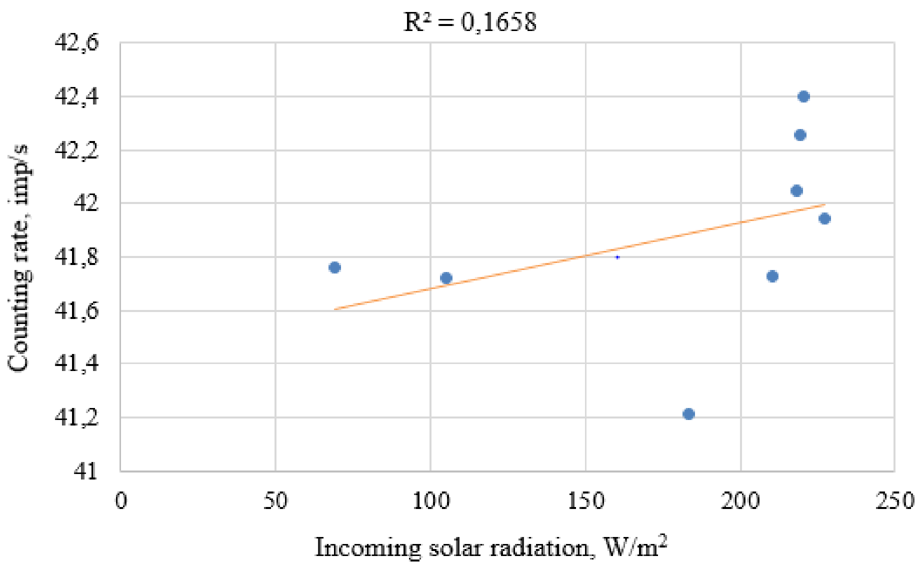


Figure 19 – Average daily dynamics of the gamma background and incoming solar radiation in the period from 21.08.2021 to 28.08.2021

For the period from August 14 to 19, the correlation coefficient and the determination coefficient have high values, 0.97 and 94%, respectively (Fig. 20a), which indicates a strong dependence. For the period after the rain, the coefficients of correlation and determination have lower values, 0.41 and 17% (Fig. 20b), respectively.



a)



b)

Figure 20 - Regression dependence between the gamma background and incoming solar radiation a) in the period from 14.08.2021 to 19.08.2021; b) in the period from 21.08.2021 to 28.08.2021

3.2 Investigation of the relationship between the gamma background of the surface atmosphere and the relative humidity of the air

To study the relationship between the gamma background and relative air humidity, the same time intervals chosen as in the study of the relationship between the gamma background and incoming solar radiation.

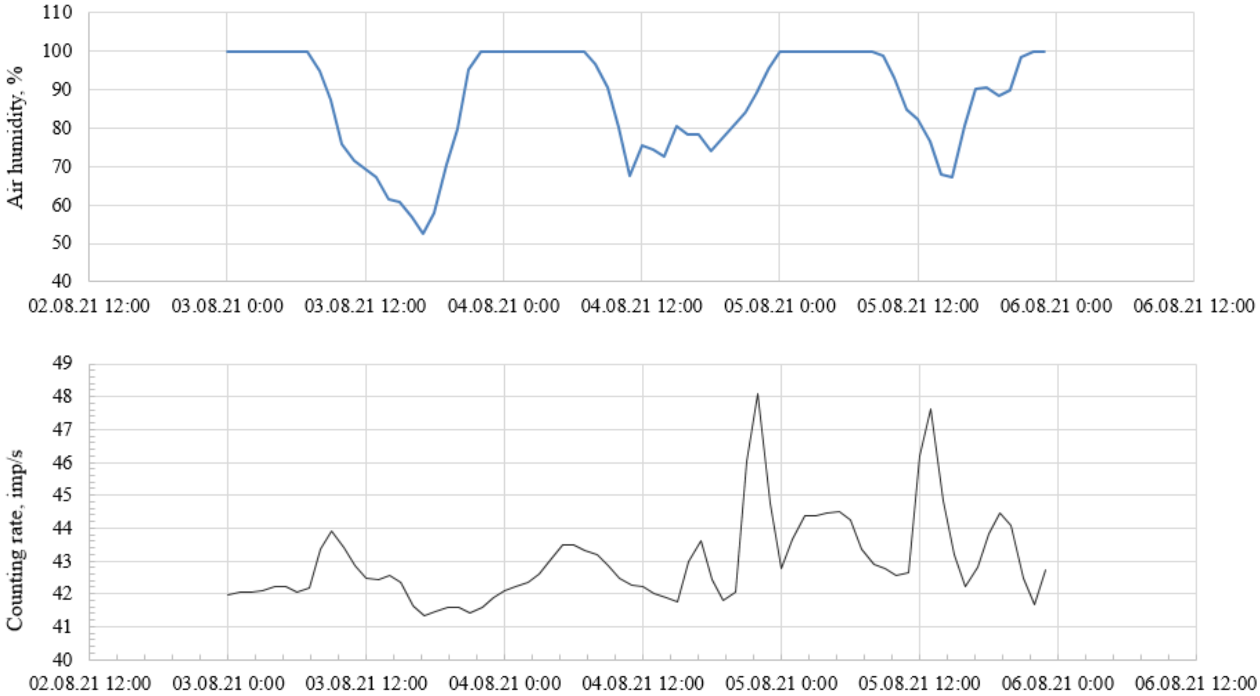


Figure 21 – Variations in the gamma background and relative air humidity in the period from 03.08.2021 to 05.08.2021

