TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

Инженерная школа ядерных технологий
Направление подготовки 14.04.02 Ядерные физика и технологии
Отделение ядерно-топливного цикла

МАГИСТЕРСКАЯ ДИССЕРТАЦИЯ

Тема работы
Исследование изменений радиационного фона вследствие влияния объектов техносферы

УДК 539.16.08: 551.521: 539.1.074

Студент

Группа	**ФИО**	**Подпись**	**Дата**
0АМ8И1	Зулу Матиас Чаматва		

Руководитель ВКР

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

КОНСУЛЬТАНТЫ ПО РАЗДЕЛАМ:

По разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Доцент ОСГН ШИП	Меньшикова Е.В.	к.ф.н.		

По разделу «Социальная ответственность»

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Доцент ОЯТЦ ИЯТШ	Веригин Д.А.	к.ф-м.н		

ДОПУСТИТЬ К ЗАЩИТЕ:

Руководитель ООП	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Управление ядерной энергетической установкой	Верхотурова В.В.	к.и.н.		

Томск – 2020 г

TOMSK POLYTECHNIC UNIVERSITY / ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

School of Nuclear Science and Engineering
Field of training (specialty) 14.04.02 Nuclear Physics and Technology, Nuclear Power Installation Operation
Nuclear Fuel Cycle Division

MASTER THESIS

Topic of research work
Investigation of changes in background radiation due to technosphere objects

UDC 539.16.08: 551.521: 539.1.074

Student

Group	Full name	Signature	Date
0АМ8И1	Zulu Mathias Chamatwa		

Scientific supervisor

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

ADVISERS:

Section “Financial Management, Resource Efficiency and Resource Saving”

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	E.V. Menshikova	PhD		

Section “Social Responsibility”

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	D.A. Verigin	PhD		

ADMITTED TO DEFENSE:

Programme Director	Full name	Academic degree, academic rank	Signature	Date
Nuclear Power Installation Operation	V.V. Verkhoturova	PhD		

Tomsk – 2020г

Expected learning outcomes

Learning outcome (LO) code	Learning outcome (a graduate should be ready)	Requirements of the FSES HE, criteria and / or interested parties
	Professional competencies	
LO1	To apply deep mathematical, scientific, socio-economic and professional knowledge for conducting theoretical and experimental research in the field of the use of nuclear science and technology.	FSES HE Requirements (PC-1,2, 3, 6, UC-1,3), Criterion 5 RAEE (p 1.1)
LO2	To demonstrate ability to define, formulate, and solve interdisciplinary engineering tasks in the nuclear field using professional knowledge and modern research methods.	FSES HE Requirements (PC-2,6,9,10,14, UC-2,3,4, BPC1,2), Criterion 5 RAEE (p 1.2)
LO3	To plan and conduct analytical, simulation and experimental studies in complex and uncertain conditions using modern technologies, and to evaluate critically research results.	FSES HE Requirements (PC-4,5,6,9,22, UC-1,2,5,6), Criterion 5 RAEE (p 1.3)
LO4	To use basic and special approaches, skills and methods for identification, analysis, and solution of technical problems in the field of nuclear science and technology.	FSES HE Requirements (PC-7,10,11,12,13, UC-1-3,BPC1,3), Criterion 5 RAEE (p 1.4)
LO5	To operate modern physical equipment and instruments, to master technological processes in the course of preparation for the production of new materials, instruments, installations, and systems.	FSES HE Requirements (PC-8,11,14,15, BPC-1), Criterion 5 RAEE (p 1.3)
LO6	To demonstrate ability to develop multioption schemes for achieving production goals with the effective use of available technical means and resources.	FSES HE Requirements (PC-12,13,14,16, BPC-2), Criterion 5 RAEE (p 1.3)
	Cultural competencies	
LO7	To demonstrate ability to use a creative approach to develop new ideas and methods for designing nuclear facilities, as well as to modernize and improve the applied technologies of nuclear production.	FSES HE Requirements (PC-2,6,9,10,14, UC-1,2,3), Criterion 5 RAEE (p 1.2,2.4,2.5)
	Basic professional competencies	
LO8	To demonstrate skills of independent learning and readiness for continuous self-development within the whole period of professional activity.	FSES HE Requirements (PC-16,17,21, UC-5,6, BPC-1), Criterion 5 RAEE (p 2.6) coordinated with the requirements of the international standard EURACE & FEANI
LO9	To use a foreign language at a level that enables a graduate to function successfully in the international environment, to develop documentation, and to introduce the results of their professional activity.	FSES HE Requirements (BPC-3, UC-2,4), Criterion 5 RAEE (p 2.2)

LO10	To demonstrate independent thinking, to function efficiently in command-oriented tasks and to have a high level of productivity in the professional (sectoral), ethical and social environments, to lead professional teams, to set tasks, to assign responsibilities and bear liability for the results of work.	FSES HE Requirements (PC-18,20,21,22,23, UC-1,4, BPC-2), Criterion 5 RAEE (p 1.6,2.3) coordinated with the requirements of the international standard EUR-ACE & FEANI

TOMSK POLYTECHNIC UNIVERSITY — ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

School of Nuclear Science and Engineering
Field of training (specialty) 14.04.02 Nuclear Physics and Technology, Nuclear Power Installation Operation
Nuclear Fuel Cycle Division

APPROVED BY:
Programme Director
_____________ Verkhoturova V.V.
«____» ____________ 2020

ASSIGNMENT
for the Graduation Thesis completion

In the form:

Master Thesis

For a student:

Group	Full name
0АМ8И1	Zulu Mathias Chamatwa

Topic of research work:

Investigation of changes in background radiation due to technosphere objects	
Approved by the order of the Director of School of Nuclear Science & Engineering (date, number):	№129-4/c at 08.05.2020

Deadline for completion of Master Thesis:	01.06.2020

TERMS OF REFERENCE:

Initial date for research work: *(the name of the object of research or design; performance or load; mode of operation (continuous, periodic, cyclic, etc.); type of raw material or material of the product; requirements for the product, product or process; special requirements to the features of the operation of the object or product in terms of operational safety, environmental impact, energy costs; economic analysis, etc.)*	investigation of changes in background radiation due to technosphere objects in the urban environment. The background radiation was studied using BDKG-03, a highly sensitive scintillation intelligent gamma radiation detection unit designed to search, quickly detect and localize gamma radiation sources with sensitivity of ^{137}Cs 350 (imp / s) / (μSv / h), as well as to measure ambient

	equivalent dose rate and gamma dose -radiation in the energy range 50 keV - 3 MeV
List of the issues to be investigated, designed and developed *(analytical review of literary sources with the purpose to study global scientific and technological achievements in the target field, formulation of the research purpose, design, construction, determination of the procedure for research, design, and construction, discussion of the research work results, formulation of additional sections to be developed; conclusions).*	❖ To review the literature ❖ To formulate the goals and objectives of the study ❖ To Measure gamma background radiation in urban environment. ❖ To Calculate radiation doses ❖ To compare calculated radiation dose with recommended safe limits and world average values
List of graphic material *(with an exact indication of mandatory drawings)*	

Advisors to the sections of the Master Thesis
(with indication of sections)

Section	Advisor
One: Literature Review	Professor Yakovleva V.S.
Two: Materials and Methods	Professor Yakovleva V.S.
Three: Results and Discussion	Professor Yakovleva V.S.
Four: Financial management, resource efficiency and conservation	Associate professor Menshikova E.V.
Five: Social Responsibilities	Senior Lecturer Verigin D.A.

Date of issuance of the assignment for Master Thesis completion according to the schedule	01.06.2020

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

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

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0AM8И1	Zulu Mathias Chamatwa		

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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

School of Nuclear Science and Engineering
Field of training (specialty) 14.04.02 Nuclear Physics and Technology, Nuclear Power Installation Operation
Level of education: Master degree programme
Nuclear Fuel Cycle Division
Period of completion: spring semester 2019/2020 academic year

Form of presenting the work:

Investigation of changes in background radiation due to technosphere objects

Master Thesis

SCHEDULED ASSESSMENT CALENDAR
for the Master Thesis completion

Deadline for completion of Master's Graduation Thesis:	01.06.2020

Assessment date	**Title of section (module) / type of work (research)**	**Maximum score for the section (module)**
7.03.2020	Literature Review and Methodology	…
12.04.2020	Data collection	…
21.04.2020	Analysis of the obtained experimental data	
26.04.2020	Preparation of the results and report submission	
20.05.2020	Defense preparation	

COMPILED BY:
Scientific supervisor:

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

AGREED BY:

Programme Director	**Full name**	**Academic degree, academic status**	**Signature**	**Date**
Nuclear Power Installation Operation	V.V. Verkhoturova	PhD		

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

To the student:

Group	Full name
0АМ8И1	Zulu Mathias Chamatwa

School	Nuclear Science and Engineering	**Division**	Nuclear Fuel Cycle
Degree	Master	**Educational Program**	14.04.02 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*	– Salary costs – 183195rubles – STR budget – 328666rubles
2. *Expenditure rates and expenditure standards for resources*	– Electricity costs – 5.8 rub per 1 kW
3. *Current tax system, tax rates, charges rates, discounting rates and interest rates*	– Labor tax – 27.1 %; – Overhead costs – 30%;
The list of subjects to study, design and develop:	
1. *Assessment of commercial and innovative potential of STR*	– comparative analysis with other researches in this field;
2. *Development of charter for scientific-research project*	– SWOT-analysis;
3. *Scheduling of STR management process: structure and timeline, budget, risk management*	– calculation of working hours for project; – creation of the time schedule of the project; – calculation of scientific and technical research budget;
4. *Resource efficiency*	– integral indicator of resource efficiency for the developed project.
A list of graphic material *(with list of mandatory blueprints):*	
1. *Competitiveness analysis* 2. *SWOT- analysis* 3. *Gantt chart and budget of scientific research* 4. *Assessment of resource, financial and economic efficiency of STR* 5. *Potential risks*	

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

Task issued by adviser:

Position	Full name	Scientific degree, rank	Signature	Date
Associate professor	E.V. Menshikova	PhD		

The task was accepted by the student:

Group	Full name	Signature	Date
0АМ8И1	Zulu Mathias Chamatwa		

Task for section
«Social responsibility»

To student:

group	Full name
0АМ8ИI	Zulu Mathias Chamatwa

School	**Nuclear Science and Engineering**	**Department**	**Nuclear fuel cycle**
Degree	Master programme	**Specialization**	Nuclear Power Installation Operation

Тема ВКР:

Initial data for section «Social Responsibility»:	
1. Information about object of investigation (matter, material, device, algorithm, procedure, workplace) and area of its application	Background radiation in the urban environment. Application area: Radiological protection.
List of items to be investigated and to be developed:	
1. Legal and organizational issues to provide safety: – Special (specific for operation of objects of investigation, designed workplace) legal rules of labor legislation; – Organizational activities for layout of workplace.	– Labour code of Russian Federation #197 from 30/12/2001 GOST 12.2.032-78 SSBT – Sanitary Rules 2.2.2/2.4.1340-03. Hygienic requirements for PC and work with it
2. Work Safety: 2.1. Analysis of identified harmful and dangerous factors 2.2. Justification of measures to reduce probability of harmful and dangerous factors	– Enhanced electromagnetic radiation level – Insufficient illumination of workplace – Excessive noise – Deviation of microclimate indicators – Electric shock – Increased levels of ionizing radiation
3. Ecological safety:	– Human manipulation of the environment for economic and social means, has led to what is known as "technologically enhanced naturally occurring radioactive materials
4. Safety in emergency situations:	– Fire safety;

Assignment date for section according to schedule	01.06.2020

The task was issued by consultant:

Position	Full name	Scientific degree, rank	Signature	date
assistant professor	Verigin D.A.	Cand.of Sc.		

The task was accepted by the student:

Group	Full name	Signature	date
0АМ8И1	Zulu Mathias Chamatwa		

Abstract

The master's dissertation consists of (128) pages; 49 figures; 59 tables; 60 references

Keywords: investigation, changes, background, radiation, Technosphere, objects.

The objective of study is investigation of changes in gamma background radiation due to technosphere objects in the urban environment.

The dissertation presents results of investigation of changes in gamma background radiation due to technosphere objects in the urban environment. The study was carried out in the city of Tomsk, Russia. Background radiation was studied using highly sensitive intelligent gamma detectors BDKG-03. It was found that, within a radius of 1m from certain technosphere objects the absorbed dose was 1.5 to 4.4 higher than the UNSCEAR recommended safe limit. The highest recorded dose for a person standing 50cm away from the technosphere objects was $204nGy/h \pm 5.5nGy/h$ which is 2.4 times higher than the recommended safe limit and 3.5 times higher than the world average. The range of absorbed dose was $44nGy/h \pm 1.9nGy$ to $374nGy/h \pm 0.26nGy/h$.The calculated range of AEDE was $0.05mSv/y$ to $0.46mSv/yr$ and ELCR was 0.175×10^{-3} to 1.60×10^{-3}.

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

Cost-effectiveness/value of the work: The project is feasible and not very expensive.

Future plans: To continue research in this area, possibly encamps a wide range of Technosphere objects and possible Simulation to determine the exact contribution of technosphere objects to background radiation

List of Acronyms and Abbreviations

ED- Equivalent Dose

ADR-Absorbed Dose Rate

AEDE-Annual Effective Dose Equivalent

ELCR-Excess Life time Cancer Risk

TENORM- Technologically Enhanced Naturally Occurring Radioactive Materials

HNBR-High Natural Background Radiation

IAEA International Atomic Energy Agency

ICRP - International Commission of Radiology Protection

UNSCEAR- United Nations Scientific Committee on the Effects of Atomic Radiation

ICRU -International Commission on Radiation Units and Measurements

Governmental

Table of Contents

List of Tables

Introduction

The modern era has been characterized by rapid industrial development consequently, manufacturing plants widely interact with the natural environment on a large scale. This rapid change in technological advances has put pressure on the ecosystem, this has led to global environmental issues. Human manipulation of the environment for economic and social means has led to what is known as "technologically enhanced naturally occurring radioactive materials," and the materials constitute some of the objects of the technoshere. The existence of technologically enhanced naturally occurring radioactive materials may result in increased in radiation doses within an urban environment. Industries may release significant amounts of radioactive material into the environment which may result in the potential for widespread exposure to ionizing radiation. These industries may include mining, phosphate processing, metal ore processing, heavy mineral sand processing, titanium pigment production, fossil fuel extraction and combustion, manufacture of building materials, thorium compounds, aviation, and scrap metal processing (Vearrier et al., 2009).

The influence of various objects of the Technosphere on gamma-background of the urban atmosphere has practically not been studied by anyone. It is not known which objects will increase the total urban gamma background radiation, and which ones will decrease it. And these objects have a potential to increase radiation doses with an urban environment. As the level of urbanization rises every year, the number of technoshere objects which have the potential to increase radiation dose also increase. Technosphere is that part of the environment that is made or modified by humans for use in human activities and human habitats. It is one of the Earth's spheres (Baeza et al., 2016). In this regard Background ionizing radiation has become a huge public concern all over the world.

Statement of the problem

Naturally occurring radioactive materials are ubiquitous throughout the earth's crust but Human manipulation of the environment for economic and social means has led to what is known as "technologically enhanced naturally occurring radioactive materials," often called TENORM. Technologically enhanced naturally occurring radioactive materials are present almost everywhere in the Technosphere in the form of Technosphere objects. The presence of Technosphere objects may result in anthropogenic anomalies in the environment. Which can be areas of increased gamma background radiation. The influence of various objects of the Technosphere on gamma background radiation has not been fully investigated and the contribution of technosphere objects to the total background radiation still remains unknown. Moreover, it is not known which Technosphere objects will increase the overall gamma background radiation and which objects will decrease it. Understanding the health impacts of public exposure to gamma background radiation is critical to providing a rational basis for regulating radiation exposure in today's society. There are several scenarios of such exposures in the technosphere, from nuclear activities such as, Techa riverside residents in the 1950s, Chernobyl, and radioactive contamination in buildings in Taiwan. But the question continues to be asked whether there is evidence of risk or expectation of detriment based on projections from other sources of evidence. There are few opportunities to conduct relevant studies that can successfully quantify such risks directly (Hendry et al., 2009). Since gamma-emitting radionuclides are common to most forms of nuclear-related fallout, near-surface monitoring of the «ambient equivalent gamma radiation dose rate «has become widely adopted as a means of identifying such events. The ambient equivalent gamma radiation dose rate (hereafter "ambient gamma dose") is measurable equivalent of the effective gamma radiation dose, which quantifies the human health risk associated with gamma radiation exposure (ICRU, 1993).

Several international studies carried out in recent years, have reported different findings regarding the effect of background radiation on human health. However, despite extensive knowledge of radiation risks gained through epidemiologic investigations and mechanistic considerations, the health effects of chronic low-level radiation exposure are still poorly understood.(Hendry et al., 2009).

Objectives

To investigate changes in gamma background radiation due to Technosphere objects in the urban environment.

Specific Objectives

To investigate Technosphere objects which cause significant increase or decrease in gamma background radiation in the urban environment.

To compute the annual effective dose equivalent.

To compute excess lifetime cancer risk associated with an increase in gamma background radiation due to Technosphere objects.

To compare calculated doses with the recommended safe limit and world average

Research Questions

What factors affect background radiation?

How do Technosphere objects affect radiation doses in the urban environment?

Is there any healthy risk associated with an increase in gamma background radiation due to Technosphere objects in urban environment?

What type of Technosphere objects increase or decrease gamma background radiation?

Chapter 1 Literature review

1.1 Technosphere

The value of ecosystem functions and biodiversity, and the associated capacity of ecosystems to supply services in support of human well-being necessarily depends upon the long-lasting and durable interaction among all ‘earth’ spheres (Rugani et al., 2018) . The Earth that sustains us may be considered in terms of different spheres. There is the lithosphere, made up of the rocky foundations of our planet; the hydrosphere, representing our planet’s water; and the cryosphere, comprising the frozen polar regions and high mountains. The atmosphere is the air we breathe, and we are also part of the biosphere, made up of the Earth’s living organisms. These spheres have been in existence, in one form or another, for most, or all, of our planet’s 4.6-billion-year existence. Most recently, a new sphere has emerged which is referred to as the technosphere. The technosphere is comprised of all of the structures that humans have constructed to keep them alive on the planet (*Ephys.org*, 2016). The technoshere is also referred to us the anthroposphere. According to the article “Impacts of Global Change on the Hydrological Cycle in West and Northwest Africa” The anthroposphere may be defined as the part of the environment that is made or modified by humans. Put differently, the anthroposphere is the sphere of the earth system or its subsystems where human activities constitute a significant source of change through the use and subsequent transformation of natural resources, as well as through the deposition of waste and emissions (Speth et al., 2010)

1.1.1 Components of the technosphere

In the article (Zalasiewicz et al., 2017) the technosphere consisting of technological materials within which a human component can be distinguished, with part in active use and part being a material residue. The active technosphere is made up of buildings, roads, energy supply structures, all tools, machines and consumer goods that are currently in use or useable, together with farmlands and managed forests on land, the trawler scours and other excavations of the seafloor in the oceans, and so on (Zalasiewicz et al., 2017)

1.2 Background ionizing radiation

Monitoring of environmental radionuclides is necessary to determine the presence of natural and artificial radionuclides in order to assess the risk of the population exposure to ionizing radiation (Avdic et al., 2020). Background radiation estimation plays an important role in the anomalous radiation detection. Accurately estimating temporal and spatial fluctuations of background radiation helps to reduce the false alarm rate and improve the estimation accuracy of anomalous source location (Liu & Sullivan, 2019).

Background ionizing radiation has been existent on earth since the earth's formation. The exposure of humans and other living creatures to this radiation is a feature of the earth's environment which is continuing and inescapable. People are aware that ionising radiation exposures come from X-ray machines, nuclear reactors, nuclear explosions, extraction and processing of mineral ores including uranium mining, and the use of radioactive materials. However, not everyone is aware that we are all exposed to ionising radiation because of the very nature of the environment in which we live in (Bibbo & Piotto, 2014). Natural radionuclides in the atmospheric environment are shown in table 1.1 (Ramachandran, 2011).

Table 1.1 Natural Radionuclides in the Atmospheric Environment.

Isotope produced by cosmic rays			Isotopes produced from terrestrial sources		
Isotope	Half-life	Radiation emitted	Isotope	Half-life	Radiation emitted
^{14}C	5730 y	Beta	^{22}Rn (Radon)	3.82d	Alpha
^{32}Si	650 y	Beta	^{218}Po (RaA)	3.05m	Alpha
^{39}Ar	269 y	Beta	^{214}Pb (RaB)	26.8m	Beta, gamma
^{3}H	12.3 y	Beta	^{214}Bi (RaC)	19.7m	Alpha, beta, gamma
^{22}Na	2.6 y	Beta, Gamma	^{210}Pb (RaD)	20.4y	Beta

^{35}S	87 d	Beta	^{210}Bi (RaE)	5.0d	Beta
^{7}Be	53 d	Gamma (EC)	^{210}Po (RaF)	138.4d	Alpha
^{37}Ar	35 d	Gamma (EC)	^{20}Rn (Thoron)	55s	Alpha
^{33}P	25 d	Beta	^{216}Po (ThA)	0.158s	Alpha
^{32}P	14 d	Beta	^{212}Pb (ThB)	10.64h	Beta, gamma
^{24}Na	15 hr	Beta, Gamma	^{212}Bi (ThC)	60.6m	Alpha, Beta, gamma

Background ionizing radiation represents electromagnetic waves and particles that can ionize, that is, remove an electron from an atom or molecule of the medium through which they propagate. Ionizing radiation may be emitted in the process of natural decay of some unstable nuclei or following excitation of atoms and their nuclei in nuclear reactors, cyclotrons, x-ray machines or other instruments. For historical reasons, the photon (electromagnetic) component of ionizing radiation emitted by the excited nucleus is termed gamma rays and that emitted from machines is termed x rays. The charged particles emitted from the nucleus are referred to as alpha particles (helium nuclei) and beta particles (electrons) (United Nations, 2000).

A high natural background radiation (HNBR) area is defined as an area or a complex of dwellings where the sum of cosmic radiation and natural radioactivity in soil, indoor and outdoor air, water, food, etc leads to chronic exposure situations from external and internal exposures that result in an *annual effective dose* to the public above a defined level.(Hendry et al., 2009)

1.3 Sources of background radiation

More than sixty radionuclides can be found in the environment, which can be divided into three general categories: Primordial (which formed before the earth creation), cosmogenic (which formed as a consequence of cosmic ray interactions), and human produced (which formed due to human actions; they are minor amounts compared to natural). Radionuclides are found naturally in air, soil, water, and food. (Shahbazi-Gahrouei et al., 2013). Human produced radioactive materials are due to the manipulation of the environment for economic and social benefits. And these materials are part of the technosphere. Exposure to manmade radiation has origins such as medical diagnostic and therapeutic procedures; nuclear weapons production and testing; natural background radiation; nuclear electricity generation; accidents such as the one at Chernobyl in 1986; and occupations that entail increased exposure to artificial or naturally occurring sources of radiation.(United Nations, 2010)

The main natural sources of exposure are cosmic radiation and natural radionuclides found in the soil and in rocks. Cosmic radiation is significantly higher at the cruising altitudes of jet aircraft than on the Earth's surface. External exposure rates due to natural radionuclides vary considerably from place to place, and can range up to 100 times the average. An important radionuclide is radon, a gas that is formed during the decay of natural uranium in the soil and that seeps into homes. Exposures due to inhalation of radon by people living and working indoors vary dramatically depending on the local geology, building construction and household lifestyles; this mode of exposure accounts for about half of the average human exposure to natural sources.(United Nations, 2010)

1.4 Cosmic rays

Cosmic radiation is one of the sources of natural background radiation. Cosmic rays originate from the sun, stars, collapsed stars (such as neutron stars), quasars, and in the hot galactic and intergalactic plasma. It has many components, such as X-rays, gamma rays, and particles, which may be mesons, electrons, protons, neutrons, or hyperons. Cosmogenic radionuclides are produced in the atmosphere and the uppermost layer of the Earth's crust, in the interactions of cosmic radiation with constituents of those reservoirs. This group comprises more than 20 isotopes of elements ranging from hydrogen to krypton.(Dinh Chau et al., 2011).

Cosmic sources can vary with the solar cycle and are influenced by latitude, barometric pressure, solar activity, diurnal cycle, and weather(Keller & Kouzes, 2009;

Mitchell et al., 2009). Studies have shown that cosmic rays strongly depend on latitude. And research has shown that natural dose rates from cosmic rays depend strongly on the altitude and slightly on the latitude (Daryoush Shahbazi-Gahrouei et al., 2013). In addition, the amount of cosmic radiation that reaches the Earth and its environment is a function of solar cycle, altitude and latitude (Shea & Smart, 2000). Furthermore, since cosmic-radiation particles interact with the atmosphere, longer paths through the atmosphere result in lower background levels. This notion is further supported by (Keller & Kouzes, 2009) Cosmic radiation is highly dependent on elevation with higher backgrounds at higher elevations but some cosmic radiation-induced neutrons make it to the Earth's surface. The interaction of charged cosmic particles and the Earth's atmosphere is also controlled by the Earth's magnetosphere (Keller & Kouzes, 2009). Cosmic ray dose rate at various altitude and global production rates and levels of cosmogenic radionuclides in the atmosphere is shown in table 1.1 and table 1.2 (Ramachandran, 2011).

Table 1.2 Cosmic Ray Dose Rates at Various Altitudes.

Elevation Above Sea level (m)	Equivalent Dose Rate ($\mu Sv.y^{-1}$)	Elevated Above Sea Level (m)	Equivalent Dose Rate ($\mu Sv.y^{-1}$)
0 – 150	260 – 270	1220 –1828	390 - 520
150 – 305	270 – 280	1828 – 2438	520 – 740
610 – 1220	280 – 310	1438 – 3408	740 – 1070
610 – 1220	310 – 390	> 3408	1070

Table 1.3 Global Production Rates and Levels of Cosmogenic Radionuclides in the Atmosphere.