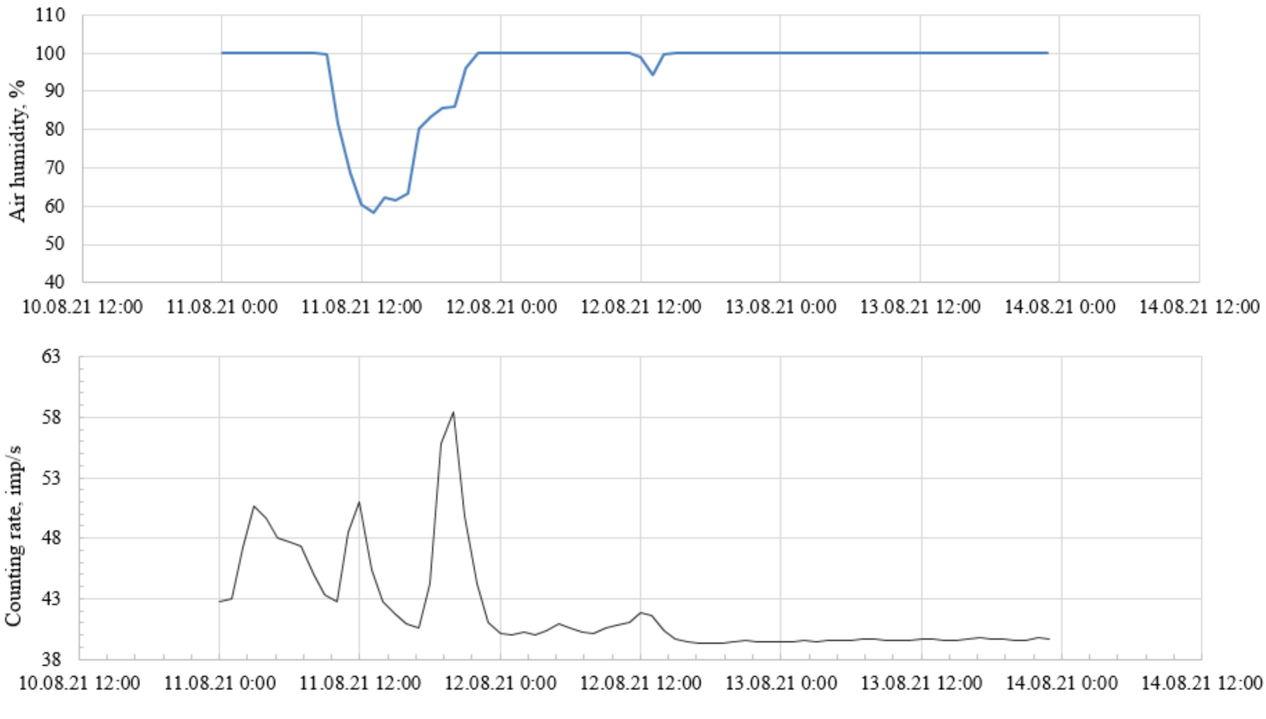


Figure 22 – Variations in the gamma background and relative air humidity in the period from 11.08.2021 to 13.08.2021

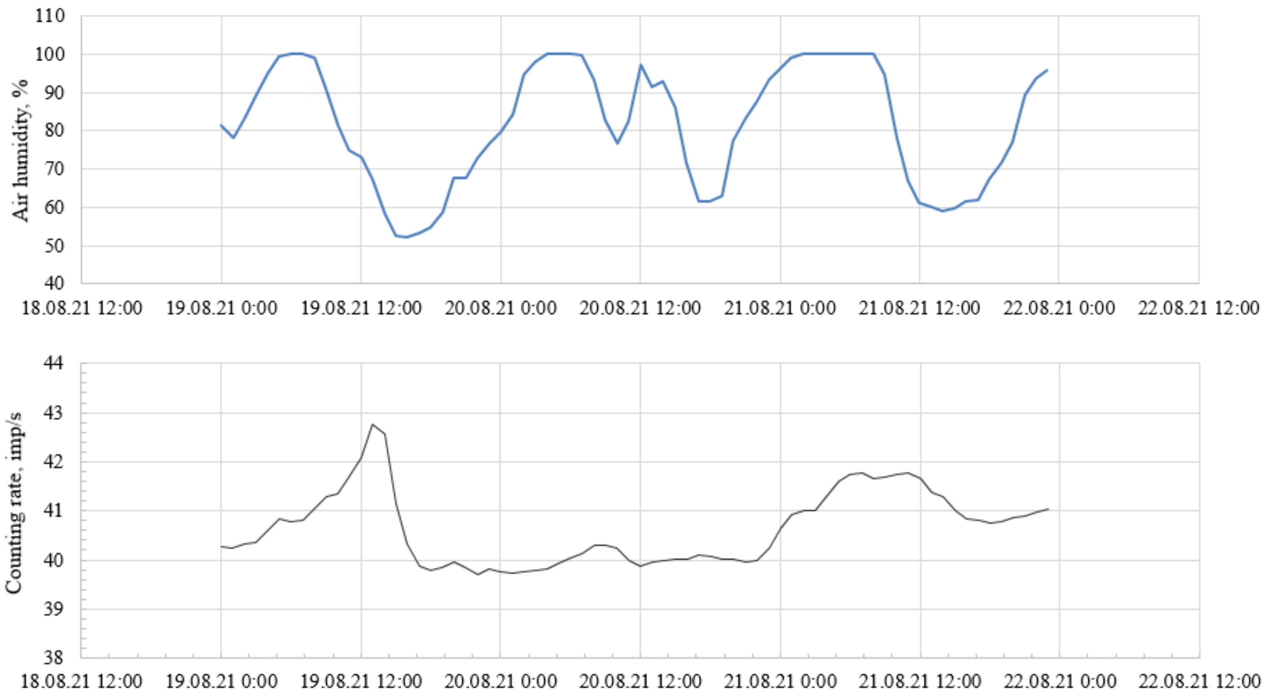
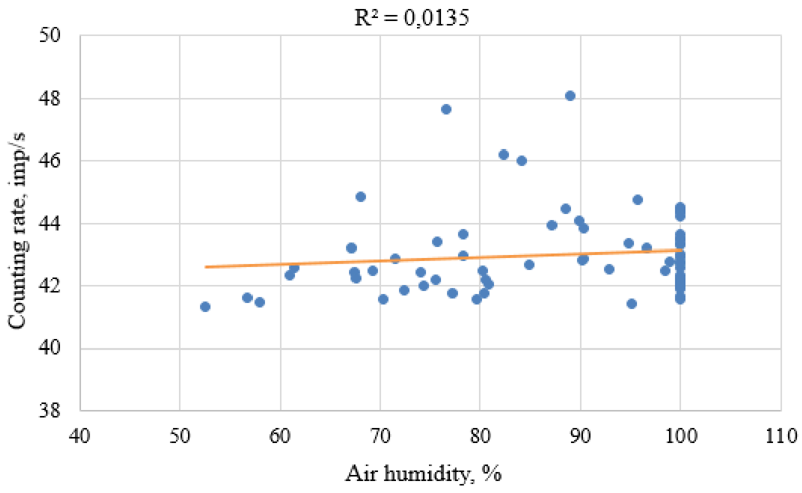


Рисунок 23 – Variations in the gamma background and relative air humidity in the period from 19.08.2021 to 21.08.2021

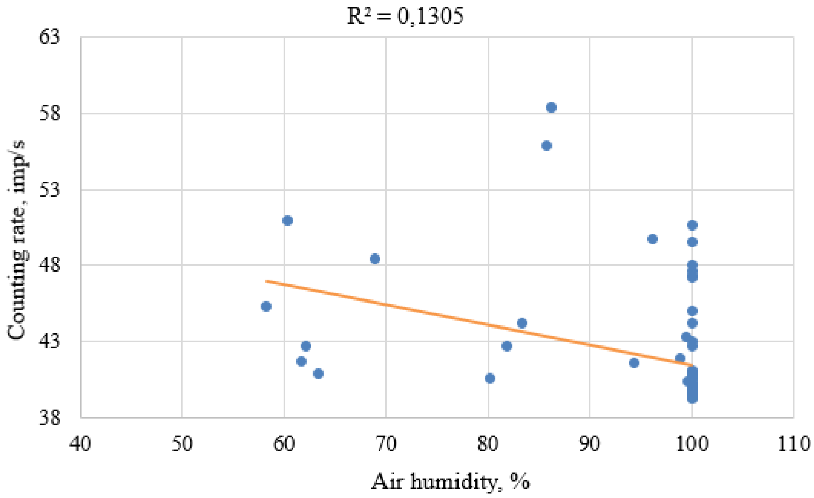
From the graphs in Figures 21-23, it can be seen that there is a correlation between the data. However, the obtained correlation coefficients for each individual day (Table 6) turned out to be less than the correlation coefficients for incoming solar radiation. The greatest dependence between the gamma background and relative humidity observed on August 12 (correlation coefficient -0.51).