	Global Production Rate		Global inventory (P.Bq)
	Per unit area (atoms. m^{-2}. s^{-1})	(PBq .y^{-1})	
^{3}H	2500	72	1275
^{7}B	810	1960	413
^{10}B	450	0.000064	230
^{14}C	25000	1.54	12750
^{22}Na	0.86	0.12	0.44
^{26}Al	1.4	0.00001	0.71
^{32}Si	1.6	0.00087	0.82
^{32}P	8.1	73	4.1
^{33}P	6.8	35	3.5
^{35}S	14	21	7.1
^{36}Cl	11	0.000013	5.6
^{37}Ar	8.3	31	4.2
^{39}Ar	56	0.074	6
^{81}Kr	0.01	1.7×10^{-8}	0.005

1.5 Terrestrial rays

Terrestrial radiations from natural radioactive elements in the ground, stones, trees, and walls of houses contribute on the average about 0.28 mSv/year. The terrestrial sources vary significantly from place to place. These are categorized into building materials and soils surface. Table 1.3 shows Concentration of primordial radionuclides in various environmental matrices (Ramachandran, 2011).

Table 1.4 Concentration of primordial radionuclides in various environmental matrices.

Environmental Matrix	^{238}U	^{226}Ra	^{40}K	^{87}Rb
Igneous rock (Bq/g)	0.04	0.048	1.2	
Phosphate rock(Bq/g)	1.60	1.50	0.4	
Lime stone (mBq/g)	16.0	5-20	30-150	
Soil (mBq/g)	37.0	16	100	
Air (μBq/m3)	1.2	1.5	22	
Surface water (mBq/l)	0.18-62.9	0.4-111.0	$2.7\times10^{2}-1.4\times10^{5}$	
Ocean surface water (mBq/l)	44.4	1.3-3.1	1.1×10^{4}	0.9
Ocean bottom water (mBq/l)	40.0	3.0-5.6	1.1×10^{4}	100
Human (Bq)	1,3-1.6	1.0-1.5	6300	455
Daily intake by human (mBq)	13.0	190-270	$1\times10^{5}-1.4\times10^{5}$	7000
Annual effective dose (μSv)	1.2	7.0	180	6

1.5.1 Building materials

Determining population's exposure to radiation from building materials is important, because human's life is spent inside or close to these Technosphere objects.

Modified materials sometimes find themselves in building materials. All building materials contain amounts of natural radionuclides that cause exposure of people to ionizing radiation. Some waste materials from mining and industry, such as fly ash, phosphor gypsum and red mud are often used as additives to building materials (Krstić et al., 2007) and all these materials are known as technologically enhanced natural radioactive materials (TENORM) (Ramachandran, 2011). Investigation indicated that terrestrial background gamma radiation in an urban space depends on the type of building materials used for the construction of roads and pavements in as much as on the density of buildings forming the geometry of the source (Nowak & Solecki, 2015).

The activity concentration of natural radionuclides in construction materials has been studied and estimated in various countries around the world, for example in countries such as such as Bangladesh (Alam et al., 2001), Pakistan(Khan & Khan, 2001), Tanzania(Banzi & Msaki, 2000), Cyprus.(Michael et al., 2010), China (Yang et al., 2005), Angola (Salupeto-Dembo et al., 2020), Nigeria (Maxwell et al., 2018) and the state of Kuwait (Bou-Rabee & Bem, 1996). The findings from all the investigation found that building materials contain a significate amount of radioactive materials.

In the investigation of the effect of altitude on background radiation, the outdoor radiation measurements were performed by placing the detectors at least six meters away from any building or wall and one meter higher than the ground, to reduce their effects of buildings on background radiation on (D Shahbazi-Gahrouei, n.d.) This clearly shows the strong influence that building material have on the background radiation.

Moreover, the metal recycling industry has become increasingly aware of an unwanted component in metal scrap-radioactive material. Most of these metal parts are used in the construction industry. In a study carried out in recent past Worldwide, there have been 35 instances where radioactive sources were unintentionally smelted in the course of recycling metal scrap. In some cases contaminated metal consumer products were distributed internationally (Jo & Jg, 1998).^{38}U and ^{232}Th decay series radionuclides and also the ^{40}K are common elements to all earth born materials. All radioactive progenies of ^{238}U and ^{232}Th parents emit α or β particles followed by γ-rays until they end up to stable ^{208}Pb and ^{206}Pb. However, majority of the emitted α and β particles cannot come out from the sample matrix of the metal to the outside environment due to their low penetration power. On the other hand, most of the γ-rays can easily penetrate the sample matrix of the metal and enter into the building atmosphere (Asaduzzaman et al., 2015). In this regard gamma background measurements offers an effective means of investigating the effect of Technosphere objects on the background radiation.

In a review paper titled "Radioactive Materials in Recycled Metals." 35 accidental melting of radioactive sources in metal mills were reported, including 22 in the U.S., along with 293 other events in the U.S. where radioactive material was found in metals for recycling. There has been additional accidental melting of radioactive sources in metal mills both in the U.S. and other countries around the world. There also was an incident in Texas that involved stolen radioactive devices, which resulted in exposures of members of the general public. Also, the U.S. Nuclear Regulatory Commission took steps to address the underlying problem of inadequate control and accountability of radioactive materials licensed by the Nuclear Regulatory Commission. The Steel Manufacturers Association made available data collected by its members beginning in 1994 that expanded the database for radioactive materials found by the metal recycling industry in recycled metal scrap to over 2,300 reports as of 30 June 1997. (Jo & Jg, 1998)

1.5.2 Cements

Because background ionizing radiation has become a huge public concern a lot of survey has been carried out on Portland cement industry in many countries as it is one of the key ingredients in the construction of buildings (technoshere objects). During the manufacturing process in the cement industry, raw materials of different levels of natural radioactivity are utilized(Stojanovska et al., 2010). Cement is one of the most common material in building hence understanding its composition is an important aspect of radiation protection. Evaluation of the specific activity (Bq kg^{-1}) of its raw materials is an important issue, for they could be a source of considerable indoor and outdoor radiation dose rate. In this study of the radiological impact of cements as a building material and the different raw materials used in their manufacture results showed that the highest mean specific activity in fly ash (^{226}Ra, 107 ± 45 Bq kg^{-1}; ^{232}Th, 109 ± 30 Bq kg^{-1}; 40K, 685 ± 171 Bq kg^{-1}), which is used as a raw material. However, the final cement product usually has relatively lower activity compared with the activity of the raw material and the mean specific activity of the final cement products were lower (^{226}Ra, 42 ± 10 Bq kg^{-1}; ^{232}Th, 28 ± 6 Bq kg^{-1}; 40K, 264 ± 50 Bq kg^{-1}).

1.5.2.1 Fly ash

Fly ash is the residue of coal combustion collected by electrostatic or cyclone separator. It is one of the largest quantities of waste disposed in the world. Utilization of fly ash depends on its chemical, mineralogical composition and morphology. Because of coal nature, fly ash represents a significant drawback with presence of radionuclides such as ^{226}Ra, ^{232}Th and ^{40}K. The fly ash can be used for various applications. The main amount of the fly ash is used for building materials production as cement additive and concrete production (Temuujin et al., 2019). Coal and its byproducts often contain significant amounts of radionuclides, including uranium which is the ultimate source of the radioactive gas radon. Burning of coal and the subsequent emission to the atmosphere cause the re-distribution of toxic trace elements in the environment. Due to considerable economic and environmental importance and diverse uses, the collected fly ash has become a subject of worldwide interest in recent years (Mahur et al., 2008)

1.5.3 Radon in building materials

The largest contribution to exposure from natural background radiation comes from radon, thoron and their progeny. Extensive investigations have been carried out in different countries to estimate the concentration and emanation of radon from building material for example; Algeria (Amrani & Cherouati, 1999), India (Bala et al., 2017) , Saudi Arabia (Amin, 2015), Iran (Abbasi, 2017). The natural radioactivity in building materials (technoshere objects) gives rise to internal and external radiation exposure. The worldwide average indoor effective dose due to gamma rays from building materials is estimated to be about 0.4 mSv per year (United Nations, 2000). The average effective dose to the human population from this source amounts to 54% (1.3 mSv annually) of the total background exposure of 2.4 mSv per year (Mahat & Amin, 1990).

The sources of 222Rn in most dwellings are from the soil underneath and the building materials used for construction of the house. Sources of radon are the walls and floors of building that are made of soil material such as bricks, concrete, cement and tiles (Mahat & Amin, 1990). It has been determined that: The emission of radon per unit area per unit time is called exhalation rate and depends upon: (a) radium concentration in the material which in turn depends on the uranium concentration in the material, (b) emanation factor of radon from the material, (c) porosity and density of the material, and (d) diffusion coefficient of radon in the material. Radon gas ionizes the ambient atmospheres both indoor and outdoor (Bala et al., 2017)

1.5.4 Radioactivity in soils surface

Levels of terrestrial radiation differ from place to place in soils as the concentrations of these nuclides in earth's crust vary considerably. According to a research carried out in India, regions of Maharashtra and South Gujarat covered by the Decan lava basalt are found to have low radioactivity content. Gangetic alluvial regions covering parts of Uttar Pradesh, Bihar and West Bengal have higher natural radioactivity, while the granite region of Andhra Pradesh exhibits higher levels of the primordial radioactivity (Ramachandran, n.d.). In addition to being the main source of continuous radiation exposure to human, soil acts as a medium of migration for transfer of radionuclides to the biological systems and hence, it is the basic indicator of radiological contamination in the environment.(Al-Hamarneh & Awadallah, 2009). Most of the radioactivity in the terrestrial environment whether it is natural or man-made, is bound to the components of the soil. Transportation of this radioactivity from soil is possible to vegetation via dust deposition or root uptake, water sources by flood wash-down, and forward to humans through inhalation, breathing and soil ingestion. Therefore, all pathways of exposure that originate from soil are potentially important for the purpose of radiation risk assessment. Hence in the investigation of changes in gamma background radiation due to technosphere objects, considerable attention has been given to the soil radioactivity. As it is the means of establishing baseline data for future radiation impact assessment, radiation protection and exploration (Ramli et al., 2005)

Soil radionuclide activity concentration is one of the molar determinants of the natural background radiation. A number of decay products of Th and U series and 40K are the main components of gamma radiation originating from soil. About two thirds of natural radioactivity which exposes public is attributed to progeny of U series and 222Rn. The worldwide annual effective dose from natural sources is estimated to be 2.4 mSv (UNSCEAR 2000). Natural radionuclides of the uranium–radium and the thorium series as well as 40K are distributed in soil almost homogeneously, regardless of the depth (*Dołhańczuk-Śródka, 2012*.). Their concentration depends on local geological conditions. In addition to being the main source of continuous radiation exposure to human, soil acts as a medium of migration for transfer of radionuclides to the biological systems and hence, it is the basic indicator of radiological contamination in the environment. (Al-Hamarneh & Awadallah, 2009). Moreover, the soil radioactivity is usually important for the purposes of establishing baseline data for future radiation impact assessment, radiation protection and exploration (Ramli et al., 2005).

1.6 Mineral extraction activities

Mineral extraction activities, such as those conducted by oil, gas and coal industries, are widespread throughout the Arctic region. Waste products of these activities can result in significant contributions to the radioactive burden of the surrounding environment due to increased concentrations of naturally occurring radioactive materials (NORM) to levels that would not normally be found in the environment. Coal contains radionuclides of the uranium and thorium series as well as 40K. Extraction and processing of coal can result in releases of these radionuclides to the broader environment with subsequent impact on the human and non-human inhabitants of the area. In the study on environmental radioactivity resulting from historical coal mining operations conducted at Ny-Alesund, Spitsbergen, in the Svalbard archipelago. It found that there was an increased concentration of radionuclides found in materials associated with these operations from the spatial dosimetric survey conducted over an area affected by coal mining (Dowdall et al., 2004).

1.7 The Effects of Radiation Exposure

Radiation exposure can damage living cells, causing death in some of them and modifying others. Most organs and tissues of the body are affected by loss of even considerable numbers of cells. However, if the number of is large enough, there will be observable harm to organs that lead to death. Such harm occurs in individuals who are exposed to radiation in excess of a threshold level. Other radiation damage may also occur in cells that are not killed but modified. Such damage is usually repaired. If the repair is not perfect, the resulting modification will be transmitted to further cells and may eventually lead to cancer. The assessment of the radiation level and its impact on the environment has received great attention worldwide. This is because of the negative health effects ionizing radiation has on biological tissues (Ugbede & Echeweozo, 2017). When a nuclear radiation type passes through a living cell, both excitation and ionization take place thereby altering the structure of the cells. These cells may be damaged directly by the radiation or indirectly by the free radicals (OH and H) produced in the adjacent cells. Many forms of damage could occur from radiation but the most important is that done to the deoxyribonucleic acid (DNA) (Emelue, 2014). A damage to the DNA results in gene mutation, chromosomal aberration and breakages or cell death.

When highly energetic ionizing radiation interacts with biological tissues, it causes ionization with subsequent release of charged particle and free radicals thereby causing alteration in cell structure and damage to deoxyribonucleic acid (DNA). A radiation induced cancer can develop from a single damaged cell independently of other damaged cells in the tissue of interest. The period between radiation exposure and the detection of cancer is known as the latent period and could be many years. Therefore, excess lifetime cancer risk is the probability that an individual will develop cancer over his/her lifetime of exposure (Emelue, 2014).

1.8 Radiation exposure to low dose radiation

The increasing exposure to low-dose radiation from diagnostic testing has prompted renewed interest in evaluating its carcinogenic risk, but quantifying health risk from low-dose radiation exposure remains controversial (Nguyen & Wu, 2011). Despite the growing concern of the public and federal regulators, it remains unclear whether low-dose radiation causes an increased risk of cancer. But in the investigation of cancer risks of low radiation doses, which focused on survivors with doses less than 0.5 Sv within 3, 000 m of the hypocentre of the bombs, investigation was based on solid cancer incidence from 1958-1994, involving 7,000 cancer cases among 50,000 survivors in that dose and distance range. It was found that there is a statistically significant risk in the range 0-0.1 Sv (Pierce & Preston, 2000) ..

1.9 Gamma radiation

Ambient background gamma dose rate in air at any specific location fluctuate in time due to a contribution of radon progenies on the ground by rainfall as well as due to soil moisture and snow cover. Precipitation such as rain and snow lead to deposition of Rn progenies from the atmosphere on the ground surface and this creates Rn peaks (Avdic et al., 2020). Natural gamma background radiation originates from four distinct components: cosmic ray shower events, cosmic ray produced atmospheric activity, terrestrial sources, and skyshine from terrestrial source (Mitchell et al., 2009).The measurement of natural gamma radiation is one of the most important subjects in health physics (Saghatchi et al., 2008). Gamma radiation or gamma rays are high-energy photons that are emitted by radioactive decay of atomic nuclei. This type of radiation is very high-energy form of ionizing radiation, with the shortest wavelength. The most common terrestrial radioelements that produce gamma-rays are uranium-238, thorium-232 and potassium-40 (Ramli et al., 2005). Gamma rays are emitted in an attempt by the radionuclide to become stable. Gamma rays have moderate-to-high penetrating power, are often able to penetrate deep into the body, and generally require some form of shielding, such as lead or concrete. Visible light is also in the form of photons. Gamma photons behave similarly to light, but they are invisible. For ranges of Energies between 10keV and 2MeV, three types of interaction are important. The first effect, which is predominates at lower energies is photovoltaic effect. This occurs when a photon interacts with an electron from the inner orbit. The electron is ejected with an energy equal to that of the photon minus its binding energy.

Various research has been carried out to investigate gamma background radiation in the urban environment for example, an investigation of Annual Effective Dose From Environmental Gamma Radiation in Bushehr City showed that, the average annual effective dose from background gamma radiation in Bushehr city was less than global level (Mahmoud Pashazadeh et al., 2014), while in an investigation of gamma dose rates in the high background radiation area of Mangalore region, India showed that, at certain beach locations the radiation level is higher due to the natural deposits of monazite bearing sand. The gamma absorbed dose observed at locations of monazite deposit is an order of magnitude higher when compared to normal background regions (Al-Azmi et al., 2019).

1.10 Factors affecting background radiation

Research has shown that background radiation is affected by a number of factors. Temperature, pressure, wind speed and precipitation are some of the factors that affect background radiation. In addition, meteorological elements that affect background radiation in the environment each have each have a different weight in the formation of the background radiation. The strongest influence on the spread of radioactive contamination have winds. And also different rainfall and the permeability of the atmospheric layer no solar radiation reaching us (Dolchinkov, 2017).

1.10.1 Precipitation

It is very common for natural background radiation levels to change during precipitation events such as rain, sleet or snow. It has long been observed that the environmental gamma-ray dose rate increases noticeably during precipitation intervals. This increase, due to the presence of radon progeny in the rain droplets. This can affect the reliability of the monitoring of artificial radioactivity and long term estimates of exposure to ambient natural radionuclides in surveillance network (Mercier et al., 2009). Radon and radon decay products, which occur naturally may be captured in the precipitation and brought to the ground, causing a temporary increase in radiation levels. In a research carried out in japan, Radon daughter concentrations in precipitation and in surface air were observed since 1977 in Maizuru, in order to study the relationship between the two concentrations and the influence of precipitation patterns on the concentration in precipitation. Results obtained from analysis of the observed data suggest that radon daughters in precipitation originate mainly from scavenging within the cloud (rainout) and not from that below the cloud (washout) (Fujinami, 1996). Although various radionuclides such as ^{7}Be, ^{212}Pb and ^{210}Pb are observed in precipitation, most of the activity is owing to the radionuclides ^{214}Pb and ^{214}Bi (Fujinami, 1996; Mercier et al., 2009). Therefore, the rain contribution to the environmental gamma-ray intensity decreases according to the half-lives of ^{214}Pb and ^{214}Bi after cessation of precipitation (Fujinami, 1996; Mercier et al., 2009). In the study of Rain-induced increase in background radiation detected by Radiation Portal Monitors (Livesay et al., 2014) found that Time-correlated data from a RPM, HPGe, and a weather station proved the increase in background recorded onRPMs during precipitation is a result of the deposition of radon progeny on the ground.

While there are many more factors that affect radiation levels than just precipitation. However, barometric pressure and the vertical temperature profile, which determine the “lid” under which the radon is generally trapped, may negate the precipitation effect on radiation. Therefore, it is also possible that radiation levels won’t rise during a precipitation event. Snow and sleet may cause radiation levels to decrease since their build up on the ground may shield radon migration into the atmosphere, as well as shield direct radiation from the ground. Each year there are seasonal changes in the gamma radiation dose rate value. Additionally, daily changes and changes caused by precipitation are observed. These changes are due to differences in exhalation of radon from soil and in the case of precipitation washing out radon isotopes from the air and deposition on the soil surface.

1.10.2 Technosphere

In the study of the influence of the city (Technosphere) on the variations of electrophysical and radiation quantities (Nagorskiy et al., 2017). It was found that: the presence of the building does not change the spectral-temporal picture of variations (UHF) (magnetic field, atmospheric pressure); 2) the presence of the building partially changes the UHF (γ - background, temperature); 3) the presence of the building completely changes the UHF (relative air humidity, turbulent and wind characteristics of the air, electric field strength, the number of light ions of both polarities,α- and β in the background) (Nagorskiy et al., 2017).

1.11 Radiation doses

1.11.1 Ambient dose equivalent

The ambient dose equivalent, is the dose equivalent at a point in a radiation field that would be produced by the corresponding expanded and aligned field in the ICRU sphere at depth of 10 mm on the radius opposing the direction of the aligned field (Al Kanti et al., 2019). The ambient dose equivalent H*(10) is recommended by the ICRP as the operational quantity for assessing effective dose in area monitoring (*ICRP 103*, 2017). In most practical situations of external radiation exposure, the ambient dose equivalent fulfils the aim of providing a conservative estimate or upper limit for the value of the limiting quantities(Casanovas et al., 2016). The ICR sphere is a sphere of 30-cm diameter made by tissue equivalent material with a density of 1 g/cm3 and a mass composition of 76.2% oxygen, 11.1 % carbon, 10.1 % hydrogen and 2.6% nitrogen. The ambient equivalent dose is defined as a product of Q and D at a point in tissue, where D is the absorbed close and Q the quality factor at the point.

1.11.2 Effective dose equivalent

The effective dose can be defined as the sum of all equivalent doses H_T in all exposed organs and tissues, taking into account the dimension assigned to them less the tissue weighting factor W_T (Jakubowska & Długosz-Lisiecka, 2020). Calculation of effective dose is shown in the equation below (*ICRP*, 2017)

$$E = \sum_T W_T \sum_R W_R D_{T,R} \qquad (1.1)$$

where W_R is the radiation weighting factor (being unity for gamma rays), $D_{T,\ R}$ is the absorbed dose to an organ or tissue, WT is the tissue weighting factor and E is the effective dose.

In order to obtain information about the equivalent dose of H_T in a given organ or tissue, it is necessary to multiply the average dose D absorbed by a given organ or tissue by the dimensionless mass ratio of W_R radiation, which takes into account the relative biological effectiveness of a given type of radiation. In mixed fields, the equivalent dose is the sum of the products of the doses absorbed for a given volume and the corresponding radiation weighting factors for all components of the mixed radiation field (Jakubowska & Długosz-Lisiecka, 2020)

$$H = \sum W_R \cdot D_{R,T} \qquad (1.2)$$

The ICRP 2017 standard values for relative effectiveness are given below. The higher radiation weighting factor for a type of radiation, the more damage the radiation courses.

Table 1.5 Radiation weighting factor for a type of radiation

Radiation	Energy WR
x-rays, gamma rays, beta particles, muons	1
neutrons (< 1 MeV)	$2.5 + 18.2e^{-[\ln(E)]2/6}$
neutrons (1 - 50 MeV)	$5.0 + 17.0e^{-[\ln(2E)]2/6}$
neutrons (> 50 MeV)	$2.5 + 3.25e^{-[\ln(0.04E)]2/6}$
protons, charged pions	2
alpha particles, nuclear fission products, heavy nuclei	50

1.11.3 Excess lifetime cancer risks

The excess lifetime cancer risks (ELCR) is computed from annual effective dose equivalent (Abdullahi et al., 2019). The annual effective dose equivalent (AEDE) is calculated by using the following equation (Njinga & Tshivhase, 2016; Taskin et al., 2009):

$$AEDE = ADR \times T \times OF \times DCF \quad (1.3)$$

where ADR IS absorbed dose rate in air ($nGyh^{-1}$), OF is the outdoor occupancy factors of 0.2, DCF dose conversion factor (0.7 Sv/Gy) and T is the time in years (8760 hyr^{-1}). Excess lifetime cancer risk (ELCR) was calculated by using the Equation below

$$ELCR = AEDE \times DL \times RF \quad (1.4)$$

where DL is the life duration (70 years) and RF is the fatal cancer risk factor for stochastic effect which is 0.055 Sv^{-1} for the general public.

Chapter 2 Materials and Methods

The investigation was carried out in the city of Tomsk, Russia. Gamma background radiation was studied using gamma radiation detection unit BDKG-03. 14 sites were studied in 5 location, the location included:

1. Largerny Garden (sites LA1A, LA1B and LA1C);
2. Lenta (site LE2A and LE2B);
3. University building No. 10 TPU (sites UB3A and UB3B);
4. Novo-Sobornaya Square (site N034A and NO4B);
5. Alley of Geologist (sites GL5A, GL5B, GL5C, GL5D and GL5E);

The site for investigation were picked depending the number of people who visit these sites, the presence and the types of technoshere objects, the absence of technoshere objects and proximity. Measurements were done 1m above the ground level with the detector facing the point under investigation. Points ranging from 1 to 10 were picked for investigation depending on the characteristic of the site under investigation. The duration of measurement for each point was 5 minutes. Measurements were done in autumn, winter and spring.

2.1 Gamma radiation detection unit BDKG-03

BDKG-03 is a highly sensitive scintillation intelligent gamma radiation detection unit designed to search, quickly detect and localize gamma radiation sources with sensitivity of ^{137}Cs 350 (imp / s) / (μSv / h), as well as to measure ambient equivalent dose rate and gamma dose -radiation in the energy range 50 keV - 3 MeV. Areas of use include:

- Search, detection and localization of ionizing radiation sources;
- Radiation monitoring of scrap metal - MUK 2.6.1.1087-02;
- Radiation monitoring of the environment, territories, objects, raw materials;
- Dosimetric and radiometric control in industrial enterprises;
- Contamination heterogeneity control;

Figure 2.1-Gamma radiation detection unit BDKG-03

Figure 2.2-instrument setup

Table 2.1 Gamma radiation detection unit BDKG-03 main technical Specifications

Detector	NaI (Tl), ø25x40 mm
Range of measurement of ambient equivalent dose rate of gamma radiation, $\mu Sv\ /\ h$	0.03 μSv - 10 mSv
Energy range	50 keV - 3 MeV
The main measurement error, %	no more than ± 2
Energy dependence of sensitivity, %	± 20
Sensitivity at 137 Cs, imp • s^{-1} / $\mu Sv\ \bullet\ h\ -1$	350
Operating temperature range, ^{o}C	-30 - +50
Relative humidity at a temperature of 35 ^{o}C, %	no more than 98
Protection class	IP64
Continuous work hours	not less than 24
Level of industrial interference	
- STB GOST R 51318.22-2001	
Electromagnetic compatibility	
- STB GOST R 51317.4.2-2001	
- STB GOST R 51317.4.3-2001	
Overall dimensions, mm.	ø60x295
Weight kg	0.6

2.2 Desk Research

Desk research aimed at collecting as many information as possible concerning the possibility of data source. The information was collected through journals of published research work which has already been done by other researchers. More than 35 academic studies have been reviewed, this sample is substantial and representative, but is not intended to be comprehensive. Academic studies were selected via keyword search, which directed attention predominantly to specialist journals, including: radiation background, sources of background radiation, Technosphere objects, technologically enhanced background radiation, gamma radiation, factor affecting gamma background radiation, Seasonal dynamics of background radiation, radiation due to building materials, Excess life time cancer risk

The grey literature search reflected the recommendations of experts in the field and include: The International Atomic Energy Agency (IAEA), International Radiation

Protection Authority (IRPA), International Commission of Radiological Protection (ICRP), Federal Nuclear and Radiation Safety Authority in Russia (FNRSA).