Table 6 – Correlation coefficients for counting rate and relative air humidity

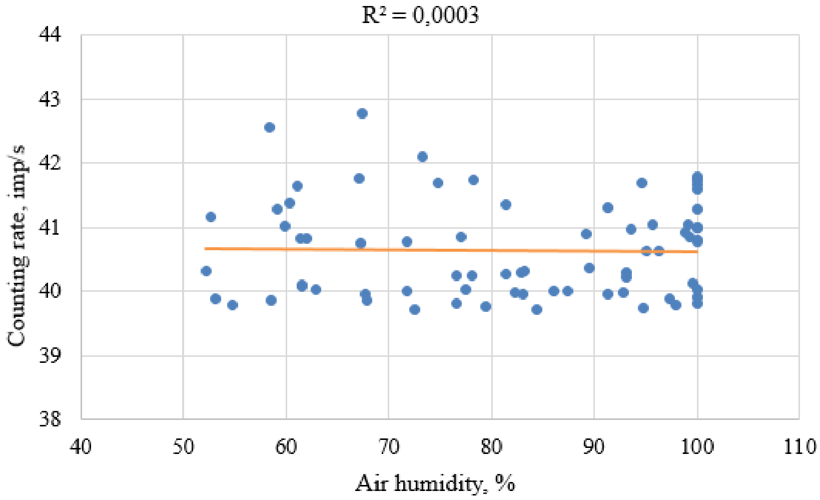
Date	Correlation coefficient
03.08.2021	0,07
04.08.2021	0,22
06.08.2021	-0,33
11.08.2021	0,11
12.08.2021	-0,51
19.08.2021	0,08
20.08.2021	-0,22
21.08.2021	0,15



a)



b)



c)

Figure 24 – Regression dependences between the gamma background and relative air humidity: a) the period from 03.08.2021 to 05.08.2021; b) the period from 11.08.2021 to 13.08.2021; c) the period from 19.08.2021 to 21.08.2021

3.3 Chapter Conclusion

At the site of the IMCES SB RAS in the summer period of 2021, measurements of incoming solar radiation, gamma background and relative air humidity were made.

Correlation and regression analysis of experimental data was carried out.

The results of the analysis indicate the existence of a relationship between the incoming solar radiation and the gamma background; in certain time intervals the correlation coefficient reaches values of 0.7-0.8, in some cases up to 0.97. At the same time, it is clear that such external factors as precipitation violate this dependence.

Comparison of the dependence of the gamma background and the relative humidity of the air showed a weak dependence. Correlation coefficients turned out to be less than for incoming solar radiation.

Thus, the values of the gamma background can be used in modeling the processes of evaporation from the soil surface during the time free from precipitation.

4 Financial management, resource efficiency and resource saving

4.1 Assessment of the commercial potential and prospects for conducting scientific research from the standpoint of resource efficiency and resource saving

This work is part of a study to determine the relationship between the evaporation rate and the gamma background.

The object of the chapter is to assess the prospects of the conducted scientific research and design a competitive method that meets modern requirements in the field of resource efficiency and resource saving. To achieve the object, the following tasks were accomplished: assessment of commercial potential and perspective of scientific research; scheduling of scientific research; determination of resource and financial efficiency of the research.

4.1.1 Potential consumer of the research results

Various meteorological and geological organizations can show interest in the study conducted. During the market research, a number of enterprises were identified that could potentially be interested in the results of the research.

- Federal Service of Russia for Hydrometeorology and Environmental Monitoring;
- Federal State Unitary Enterprise "Emergency Technical Center of the Ministry of Atomic Energy of Russia";
- Tomsk Center for Hydrometeorology and Environmental Monitoring.

4.1.2 Analysis of competitive technical solutions

Analysis of competitive technical solutions from the standpoint of resource efficiency and resource saving makes it possible to assess the comparative effectiveness of scientific development and determine directions for its future improvement.

The analysis carried out using a scorecard (Table 7). For this, two competitive developments were selected. The criteria for comparing and evaluating resource efficiency and resource saving are given in Table. 7, were selected based on the selected objects of comparison, taking into account their technical and economic features of development, creation and operation.

Table 7 – Scorecard for comparing competitive technical solutions

Criteria for evaluation	Criteria weight	Points			Competitiveness		
		P_f	P_{c1}	P_{c2}	C_f	C_{c1}	C_{c2}
1	2	3	4	5	6	7	8
Technical criteria for evaluating resource efficiency							
1. Data run time	0,2	5	4	4	0,5	0,4	0,4
2. Noise immunity	0,07	4	4	3	0,5	0,5	0,3
3. Security	0,2	5	5	4	0,4	0,4	0,3
4. Demand for memory resources	0,05	5	3	3	0,5	0,3	0,3
5. Functional capacity (provided opportunities)	0,06	5	4	4	0,35	0,3	0,3
6. Easy operation	0,09	5	3	4	0,45	0,35	0,3
7. Availability of expensive equipment	0,1	5	4	4	0,5	0,4	0,4
Economic criteria for evaluating efficiency							
1. Product competitiveness	0,03	5	3	2	0,2	0,2	0,15
2. Price	0,1	5	3	1	0,4	0,3	0,3
3. Financing of scientific development	0,05	3	4	2	0,3	0,3	0,4

The position of the development and competitors was evaluated for each criteria by a five-point scale, where 1 is the weakest position, and 5 is the strongest. The weights of the criteria, determined by an expert, should add up to 1.

Analysis of competitive technical solutions determined by the formula:

$$C = \sum W_i \cdot P_i , \quad (1)$$

where C is the competitiveness of a scientific development or a competitor;

W_i – criteria weight (in fractions of a unit);

P_i – score of the *i*-th criteria.

In the existing state systems of radiation monitoring, only one parameter is continuously measured - the dose rate of γ-radiation. The developed technique is simple and economical compared to competitive methods for measuring radiation quantities in the atmosphere, since it allows measuring, in addition to gamma radiation, the flux density of beta radiation, etc.

This analysis allows us to say that the study is effective, as it provides an acceptable quality of results. Further investment in this development can be considered appropriate.

4.1.3 SWOT analysis

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

SWOT analysis consists in describing the strengths and weaknesses of the project, in identifying opportunities and threats for the implementation of the project that have manifested or may appear in its external environment. SWOT analysis of this research project presented in Table 8.

Таблица 8 – SWOT matrix

	Strengths of the research project: S1. The novelty of the idea of scientific research. S2. Sufficient reliability of the installation. S3. Installation safety. S4. Maintainability of each individual unit of the installation. S5. Ease of operation of the installation	Weaknesses of the research project: W1. Lack of funding. W2. Long processing time. W4. Lack of awareness of this type of study. W5. Long delivery time of materials and components used for scientific research.

Continuation of Table 8

Capabilities: C1. Using the innovative structure of TPU. C2. Cooperation with a number of new organizations. C3. The emergence of additional demand for a new product.	Results of the analysis of the interactive matrix of the project fields "Strengths and Capabilities": 1. Growth in demand for research of this type due to distribution among various organizations and universities. 2. Priority to this study in comparison with competitors due to the implementation of the proper reliability and safety of the installation.	Results of the analysis of the interactive matrix of the project fields "Weaknesses and Capabilities": 1. The absence of a large number of orders for research. 2. Priority of competitive organizations due to the long term of research.
Threads: T1. Competition. T2. Lack of funding from both the university and the state. T3. Depreciation of equipment.	Results of the analysis of the interactive matrix of the project fields "Strengths and Threads": 1. Implementation of the repair of the current installation without replacing the component parts. 2. Resistance to the fight against competitors due to the novelty of the idea.	Results of the analysis of the interactive matrix of the project fields "Weaknesses and Threads": 1. Lack of demand for technology due to its unstable competitiveness. 2. Research stagnation due to lack of funding.

Based on the results of the analysis of this matrix, it can be concluded that the difficulties and problems that this research project may encounter in one way or another can be solved due to the existing strengths of the study.

4.2 Research planning

4.2.1 Structure of works within the framework of scientific research

Planning designed to ensure the rational use of time and is undoubtedly an important step in the formation of research work. The planning of the complex of proposed works carried out in the following order:

- determination of the structure of work within the framework of scientific research;
- identification of participants in each work;
- establishing the duration of work;
- building a schedule for scientific research.

To carry out scientific research, a working group is formed, which may include researchers and teachers, engineers, technicians and laboratory assistants, the number of groups may vary. As part of this work, a working group was formed, which included supervisor and student. In this section, a list of stages and works for the implementation of the study was compiled, which is presented in Table 9.

Table 9 – List of stages, works and distribution of performers

Main stages	№ work	Content of works	Position of the performer
Development of technical specifications	1	Drafting and approval of technical specifications	Scientific supervisor, student
Choice of research direction	2	Selection and study of materials on the topic	Scientific supervisor, student
	3	Conducting patent research	Scientific supervisor, student
	4	Choice of research direction	Scientific supervisor
	5	Scheduling work on the topic	Scientific supervisor, student
Theoretical study	6	Search of literary sources	Scientific supervisor, student
	7	Analysis of literary sources	Student

Continuation of Table 9

Experimental study	8	Obtaining data on the dose rate of γ-radiation in the surface atmosphere from IMCES data	Scientific supervisor, student
	9	Obtaining data on solar radiation from IMCES	Scientific supervisor, student
	10	Plotting Gamma Radiation vs. Solar Radiation	Student
	11	Analysis and presentation of results	Student
Generalization and evaluation of results	12	Evaluation of the results	Scientific supervisor
Registration of a set of documentation for the FQP	13	Evaluation of the effectiveness of the study and application of the results	Student, FM consultant
	14	Development of social responsibility on the topic	Student, SR consultant
	15	Drawing up an explanatory note	Student

4.2.2 Determining the complexity of the work

The complexity of the implementation of scientific research is estimated by an expert in person-days and is probabilistic in nature, because depends on many factors that are difficult to take into account. The following formula used to determine the expected (average) value of labor intensity $t_{exp\ i}$:

$$t_{exp\ i} = \frac{3t_{min\ i} + 2t_{max\ i}}{5}, \qquad (2)$$

где $t_{exp\ i}$ – expected labor intensity of the *i*-th work, person-days; $t_{min\ i}$ – the minimum possible labor intensity of performing a given *i*-th work (optimistic assessment: assuming the most favorable set of circumstances), person-days; $t_{max\ i}$ – the maximum possible labor intensity of performing a given *i*-th work (pessimistic assessment: assuming the most unfavorable set of circumstances), person-days.

Based on the expected labor intensity of the work, the duration of each work in working days is determined, taking into account the parallel execution of work by several performers:

$$T_{w_i} = \frac{t_{exp\ i}}{N_i}, \qquad (3)$$

where T_{w_i} – duration of one work, working days; $t_{exp\ i}$ – expected labor intensity of one work, person-days; N_i – the number of performers performing the same work at the same time at this stage, pers.

4.2.3 Development of a research schedule

In accordance with the calendar plan for the execution of work, a tape schedule for the completion of the qualification paper built in the form of a Gantt chart.

For the convenience of building a schedule, the duration of each of the stages of work from working days converted into calendar days. For this, the following formula was used:

$$T_{ci} = T_{wi} \cdot k_c, \qquad (4)$$

where T_{ci} – duration of the *i*-th work in calendar days; T_{wi} – duration of the *i*-th work in working days; k_c – calendar coefficient.

The calendar coefficient determined by the following formula:

$$k_c = \frac{T_c}{T_c - T_d - T_h}, \qquad (5)$$

where T_c – number of calendar days in a year; T_d – number of days off in a year; T_h – number of holidays in a year.

Thus:

$$k_c = \frac{T_c}{T_c - T_d - T_h} = \frac{365}{365 - 52 - 14} = 1{,}22$$

Calculated values in calendar days for each work are rounded to the nearest whole number and summarized in Table 10.

Table 10 – Time indicators for scientific research

№	Title of the work	Performers	Labor intensity of work				T_{wi}	T_{ci}
			t_{min}, person-days	t_{max}, person-days	$t_{exp\ i}$, person-days	N, persons		
1	Drafting and approval of technical specifications	Scientific supervisor, student	2	4	2,8	2	1,4	2
2	Selection and study of materials on the topic	Scientific supervisor, student	15	25	19	2	9,5	12
3	Conducting patent research	Scientific supervisor, student	5	7	5,8	2	2,9	4
4	Choice of research direction	Scientific supervisor	2	3	2,4	1	2,4	3
5	Scheduling work on the topic	Scientific supervisor, student	1	2	1,4	2	0,7	1
6	Search of literary sources	Scientific supervisor, student	5	7	5,8	2	2,9	4
7	Analysis of literary sources	Student	5	7	5,8	1	5,8	8
8	Obtaining data on the dose rate of γ-radiation in the surface atmosphere from IMCES data	Scientific supervisor, student	2	4	2,8	2	1,4	2
9	Obtaining data on solar radiation from IMCES	Scientific supervisor, student	2	4	2,8	2	1,4	2
10	Plotting Gamma Radiation vs. Solar Radiation	Student	14	31	20,8	1	20,8	26
11	Analysis and presentation of results	Student	2	4	2,8	1	2,8	4

Continuation of Table 10

12	Evaluation of the results	Scientific supervisor	2	4	2,8	1	2,8	4
13	Evaluation of the effectiveness of the study and application of the results	Student, FM consultant	10	15	12	2	6	8
14	Development of social responsibility on the topic	Student, SR consultant	10	15	12	2	6	8
15	Drawing up an explanatory note	Student	7	14	9,8	1	9,8	12

Based on the table. 4 built a schedule in the form of a Gantt chart (Fig. 25). The schedule built with a breakdown by months and decades for the period of graduation. The total number of days to complete the work is 100 days.