2.3 Mathematical Model for analyzing the result

2.3.1 Equivalent dose

The instrument used in the study measured the equivalent dose. The equivalent dose to any tissue target is obtained simply by multiplying the absorbed dose to that tissue by the radiation weighting factor which accounts for differences among types of radiation in producing biological response. For gamma rays, x rays, and beta radiation, the radiation weighting factor is taken as 1.0. Equivalent dose H_T is calculated using the mean absorbed dose deposited in body tissue or organ T, multiplied by the radiation weighting factor W_R which is dependent on the type and energy of the radiation R.

$$H_T = \sum_R W_R \cdot D_{T,R} \qquad (2.1)$$

Where,

H_T is the equivalent dose in sieverts (Sv) absorbed by tissue T

$D_{T,R}$ is the absorbed dose in grays (Gy) in tissue T by radiation type R

W_R is the radiation weighting factor.

2.3.2 Annual Effective Dose Equivalent (AEDE)

It is the tissue-weighted sum of the equivalent doses in all specified tissues and organs of the human body and represents the stochastic health risk to the whole body, which is the probability of cancer induction and genetic effects, of low levels of ionising radiation (*ICRP*, 2017) .The annual effective dose equivalent radiation is computed from absorbed dose rate by applying a dose conversion factor of $0.7 Sv/Gy$, factor of 0.7 Sv/Gy recommended by UNSCEAR for the conversion coefficient from the absorbed dose in air to the effective dose received by adults and occupancy factor of 0.2 (4.8/24 hours) for outdoor radiation. This is on the estimation that an average man spends about 4.8 hours outdoors.

$$AEDE\left(mSv / yr\right) = ADR \times T \times DCF \times OF \times 10^{3} \qquad (2.2)$$

Where

ADR is absorbed dose rate

T is time for one year in hours/yr

OF is occupancy factor

2.3.3 Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk deals with the probability of developing cancer over a lifetime at a given exposure level. (Taskin et al., 2009).

$$ELCR = AEDE \times DL \times RF \qquad (2.3)$$

Where

AEDE is the annual effective dose equivalent

DL is the average duration of life

RF is the risk factor

The average duration of life (estimated to be 70 years) and for stochastic effects, ICRP uses RF as 0.05 for the public and the world permissible standard of 0.29 x 10^{-3} (Taskin et al., 2009).

The average ambient gamma equivalent dose was calculated for each point for the number of measurements made on that particular point. Absorbed dose was calculated from the equivalent dose. the absorbed dose was used to calculate the Annual effective dose equivalent using the assumption that an average adult spends 4.8hrs outdoors. Annual effective dose equivalent was used to calculate Excess life time cancer risk. The calculated radiation doses were compared with recommended safe limits and world average.

Chapter 3 Results and Discussion

The results of investigation are presented in the form of graphs and tables, the arrows on the picture indicated the points of measurements on each site investigated.

3.1 Absorbed dose, Annual effective dose equivalent and Excess life time cancer risk at Lagernyy Garden (Sites LA1A, LA1B and LA1C)

To determine the dose characteristic on the location under investigation measurements were made on site LA1A. 6points where picked for investigation, each point was 10m apart. The number and position of points are shown in figure 3.1.

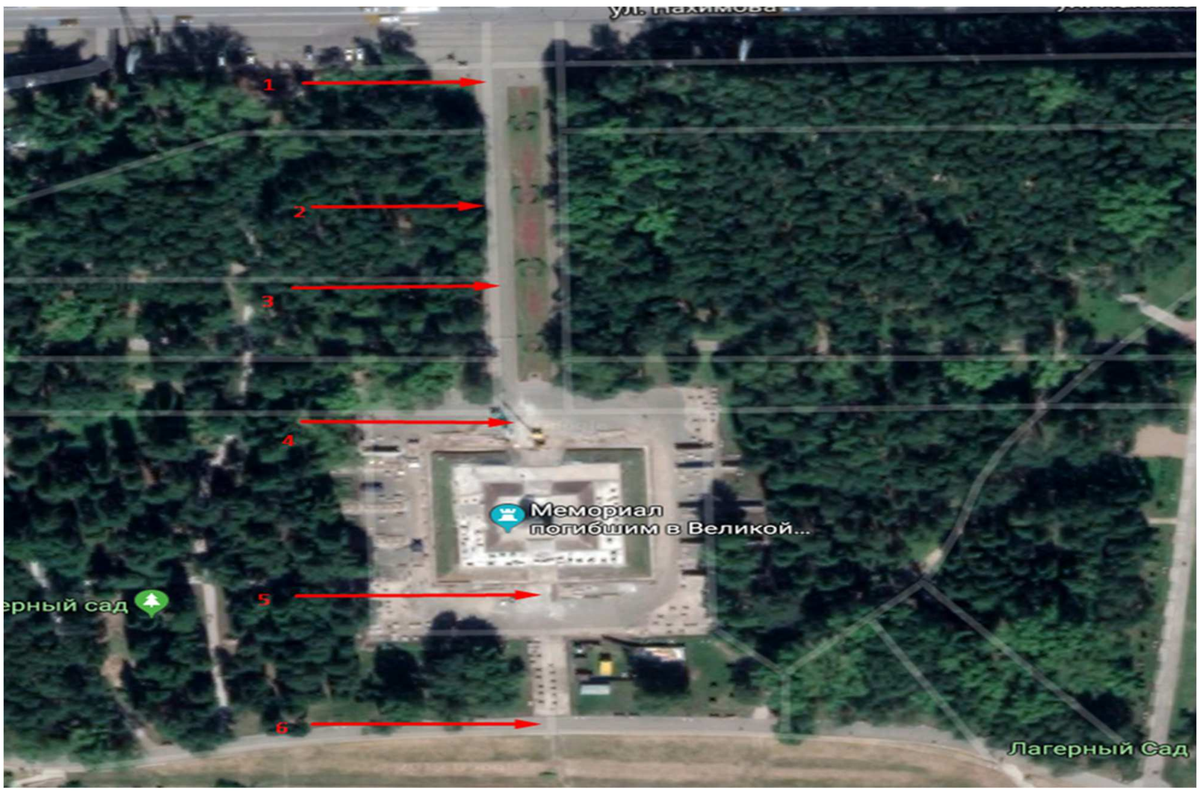

Figure 3.1 Location of measurements and measured points at site LA1A

A plot of equivalent dose against the number of points shows fluctuations in gamma background radiation from point 1 to 6. There is a high increase in gamma background radiation on 4 and 5. The increase in gamma background radiation can be attributed to the type of building materials (granite rocks) that constitute point 4 and 5. Points 1, 2, 3 and 6 are on pavement area made from different materials.

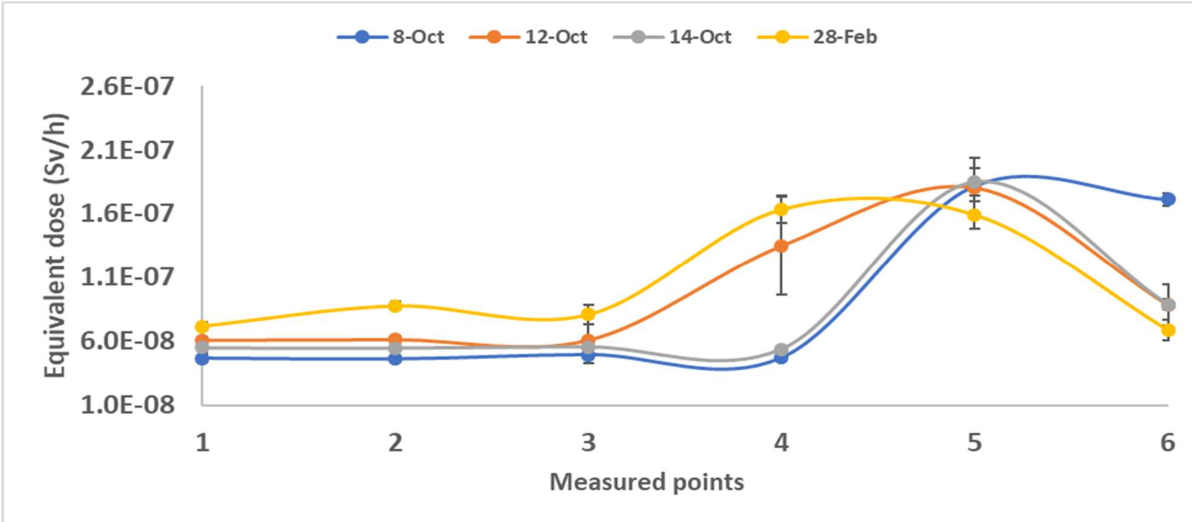

Figure 3.2 Change in equivalent dose from point 1 to 6 at site LA1A

Table 3.1 Mean equivalent dose at site LA1A

Measurements	Place of measurement		Date of measurement				Ambient temperature
БДКГ-03	Лагерный сад		**8/10/19 to 28/02/20**				
Description	Measurement Points (Each point 10m apart)						
Number of points	1	2	3	4	5	6	
Ambient Dose Equivalent Sv/h	5.85E-08	6.24E-08	6.17E-08	9.99E-08	1.77E-07	1.04E-07	
Dose error %	5.4	5.1	11.7	11.0	6.2	7.6	
Impulse Imp/s	38.37	40.04	40.35	65.57	94.88	61.87	
Impulse error %	2.0	1.9	2.1	3.1	2.0	3.0	
Impulse calculated Sv/h	6.60E-08	6.89E-08	6.94E-08	1.13E-07	1.63E-07	1.06E-07	
Impulse accuracy Sv/h	1.32E-09	1.29E-09	1.46E-09	3.47E-09	3.27E-09	3.17E-09	
Dose accuracy	3.16E-09	3.17E-09	7.22E-09	1.09E-08	1.09E-08	7.88E-09	

Table 3.2 Calculated doses at site LA1A

Description	Measurement Points					
points	1	2	3	4	5	6
ADR nGy/h	58.46	62.38	61.69	99.89	176.81	104.36
AEDE mSv/yr	0.07	0.08	0.08	0.12	0.22	0.13
ELCR$\times 10^{-3}$	0.25	0.27	0.26	0.43	0.76	0.45

To investigate the dependence between distance from technoshere objects and gamma background radiation also to determine dose characteristic within a density of technoshere objects made from the same materials. Measurements were made at site LA1B 5cm and 50cm away from the objects.

Figure 3.3 Location of measurements and number of points at site LA1B

Points 2,4,6,8 are 5cm away from the technosphere object, points 2,5,7 are in between the technosphere objects, the points 1 and 9 are several meters way from the objects. The results of the investigating are shown in figure 3.2. From the graph it can be observed how dose changes from point 1 to point 9. I was found that equivalent dose increases at point 2, 4, 6 and 8 as the detector moves from 50cm to 5cm close to the technoshere object.

A plot of equivalent dose against the number of points shows fluctuations in gamma background radiation from point 1 to 9. There is a high increase in gamma background radiation on point 2, 4, 6 and 8 at a distance of 5cm.in between the objects the fluctuations in radiation are minimal. At point 1 and 9 there is a strong decrease in radiation due to the change in the type of building material. The increase in gamma background radiation can be attributed to the type of building material. At 5cm the background radiation is 1.3 time higher than at 50cm.

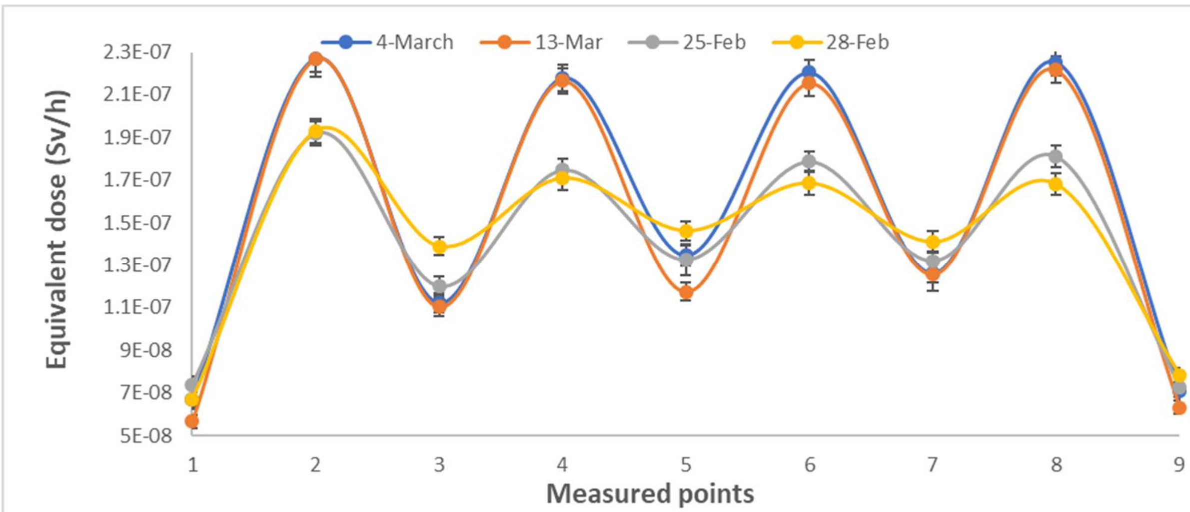

Figure 3.4 Change in equivalent dose from point 1 to 9 at site LA1B

Table 3.3 Mean equivalent dose measured 5cm from Technosphere object site LA1B

Measurements	Place of measurement		Date of measurements				Ambient temperature	
БДКГ-03	Лагерный сад (site LA1B)		**25/02/20 to 28/02/20**					
Description	Measurement Points (Points 2, 4, 6 and 8 5cm way from object)							
Number of points	1	2	3	4	5	6	7	8	9
Ambient Dose Equivalent Sv/h	6.18E-08	2.27E-07	1.11E-07	2.17E-07	1.26E-07	2.18E-07	1.26E-07	2.23E-07	6.71E-08
Dose error %	6.4	3.3	3.95	2.4	3.6	2.8	4.8	2.8	5.6
Impulse	42.3385	112.77	68.98	105.78	77.56	106.15	76.59	108.26	41.15