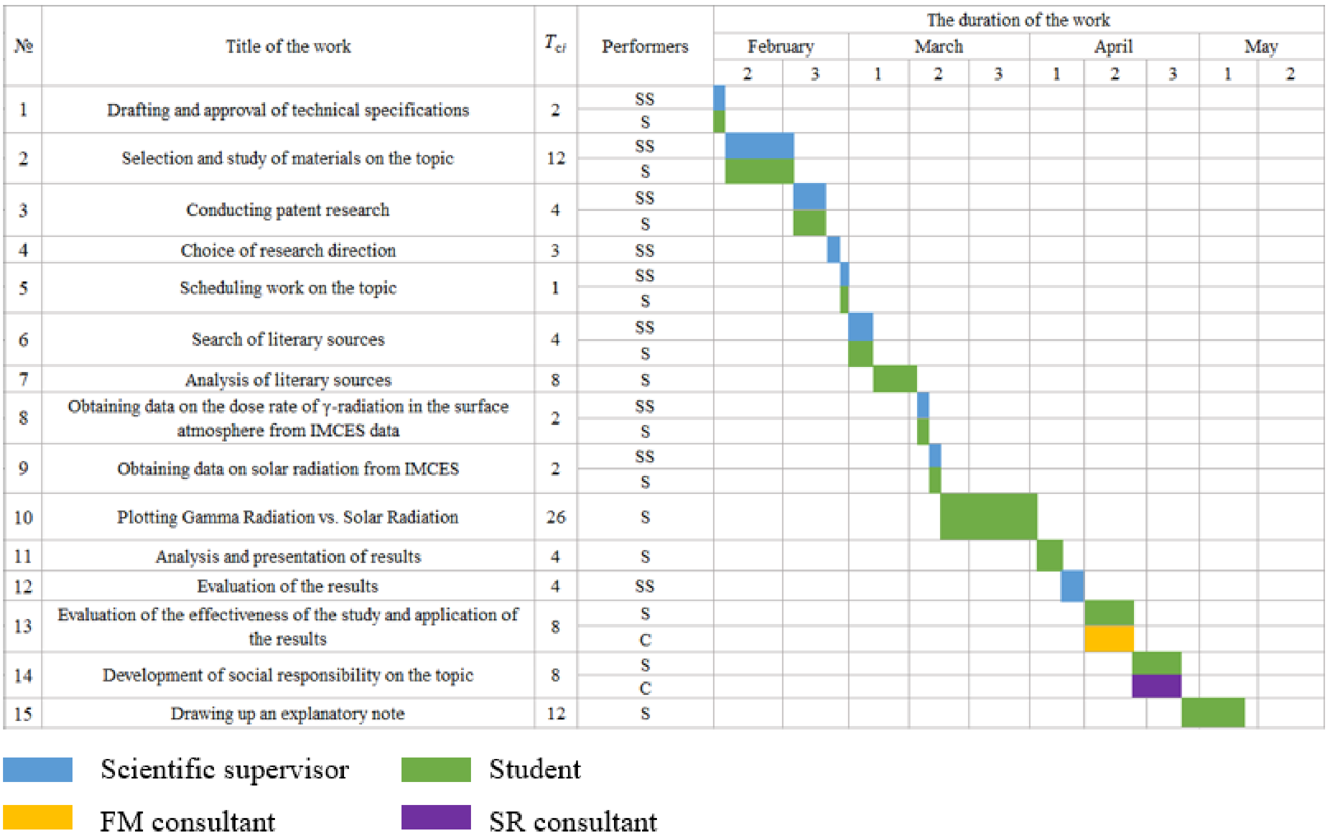


Figure 25 – Gantt Chart

4.3 Scientific and technical research (STR) budget

When planning the STR budget, a full and reliable reflection of all types of expenses associated with its implementation should be ensured. In the process of forming the STR budget, the following grouping of costs by items was used:

1) the cost of the main equipment for scientific and experimental work;
2) the main salary of the performers of the theme;
3) additional salary of theme performers;
4) contributions to off-budget funds (insurance contributions);
5) overhead costs.

4.3.1 Calculation of the cost of equipment for scientific and experimental work

The calculation of equipment costs reduced to the determination of depreciation charges, since the equipment was purchased before the start of work.

The depreciation rate calculated using the following formula:

$$N_d = \frac{1}{n}, \tag{6}$$

where n is the useful life time, measured in years.

Depreciation of equipment on a straight-line basis calculated as follows:

$$D = \frac{N_d \cdot m \cdot N}{12}, \tag{7}$$

where m – operation time, months; N – total amount, th. rub.

The main equipment used in the work was an HP Pavilion Gaming 15-cx0171ur PC purchased in January 2020 for 56999 rubles. The useful life of a PC is 5 years. As a result, the total amount of depreciation deductions amounted to:

$$D = \frac{0{,}2 \cdot 56999 \cdot 2}{12} = 1899{,}97 \approx 1900 \text{ rub.}$$

4.3.2 Basic and additional salaries of theme performers

The article includes the basic salaries of employees directly involved in the implementation of STR (including bonuses and additional payments) and additional salaries. In addition, a monthly bonus paid included from the payroll for 20-30% of the tariff or salary:

$$S_{sal} = S_{base} + S_{add}, \tag{8}$$

where S_{base} – basic salary; S_{add} – additional salary (12-20% of the basic one).

The basic salary of the head (laboratory assistant, engineer) from the enterprise (if there is a head from the enterprise) calculated according to the following formula:

$$S_{base} = S_{day} \cdot T_{\mathrm{w}}, \tag{9}$$

where T_{w} – duration of work performed by a scientific and technical worker (Table 12); S_{day} – average daily salary of a worker, rub.

The average daily salary calculated by the formula:

$$S_{day} = \frac{S_m \cdot \mathrm{M}}{F_d}, \tag{10}$$

where S_m – monthly salary of a worker, rub.; M – the number of months of work without vacation during the year: with a vacation of 24 working days M = 11.2 months, 5-day week; on vacation at 48 working days M = 10.4 months, 6-day week; F_d – actual annual fund of working time of scientific and technical personnel, working days (table 11).

Table 11 – Balance of working time

Working time indicators		Scientific supervisor	Student
Calendar number of days		365	365
Number of non-working days	Days off	52	52
	Holidays	14	14
Loss of working time	Vacation	48	48
	Absenteeism due to illness	7	7
Actual annual fund of working time		244	244

Worker's monthly salary:

$$S_m = S_{tr} \cdot (1 + k_{pr} + k_{ad}) \cdot k_r, \qquad (11)$$

where S_{tr} – salary by the tariff rate, rub.; k_{pr} – premium coefficient equal to 0.3; k_{ad} – coefficient of additional payments and allowances, is 0.2; k_r – regional coefficient equal to 1.3 (for Tomsk).

The calculation of the basic salary shown in table 12.

Table 12 – Calculation of the basic salary

Performers	Category	S_{tr}, rub.	k_r	S_m, rub.	S_d, rub.	T_w, w. days	S_{base}, rub.
Scientific supervisor	PTS4	52 700	1,3	68 510	2 920,10	34	99 283,40
Student	-	13 900	1,3	18 070	770,20	93	71 628,60
						Total S_{base}	170 912,00

The calculation of additional salaries carried out according to the following formula:

$$S_{add} = S_{base} \cdot k_{add}, \qquad (12)$$

where k_{add} – coefficient of additional salaries (at the design stage it is taken equal to 0.15).

The total salary of the work performers presented in table 13.

Table 13 – Total salary of performers

Performer	S_{base}, rub.	S_{add}, rub.	S_{sal}, rub.
Scientific supervisor	99 283,40	14 892,51	114 175,91
Student	71 628, 60	10 744,29	82 372,89
Total	**170 912,00**	**25 636,80**	**196 548,80**

4.3.3 Contributions to off-budget funds

This item of expenses reflects mandatory contributions from the cost of remuneration of employees according to the norms established by the legislation of the Russian Federation to the bodies of state social insurance (FSI), pension fund (PF) and medical insurance (FFCMI).

The amount of contributions to non-budget funds is determined based on the following formula:

$$S_{nb} = k_{nb} \cdot (S_{add} + S_{base}), \qquad (12)$$

where k_{nb} – coefficient of contributions for payments to non-budgetary funds (pension fund, compulsory medical insurance fund, etc.), equal to 30.2 %.

Contributions to non-budget funds presented in table 14.

Table 14 – Contributions to non-budget funds

Performer	Basic salary, rub.	Additional salary, rub.
Scientific supervisor	99 283,40	14 892,51
Student	71 628, 60	10 744,29
Coefficient of contributions for payments to non-budgetary funds	0,302	
Total:	59 357,74	

4.3.4 Overhead costs

Overhead costs take into account other expenses of the organization that were not included in the previous expense items: printing and photocopying of research materials, payment for communication services, electricity, postal and telegraph expenses, reproduction of materials, etc. Their value is determined by the following formula:

$$S_{oc} = k_{oc} \cdot (S_{add} + S_{base}), \qquad (12)$$

where k_{oc} – overhead factor.

The value of the overhead factor is taken in the amount of 16 %. Then

$$S_{oc} = 0{,}16 \cdot (1900 + 170912 + 25636{,}8 + 59357{,}74) = 41249{,}05 \text{ rub.}$$

4.3.5 Formation of the budget for the costs of a research project

The calculated amount of research costs is the basis for the formation of the project cost budget, which, when forming an agreement with the customer, is protected by a scientific organization as the lower limit of costs for the development of scientific and technical products.

The definition of the cost budget for the research project for each implementation option given in table 15.

Table 15 – Calculation of the STR cost budget

Name of item	Sum, rub.	Comment
1. Costs for special equipment for scientific (experimental) work	1 900,00	Paragraph 4.3.1
2. The cost of the basic salaries of theme performers	170 912,00	Paragraph 4.3.2
3. Expenses for additional salaries of theme performers	25 636,80	Paragraph 4.3.2
4. Contributions to non-budget funds	59 357,74	Paragraph 4.3.3
5. Overhead costs	41 249,05	16 % from the sum article. 1-4
6. STR cost budget	299 055,59	Sum of item 1-5

As can be seen from Table 15, the main costs of STR fall on the salaries of performers.

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

To determine the effectiveness of the study, an integral indicator of the effectiveness of scientific research calculated by determining the integral indicators of financial efficiency and resource efficiency.

The integral financial development indicator defined as:

$$I_{findev}^{impl.\ i} = \frac{\Phi_{impl\ i}}{\Phi_{max}} \tag{13}$$

where $I_{findev}^{impl.\ i}$ – integral financial development indicator; $\Phi_{impl\ i}$ – cost of the i-th variant of implementation; Φ_{max} – maximum cost 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 cost of development in times (the value is less than one, but greater than zero).

Since the development has only one implementation, then

$$I_{findev}^{impl.\ i} = \frac{\Phi_{impl\ i}}{\Phi_{max}} = \frac{299055{,}59}{299055{,}59} = 1.$$

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

$$I_{re\ i} = \sum a_i \cdot b_i\,, \tag{14}$$

where $I_{re\ i}$ – integral indicator of resource efficiency of the i-th variant of implementation; a_i – weight coefficient of the i-th variant of the implementation; b_i^a, b_i^p – scoring of the i-th variant of the implementation, is established by an expert according to the selected evaluation scale; n – number of comparison parameters.

The calculation of the integral indicator of resource efficiency is presented in the form of table 16.

Table 16 – Comparative evaluation of the characteristics of project implementation variants

Criteria \ Object of study	Weight coefficient	Impl.1
1. Promotes user productivity	0,23	5
2. Ease of operation	0,10	5
3. Noise immunity	0,20	4
4. Energy saving	0,20	3
5. Reliability	0,12	4
6. Material consumption	0,15	4
Total	1	

$$I_{re\,i} = 5 \cdot 0{,}23 + 5 \cdot 0{,}1 + 4 \cdot 0{,}2 + 3 \cdot 0{,}2 + 4 \cdot 0{,}12 + 4 \cdot 0{,}15 = 4{,}13$$

The integral indicator of the effectiveness of implementation variants ($I_{impl.i}$) is determined based on the integral indicator of resource efficiency and the integral financial indicator according to the formula:

$$I_{impl.i} = \frac{I_{re\,i}}{I_{findev}^{impl.\,i}} \qquad (15)$$

Comparison of the integral indicator of the effectiveness of implementation variants will allow you to determine the comparative effectiveness of the project (see Table 17) and choose the most appropriate option from the proposed ones. Comparative effectiveness of the project (E_{comp}):

$$E_{comp} = \frac{I_{impl.1}}{I_{impl.2}}. \qquad (16)$$

Table 17 – Comparative efficiency

№ п/п	Criteria	Impl.1
1	Integral financial development indicator	1
2	Integral indicator of resource efficiency	4,13
3	Integral indicator of the effectiveness	4,13

Comparison of the values of integral performance indicators makes it possible to understand and choose the most effective solution to the set technical problem in terms of financial and resource efficiency. In this case, there is only one variant of implementation of study. Therefore, this proposed variant taken as the best one.

5 Social responsibility

As part of the final qualification work, a study was made of the relationship between the gamma background of the surface atmosphere and the incoming solar radiation. The main part of the work was carried out on a PC located in the laboratory room No. 118B of the 10th building of TPU.

The work consisted in carrying out a statistical analysis and searching for dependencies between the data obtained on the gamma background near the soil surface and the 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 consistency in the placement of objects, tools and documentation. What is required to perform work more often should be located in the zone of easy reach of the working space (Fig. 26) [22].

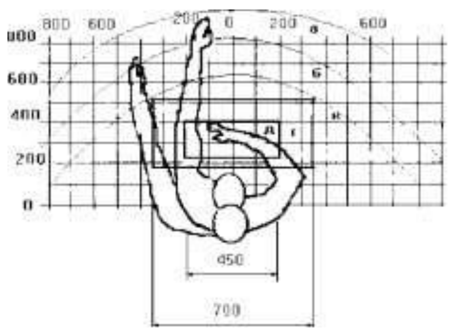


Figure 26 – Hand reach zones in the horizontal plane: a - zone of maximum hand reach; b - the reach zone of the fingers with an outstretched hand; c - zone of easy reach of the palm; g - the optimal space for rough manual work; e - optimal space for fine manual work

Optimal placement of tools and documentation within arm's reach: the display is located in the zone, a (in the center); keyboard - in the d/e zone; the system unit is located in zone b (on the left); the printer is in zone a (on the right); documentation: in the zone of easy reach of the palm - in (left) - literature and documentation necessary for work; in the drawers of the table - 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 exceed 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;
– under the table there should be legroom, at least 600 mm long, at least 500 mm wide, the depth of the space at the level of the knees should be at least 450 mm, and at the level of the outstretched legs - at least 650 mm.

The work chair should be able to adjust the height and angles of the seat and backrest. The recommended height of the seat from the floor level should not exceed 450 - 550 mm. Due to the special design of the work chair; it must 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 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:

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

For comfortable work behind the keyboard, it should be located at a distance of 100 to 300 mm from the edge of the working surface. The position of the keyboard must 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 square shape with rounded corners, and the surfaces should have a concave shape. Also, the design of the keys must provide the operator with a clicky feel when pressed, mechanical keyboards are best suited for this. The color of the keys must match the color of the operating panel.