Imp/s									
Impulse error %	2.3	2.1	1.5	1.2	1.4	1.2	1.9	1.2	2.1
Impulse calculated Sv/h	7.29E-08	1.94E-07	1.19E-07	1.82E-07	1.33E-07	1.83E-07	1.32E-07	1.86E-07	7.08E-08
Impulse accuracy Sv/h	1.64E-09	4.08E-09	1.78E-09	2.18E-09	1.87E-09	2.19E-09	2.44E-09	2.24E-09	1.49E-09
Dose accuracy Sv/h	3.93E-09	7.49E-09	4.39E-09	5.97E-09	4.47E-09	5.99E-09	5.98E-09	6.26E-09	3.72E-09

Table 3.4 Calculated doses for each point measured at site LA1B

Description	Measurement Points (Points 2, 4, 6 and 8 5cm way from object)								
points	1	2	3	4	5	6	7	8	9
ADR nGy/h	61.83	226.98	111.22	217.18	126.01	217.94	125.91	223.46	67.09
AEDE mSv/yr	0.08	0.28	0.14	0.27	0.15	0.27	0.15	0.27	0.08
$ELCR \times 10^{-3}$	0.27	0.97	0.48	0.93	0.54	0.94	0.54	0.96	0.29

Table 3.5 Mean equivalent dose for 50cm way from Technosphere object at site LA1B

Measurements	Place of measurement	Date of measurement						Ambient temperature	
БДКГ-03	Лагерный сад (site LA1B)	**4/03/20 to 13/03/20**							
Description	Measurement Points (Points 2, 4, 6 and 8 50cm way from object)								
Number of points	1	2	3	4	5	6	7	8	9
Ambient Dose Equivalent Sv/h	7.06E-08	1.93E-07	1.30E-07	1.73E-07	1.39E-07	1.74E-07	1.37E-07	1.75E-07	7.56E-08
Dose error %	4.9	3.0	3.5	3.1	4.3	3.1	3.6	3.0	5.5
Impulse Imp/s	44.18	102.23	75.32	93.45	80.18	92.98	80.05	94.42	44.04
Impulse error %	1.9	1.2	1.4	1.3	1.7	1.3	1.4	1.2	2.1
Impulse calculated Sv/h	7.60E-08	1.76E-07	1.30E-07	1.61E-07	1.38E-07	1.60E-07	1.38E-07	1.63E-07	7.58E-08
Impulse accuracy	1.41E-09	2.11E-09	1.75E-09	2.01E-09	2.28E-09	2.44E-09	1.93E-09	1.95E-09	1.59E-09

Sv/h									
Dose accuracy Sv/h	3.42E-09	5.68E-09	4.47E-09	5.36E-09	5.93E-09	5.38E-09	4.85E-09	5.24E-09	4.12E-09

Table 3.6 Calculated doses for 50cm away from technosphere object at site LA1B

Description	Measurement Points (Points 2, 4, 6 and 8 50cm way from object)								
points	1	2	3	4	5	6	7	8	9
ADR nGy/h	70.59	192.52	129.53	172.84	139.44	173.63	136.54	174.53	75.62
AEDE mSv/yr	0.09	0.24	0.16	0.21	0.17	0.21	0.17	0.21	0.09
ELCR$\times10^{-3}$	0.30	0.83	0.56	0.74	0.60	0.75	0.59	0.75	0.32

Measurements at LA1C were made to compare doses from site LA1A and site LA1B. measurements were made in soil area and each point was 10m apart to determine the dose characteristic of the soil area. Site L1C is several metres from site LA1A and site LA1B.

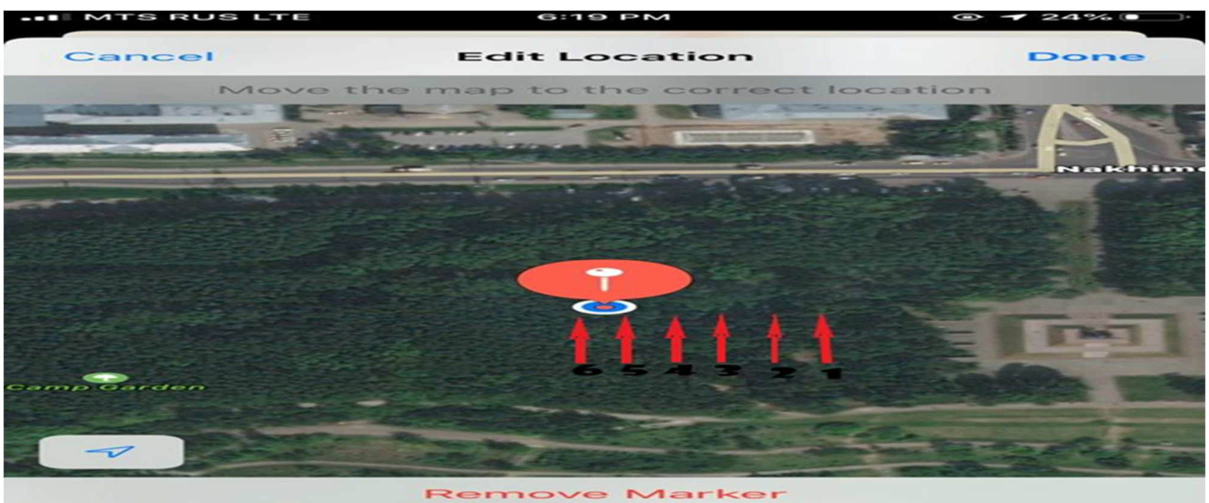

Figure 3.5 Location of measurements and measured points at site LA1C.

A plot of equivalent dose against the number of points shows minimal fluctuations in gamma background radiation from point 1 to 6. The minimal fluctuations are mainly due to uneven distribution of radionuclides in the soil area plus other factors that affect background radiation.

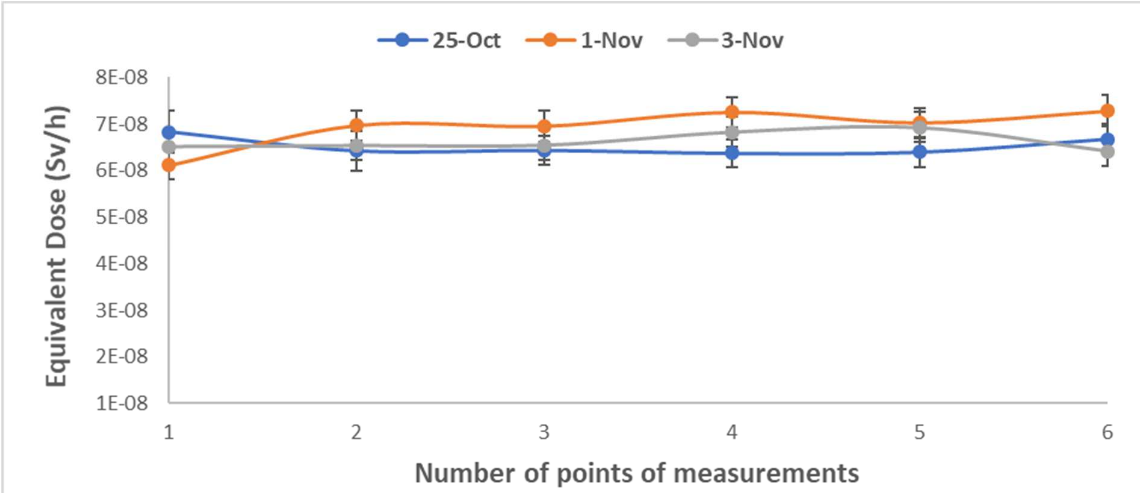

Figure 3.6 Change in equivalent dose from point 1 to 6 at site LA1C

Table 3.7 Mean equivalent dose at site L1C

Measurements	Place of measurement		Date of measurement				Ambient temperature
БДКГ-03	Лагерный сад (site L1C)		25/10/2019 to 3/10/19				
Description	Measurement Points (Points 10m apart)						
Number of points	1	2	3	4	5	6	
Ambient Dose Equivalent Sv/h	6.49E-08	6.64E-08	6.64E-08	6.82E-08	6.78E-08	6.79E-08	
Dose error %	5.6	5.4	4.8	4.7	4.8	4.8	
Impulse Imp/s	40.74	42.11	40.44	41.34	40.56	40.20	
Impulse error %	2.1	2.1	1.9	1.8	1.9	1.9	
Impulse calculated Sv/h	7.01E-08	7.25E-08	6.96E-08	7.11E-08	6.98E-08	6.92E-08	
Impulse accuracy Sv/h	1.50E-09	1.50E-09	1.30E-09	1.30E-09	1.30E-09	1.29E-09	
Dose accuracy	3.63E-09	3.57E-09	3.21E-09	3.20E-09	3.23E-09	3.26E-09	

Table 3.8 Calculated doses at site LA1C.

Description	Measurement Points					
points	1	2	3	4	5	6
ADR nGy/h	64.86	66.43	66.43	68.16	67.83	67.87
AEDE mSv/yr	0.080	0.081	0.081	0.084	0.083	0.083
ELCR$\times 10^{-3}$	0.28	0.29	0.29	0.29	0.29	0.29

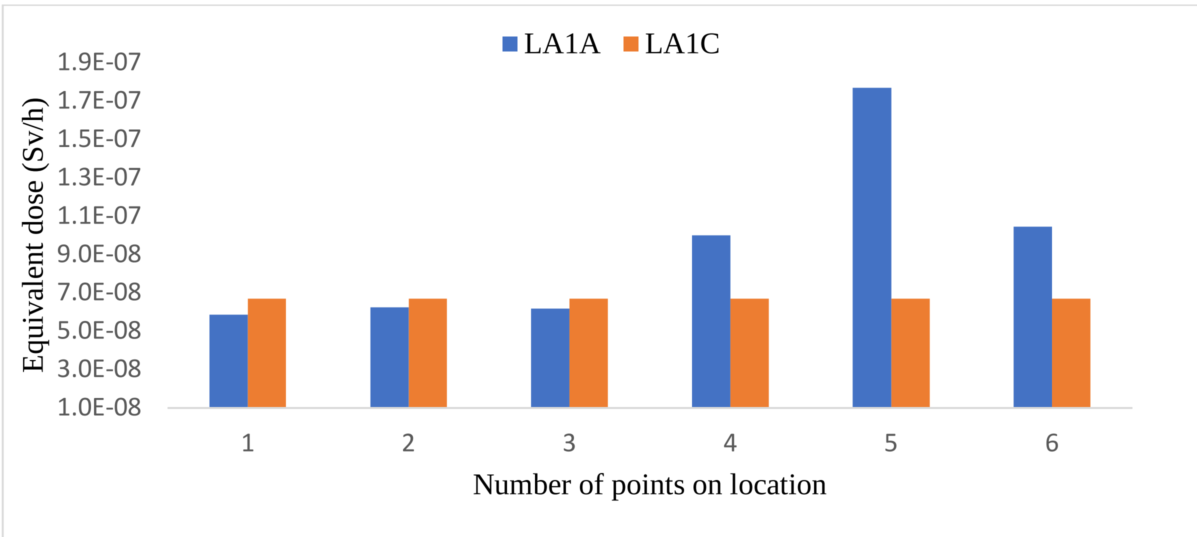

Figure 3.7 Dose comparison between site LA1A and LA1C.

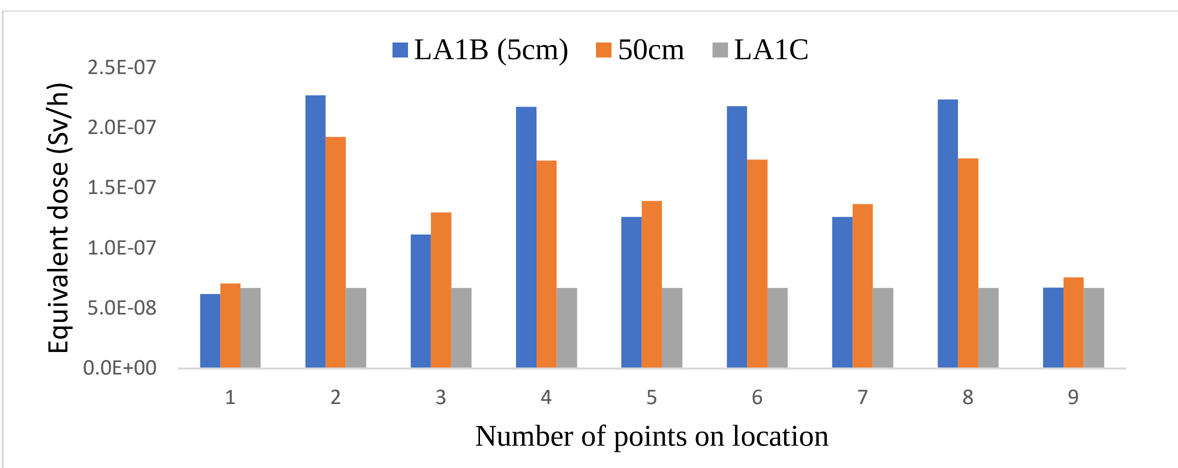

Figure 3.8 Dose comparison between site LA1B and Site LA1C

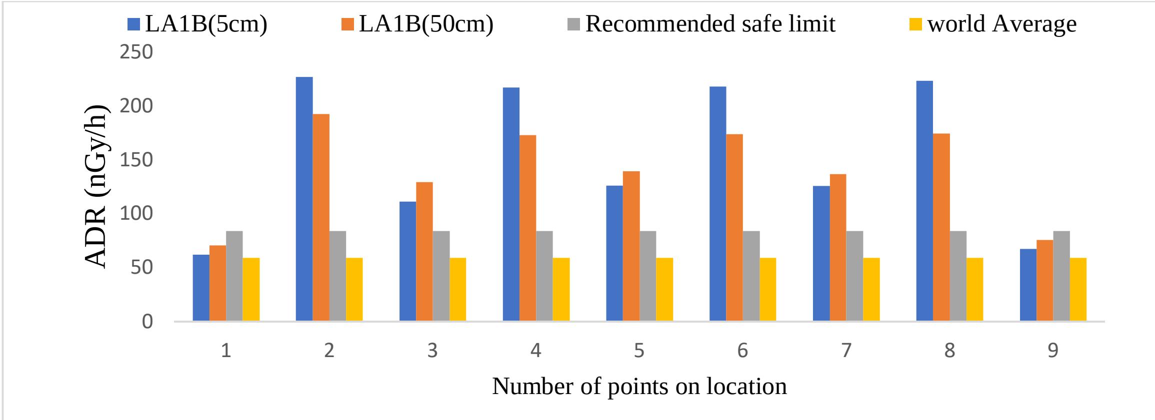

Figure 3.9 Absorbed dose rate at site LA1B compared with world average and recommended safe limit

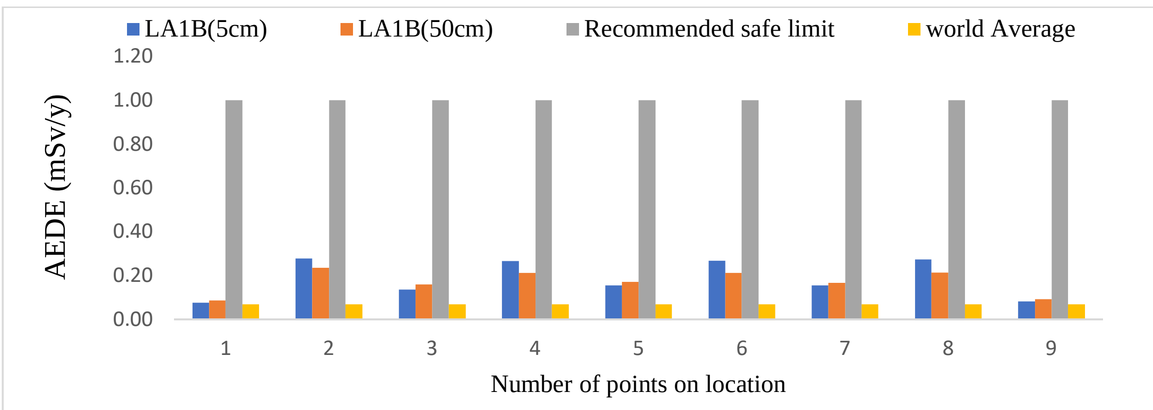

Figure 3.10 Annual effective dose equivalent at site LA1B compared with world average and recommended safe limit

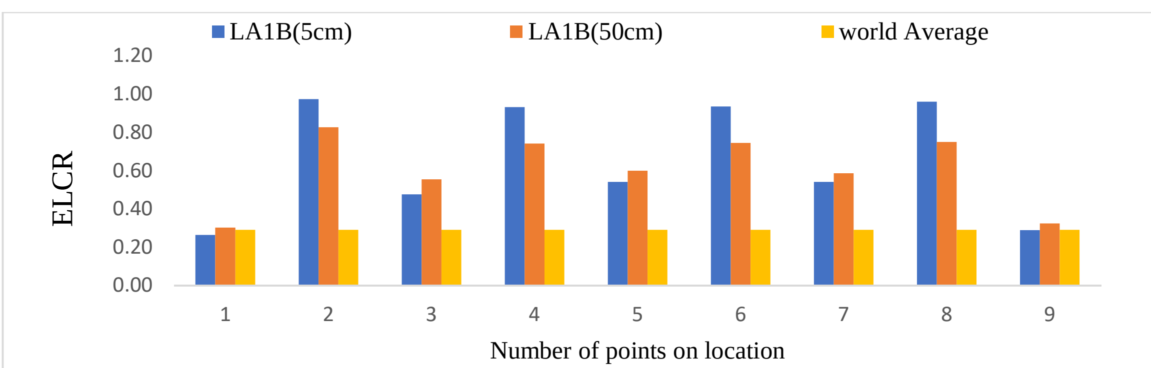

Figure 3.11 Excess life time cancer risk with compared with world average at site LA1B

At 5cm absorbed dose rate (ADR) 2.6 times higher than the recommended safe limit of 84nGy/h and 3.8 times higher the world average value of 59nGy/h. at 50cm ADR is 2.1time higher than recommended safe limit and 3 times higher than world average. Hence a person standing at a point 50cm way from the technoshere objects will receive a dose 2.1 times higher than the recommended safe limit. At all points annual effective dose equivalent is much higher than the world average, but lower than the ICRP recommended permissible limits of 1.00mSv/yr for the general public. Excess life time cancer risk is 3.3 times higher than the world average at 5cm and 2.6 times higher at 50cm.

3.2 Absorbed dose, Annual effective dose equivalent and Excess life time cancer risk at Lenta (sites LE2A and LE2B)

To determine dose characteristics of pavement area at Lenta car park, 5 point were measured each point was 10m apart. The number of points and location of measurements are shown in figure 3.12.

Figure 3.12 Location of measurements and number of points Lenta site LE2A

A plot of equivalent dose against the number of points shows minimal fluctuations in gamma background radiation from point 1 to 5.

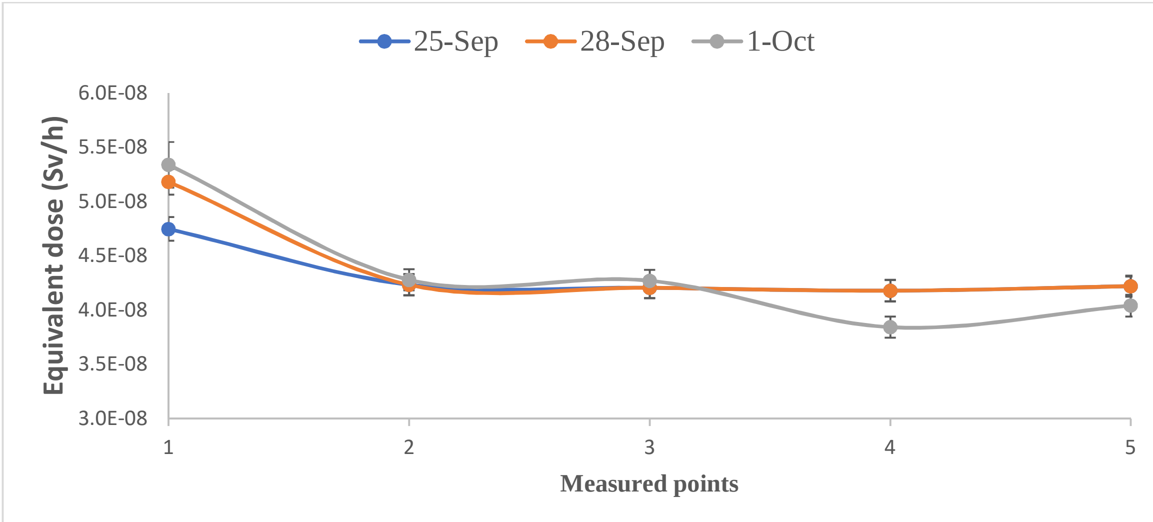

Figure 3.13 Change in gamma ambient equivalent dose from point 1 to 5 at site LE2A.

Table 3.9 Average gamma ambient equivalent dose at site LE2A.

Measurements	Place of measurement	Date of measurements				Ambient temperature
БДКГ-03	Lenta (site LE2A)	**25/09/19 to 1/10/19**				
Description	Measurement Points					
Number of points	1	2	3	4	5	
Ambient Dose Equivalent Sv/h	5.09E-08	4.25E-08	4.23E-08	4.07E-08	4.16E-08	
Dose error %	7.40	6.00	6.10	6.33	6.20	
Impulse Imp/s	29.17	24.64	24.59	23.71	23.18	
Impulse error %	2.9	2.3	2.3	2.4	2.4	
Impulse calculated Sv/h	5.02E-08	4.24E-08	4.23E-08	4.08E-08	3.99E-08	
Impulse accuracy	1.46E-09	9.75E-10	9.73E-10	9.79E-10	9.58E-10	

Sv/h						
Dose accuracy	3.77E-09	2.55E-09	2.58E-09	2.58E-09	2.58E-09	

Table 3.10 Calculated doses for site LE2A

Description	Measurement Points				
points	1	2	3	4	5
ADR nGy/h	50.89	42.49	42.28	40.67	41.61
AEDE mSv/yr	0.062	0.052	0.052	0.050	0.051
ELCR$\times 10^{-3}$	0.218	0.182	0.181	0.175	0.179

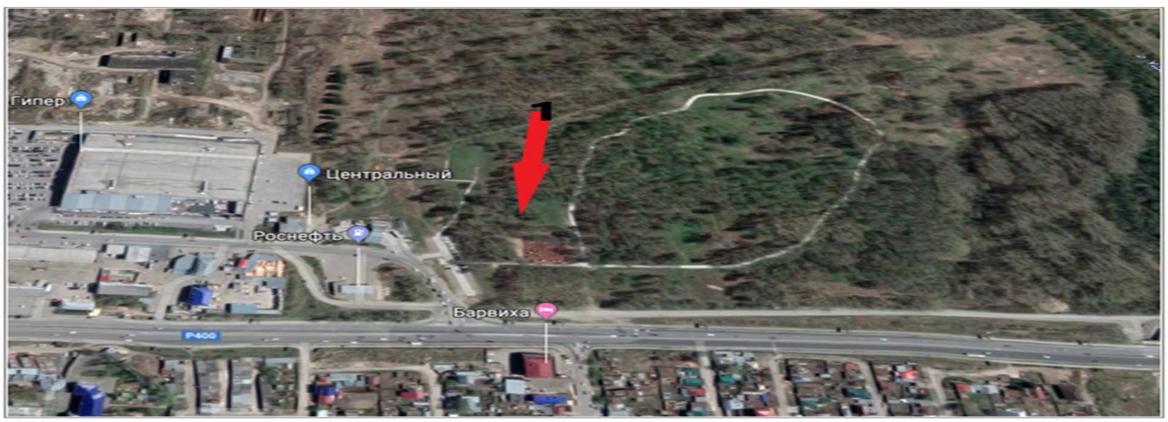

Figure 3.14 Location of measurements and number of points at site LE2B

Measurements at site LE2B were made compare dose with site LE2A.Site LE2B is several meters away from buildings and pavements in soil area. Three measurements were made on three different days, the average is given in table 3.11

Table 3.11 Average gamma ambient equivalent dose at site LE2B

Measurements	Lenta (site LE2B)						Ambient temperature
date	25/09/19 to 1/10/19						
Number of points	Ambient Dose Equivalent	Dose error	Impulse	Impulse error	Impulse calculated	Impulse accuracy	Dose accuracy
1	6.49E-08	5	40.64	1.97	**6**.99E-08	1.38E-09	3.24E-09

Table 3.12 Calculated doses for site LE2B

Description	ADR nGy/h	AEDE mSv/yr	ELCR×10^{-3}
	64.87	0.080	0.278

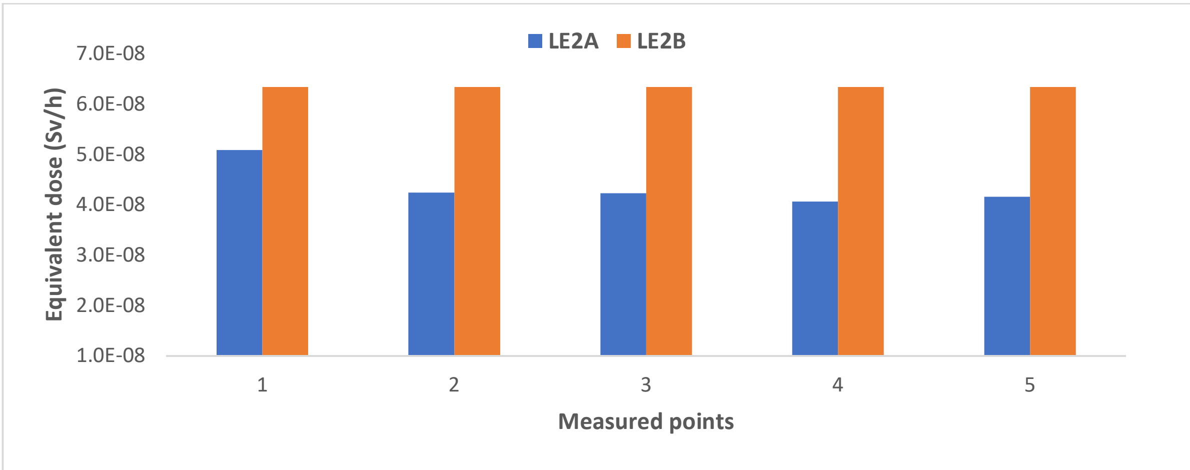

Figure 3.15 Dose comparison between site LE2A and LE2B

The dose at site LE2B is higher than dose at all points on the technosphere object. The presence of the technosphere object resulted in the decrease in gamma background radiation. The dose in soil area at site LE2B is 1.5 times high than the dose the technoshere object at site LE2A.