If the operator's work involves monotonous mental work that requires significant nervous tension and great concentration, then it is best to choose soft, low-contrast color shades (weakly saturated shades of cold blue or green colors), which do not weaken attention. If the work requires a lot of mental and physical stress, then you should use warmer shades that help increase concentration [22].

5.2 Assessment of harmful and dangerous factors

This paragraph provides an analysis of all the harmful and dangerous factors that may arise when working in the laboratory. All harmful and dangerous factors specific to the laboratory environment are presented in Table 18.

Table 18 – Possible harmful and dangerous factors

Factors (GOST 12.0.003-2015 [23])	Regulatory documents
1. Microclimate	GOST 30494-96. Buildings residential and public. Indoor microclimate parameters [24]
2. Noise	GOST 12.1.003-83. System of labor safety standards (SLSS). Noise. General safety requirements (with Amendment No. 1) [25]
3. Illumination of the working area	SNiP 23-05-95*. Natural and artificial lighting (with Amendment No. 1) [26]
4. Fire hazard	SP 12.13130.2009. Definition of categories of premises, buildings and outdoor installations for explosion and fire hazard (by amendment No. 1, approved by order of the Russian Emergencies Ministry dated 09.12.2010 No. 643) [27] GOST 12.1.004-91 System of labor safety standards. Fire safety. General requirements [28]

Continuation of Table 18

5. Electrical safety	GOST 12.1.009-76 System of labor safety standards (SLSS) [29] GOST P12.1.019-2017 SLSS Electrical safety [30] GOST R MEC 61140-2000 Protection against electric shock. General provisions on safety provided by electrical equipment and electrical installations in their relationship [31]

5.2.2 Deviation of microclimate parameters

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

Auxiliary equipment, PCs, and lighting devices generate 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, while at low temperatures, heat transfer from the skin surface increases, which leads to hypothermia of the body. Low humidity causes discomfort in the form of dryness of the mucous membranes of the respiratory tract of the worker.

When normalizing 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 and permissible meteorological conditions of temperature and humidity are established according to [32] and are given in Table 19.

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

Table 19 – Optimal values of microclimate indicators at workplaces of industrial premises

Period of the year	Category of work by the level of energy consumption, W	Air temperature, ºC	Surface temperature, ^{0}C	Relative humidity, %	Air speed, m/s
Cold	Ia (up to 139)	22-24	21-25	60-40	no more than 0.1
Warm	Ia (up to 139)	23-25	22-26	60-40	no more than 0.1

To maintain these norms of microclimate parameters, it is sufficient to have natural unorganized ventilation of the room and a local air conditioner of a full air conditioning unit, which ensures the constancy of temperature, relative humidity, circulating speed and air purity. A fan can be used to circulate air masses in the laboratory room. To calculate the ventilation rate of a fan in a laboratory with a volume of $V = 90{,}3$ m^3 ($S = 25{,}8$ m^2, $h = 3{,}5$ m), we use the formula [33]:

$$W = V \cdot k, \tag{17}$$

where k is the normalized air exchange rate (for laboratories $k = 3$), 1/h.

Substituting the data into formula (17), we obtain the characteristic of the fan air exchange rate:

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

Based on the parameters obtained, the fan SQ0832-0113 from TDM with maximum performance of 271 m^3/h is suitable for the audience.

In winter, a central heating system is required to provide a given temperature level [34]. It must provide sufficient, constant and uniform heating of the air. To maintain the required temperature, a water heating system is used. This system is reliable in operation and provides the ability to control the temperature over a wide range. When installing a ventilation and air conditioning system in the laboratory, certain fire safety requirements must be observed. In rooms with increased requirements for air purity, water heating should be used.

To protect the researcher from the action of a harmful factor of deviation of microclimate indicators, microclimatic conditions are created by heating, exchange ventilation and air conditioning in accordance with [32–34].

5.2.3 Noise

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

To assess the noise environment, it is allowed to use a numerical characteristic called the sound level (measured in dB). In accordance with [35], the permissible noise level during 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 must be marked with safety signs according to [36].

In room 118B, the main sources of noise are computers (cooling inside the system unit, DVD-ROM optical 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 rest of the cooling elements are passive and their noise level is not taken into account. The noise caused by the operation of optical drives is also not taken into account, since they are used in operation for a slightly short time.

In the auditorium in question, additional sound insulation is not required, since the limit 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, it is necessary to carry out preventive maintenance of computer system units in a timely manner (dust cleaning and lubrication of moving parts of cooling units, replacement of excessively noisy components).

Protection against elevated noise levels is carried out by methods of its reduction at the source of formation and on the propagation path, the installation of screens and sound-absorbing linings, personal protective equipment according to [35, 36].

5.2.4 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, unsuitable weather factors or time of day.

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

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

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

General lighting is called, the lamps of which illuminate the entire area of \ the premises, both occupied by equipment or workplaces, and auxiliary. Depending on the location of the lamps, uniform and localized general lighting are distinguished. With general uniform illumination, the luminaires are located evenly in the upper zone of the room, thereby ensuring the same illumination of the entire premises. It is used, as a rule, when the location of the working areas during the design is unknown or with a flexible layout. With general localized lighting, luminaires are placed taking into account the location of technological equipment, creating the required level of illumination on individual surfaces.

The combined lighting system consists of general and local lighting. General lighting is designed to illuminate passages and areas where work is not performed, as well as to equalize the brightness in the field of view of workers. Lamps located directly at the workplaces provide local lighting. It should be preferred if different visual tasks are to be solved in several working areas of the premises and therefore they require different levels of illumination. It is also necessary when workplaces are distant from each other. At the same time, it should be borne in mind that the use of only local lighting is unacceptable, since it creates a large difference in the illumination of working surfaces and the surrounding space, which adversely affects vision [26].

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

For general lighting, gas discharge lamps are used: daylight (DL), cold white (CW), warm white (WW) and white color (WC).

Let's determine the required number of light sources to fully illuminate the laboratory audience with working computers with fluorescent ceiling lights.

Luminous flux for fluorescent lamps, power 56 W:

$$F = Ra \cdot P,$$

where Ra = 80 Lm/W – minimum CRI for fluorescent lamp.

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

The required number of lamps for lighting the laboratory audience:

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

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

K – transition factor, 4.5;

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

k – safety factor, 4.5;

S – illuminated area, 25.8 м^2;

z – correction factor taking 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 fixtures is rounded up to a whole number. We get that 4 lamps are needed to properly illuminate the audience.

To protect against insufficient illumination of the working area, natural lighting in its spectrum is the most acceptable, but it is not always enough. It is related to the mode of operation. It is generally recommended to use general and combined lighting. Workplace illumination standards correspond to [26].

5.2.5 Electrical safety

Sources of the hazard are conductive cables, electrical equipment. The danger of electric shock is aggravated by the fact that a person is not able to detect voltage remotely without special devices. An electric current passing through a living organism causes thermal (burns, heating and damage to blood vessels, overheating of the heart, brain and other organs), electrolytic (decomposition of an organic fluid, including blood, which causes a significant violation of its composition, as well as tissue in general) and biological action (violation of internal bioelectrical processes inherent in 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. An electric shock hazard exists in the following cases [29, 30]:

- by direct contact with current-carrying 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 the event of a short circuit in high-voltage units: power supply unit and display scanner unit.

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

Thermal (thermal) effect is manifested in the form of burns of the skin area, overheating of various organs, as well as ruptures of blood vessels and nerve fibers resulting from overheating.

Chemical (electrolytic) action leads to electrolysis of blood and other solutions contained in the human body, which leads to a change in their physico-chemical composition, and hence to disruption of the normal functioning of the body.

Measures to ensure the electrical safety of electrical installations:

- disconnection of voltage from current-carrying parts on which or near which work will be carried out, and taking measures to ensure that it is impossible to supply voltage to the place of work;
- hanging posters indicating the place of work;
- grounding of housings of all installations through a neutral wire;
- coating of metal surfaces of tools with reliable insulation;
- inaccessibility of current-carrying parts of the equipment (conclusion in cases of electro-shocking elements, conclusion in the case of current-carrying parts) [29, 30].

The room in which the work was carried out is suitable for class 1 rooms, in which operating voltages do not exceed 1000 V.

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

The main sources of electromagnetic radiation in working areas are displays of computers and mobile devices, 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 the composition of the blood. Table 20 shows the permissible levels of parameters of electromagnetic fields [37].

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

Table 3 – Temporary permissible levels of electromagnetic fields generated by a PC

Parameters		Acceptable level
Electric field strength	In the frequency range 5 Hz - 2 kHz	25 W/m
	In the frequency range 2 kHz - 400 kHz	2,5 W/m
Magnetic flux density	In the frequency range 5 Hz - 2 kHz	250 nTl
	In the frequency range 2 kHz - 400 kHz	25 nTl
Electrostatic potential of the monitor screen		500 V

The strength of the electromagnetic field at a distance of 50 cm around the screen in terms of the electrical component must correspond to [38].

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

There are the following methods of protection against electromagnetic fields:

– increasing the distance from the source (the screen must be at least 50 cm away from the user);
– use of near-screen filters, special screens and other personal protective equipment.

In the specified audience, the electromagnetic radiation complies with the standards [37, 38].

5.2.6 Fire safety

Depending on the characteristics of the substances and materials in the premises, according to the explosion and fire hazard, the premises are divided into categories A, B, C, D and D in accordance with [27].

The room under consideration is classified as category B, as it contains solid combustible substances in a cold state. Possible causes of fire:

- work 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 taken, 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 the necessary actions in the event of a fire, certification of substances, materials and products in terms of ensuring fire safety, manufacturing and use of visual agitation to ensure fire safety [28]. Operational measures include preventive inspections of equipment. Regime measures include the establishment of rules for the organization of work and compliance with fire prevention measures. To prevent a fire, the following fire safety rules must be compliance:

- maintenance of premises in accordance with fire safety requirements;
- proper operation of the equipment (correct connection of the equipment to the power supply network, control of equipment heating);
- 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. The use of chemical and foam fire extinguishers is not allowed. Fire extinguishers should be located on the protected object in accordance with the requirements so that they are protected from direct sunlight, heat fluxes, mechanical influences and other adverse factors (vibration, aggressive environment, high humidity, etc.). They must be clearly visible and easily accessible in the event of a fire. It is preferable to place fire extinguishers near the places of the most likely occurrence of a fire, along the paths of passage, and also near the exit from the premises. Fire extinguishers should not interfere with the evacuation of people during a fire. According to fire safety requirements [27, 28], there are 2 fire extinguishers OP3 on the floor, portable powder fire extinguishers, flights of stairs are equipped with hydrants, there is a fire alarm button.

5.3 Emergencies

An emergency situation (ES) is a situation in a certain territory that has developed as a result of an accident, a natural hazard, a catastrophe, a natural or other disaster that may or have caused human casualties, damage to human health or the natural environment, significant material losses and violation living conditions of people [39]. There are two types of emergency situations:

- technogenic;
- natural.

Technogenic emergencies include fires, explosions, sabotage, releases of toxic substances. Natural emergencies include natural disasters. The most probable technogenic emergencies are fires.

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

Let's consider possible emergencies in the auditorium No. 118B of the educational building No. 10 of TPU, namely:

- the occurrence of a fire;
- electric shock;
- falling from a height of one's own height;
- falling down stairs.

Measures to prevent and eliminate the consequences of the above emergencies are presented in Table 21.

Table 21 – Examples of emergency situations and measures for their prevention and elimination at the workplace

№	Emergency situation	Prevention measures	Measures to eliminate the consequences of an emergency
1	Occurrence of a fire	1. Timely training. 2. Installation of automatic fire extinguishing equipment in the premises. 3. Installation of smoke and fire detectors. 4. Providing escape routes and maintaining them in proper condition. 4. Control of electrical appliances.	1. De-energize the room, stop the air supply; 2. Immediately report the fire to the person on duty or to the security post; 3. If necessary, call 112; 4. If possible, take measures to evacuate people, extinguish a fire and save property.
2	Electric shock	1. Grounding of all electrical installations. 2. Workspace limitation. 3. Ensuring the inaccessibility of live parts of the equipment. 4. Timely training.	1. Quickly release the victim from the action of electric current [31]; 2. Call 112; 3. If the victim has lost consciousness, but breathing is preserved, it should be conveniently laid down, unbuttoned tight clothing, create an influx of fresh air and ensure complete peace; 4. The victim should be given a sniff of ammonia, sprinkle his face with water, rub and warm the body; 5. If there is no breathing, artificial respiration and heart massage should be done immediately.

Continuation of Table 21

3	Injury as a result of falling from one's own height	1. Maintaining the premises in appropriate order. 2. Workspace limitation. 3. Timely training.	1. Examine or interview the victim; 2. Call 112; 3. Stop bleeding if any; 4. If there is a suspicion that the victim has a broken spine (sharp pain in the spine with the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical assistance is provided.
4	Injury as a result of falling down stairs	1. Installing handrails on stairs. 2. Coating of stairs with anti-slip coating. 3. Timely training.	1. Call 112; 2. Stop bleeding if any; 3. If there is a suspicion that the victim has a broken spine (sharp pain in the spine at the slightest movement), it is necessary to provide the victim with complete rest in the supine position until qualified medical assistance is provided.

This subsection discusses potential emergencies that may arise when working in classroom No. 118B of educational building No. 10. Measures to prevent and eliminate these situations are considered, according to [31, 39].

Conclusion

The instrumental and computational methods for determining evaporation from the soil surface analyzed. Shown the advantages and disadvantages of these methods of existing methods.

To determine the amount of evaporation, it proposed to replace part of the meteorological parameters with the value of the gamma background, for which an analysis of the relationship between the gamma background, incoming solar radiation and relative air humidity carried out.

The analysis showed that there is a strong relationship between the gamma background and the incoming solar radiation, which disturbed by precipitation. The coefficients of correlation and determination can reach very high values (up to 0.97 and 0.94, respectively) and decrease significantly during and after precipitation (down to 0.41 and 0.17, respectively). The relationship between the gamma background and relative air humidity is much weaker; the average values of the correlation and determination coefficients are 0.22 and 0.1, respectively.

Based on the analysis, it can argued that, when calculating evaporation from the soil surface, the gamma background parameter can serve as a substitute for a number of meteorological parameters, the measurement of which is technically difficult or not performed for a number of independent reasons.

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