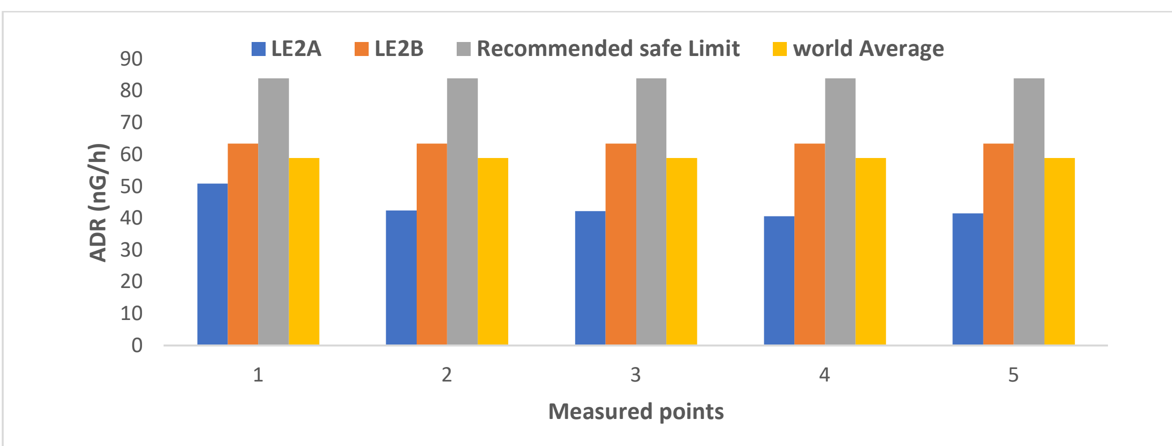

Figure 3.16 ADR at site LE2A and LE2B compared with world average and recommended safe limit

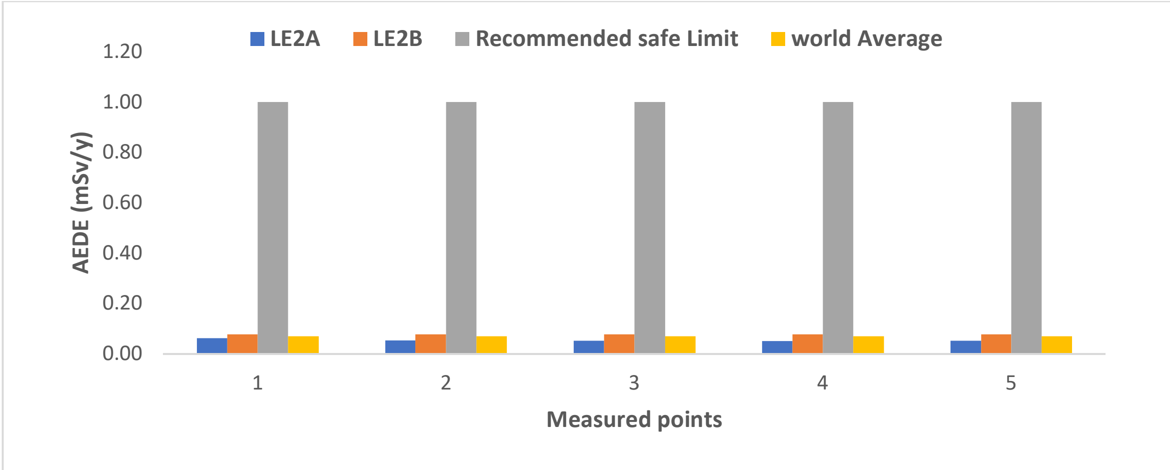

Figure 3.17 AEDE at site LE2A and LE2B compared with world average and recommended safe limit

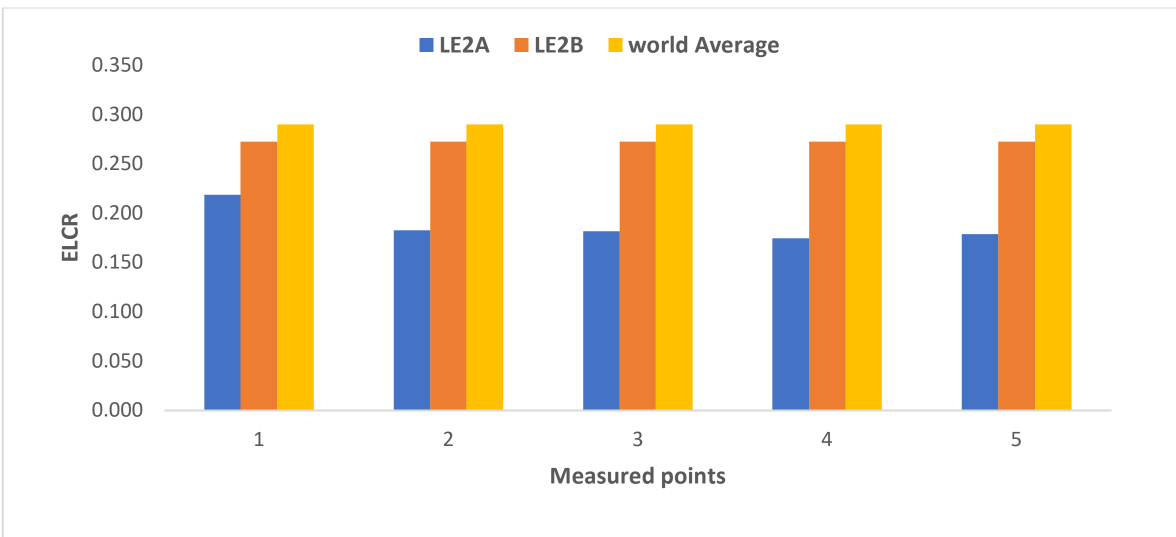

Figure 3.18 ELCR at site LE2A compared with world average and recommended safe limit

Absorbed dose rate (ADR) on the technoshere object is 1.9 times lower than the recommended safe limit of 84nGy/h and 1.4 times lower than the world average value of 59nGy/h. At all points annual effective dose equivalent is much lower than the ICRP recommended permissible limits of 1.00mSv/y for the general public. Excess life time cancer risk is 1.6 times lower than the world average.

3.3 Absorbed dose, Annual effective dose equivalent and Excess life time cancer risk at TPU University building No. 10 (sites UB3A and UB3B)

Figure 3.19 shows the Location of measurements and the number of points measured. Measurements are made on different types of technoshere objects. Points (1, 2, 3) are near the, building points (4, 5, 6) are on the pavement and points (7, 8, 9) are near the building. The area from point 1 to 9 is covered by a pavement.

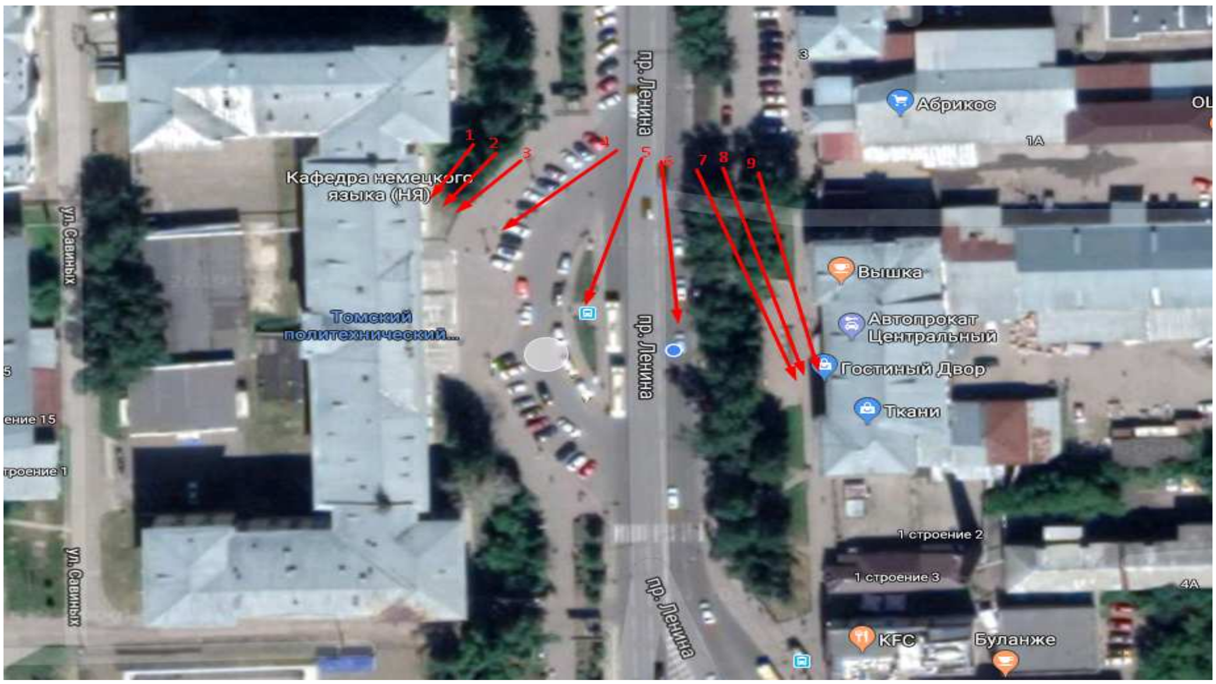

Figure 3.19 Location of measurements and number of points in front of University building No.10 site UB3A

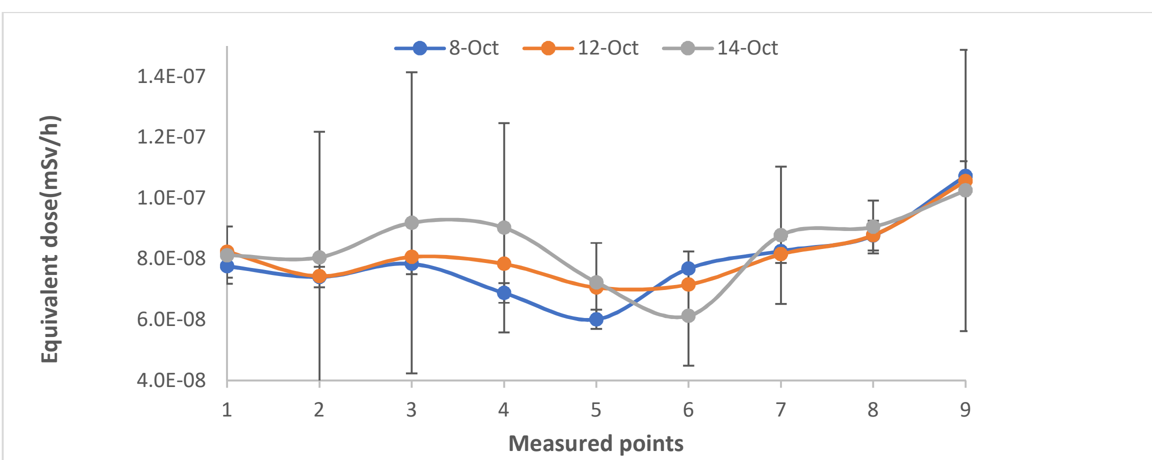

Figure 3.20 Change in ambient Equivalent Dose from point 1-9 at site UB3A

A plot of equivalent dose against the number of points shows how gamma background radiation changes from point 1 to 9. The background radiation increases from 7, 8 ,9 this due to the change in the type of building materials.

Table 3.13 Average gamma ambient equivalent dose at site UB3A

Measurements	Place of measurement	Date of measurement							Ambient temperature
БДКГ-03	University building No 10. (Ub3A)	**8/10/19 to 14/10/19**							
Description	Measurement Points								
Number of points	1	2	3	4	5	6	7	8	9
Ambient Dose Equivalent Sv/h	8.04E-08	7.63E-08	8.36E-08	7.91E-08	6.77E-08	6.99E-08	8.40E-08	8.87E-08	1.05E-07
Dose error %	6.9	20.1	20.8	15.7	9.3	13.1	11.6	6.4	17.8
Impulse Imp/s	45.69	43.05	48.26	41.90	37.89	43.89	49.00	51.85	54.77
Impulse error %	2.7	7.6	7.2	7.5	5.0	4.5	2.4	2.6	7.5
Impulse calculated Sv/h	7.86E-08	7.41E-08	8.30E-08	7.21E-08	6.52E-08	7.55E-08	8.43E-08	8.92E-08	9.43E-08
Impulse accuracy	2.12E-09	5.63E-09	6.01E-09	5.43E-09	3.24E-09	3.42E-09	2.02E-09	2.32E-09	7.07E-09
Dose accuracy Sv/h	5.52E-09	1.53E-08	1.74E-08	1.25E-08	6.27E-09	9.13E-09	9.71E-09	5.70E-09	1.87E-08

Table 3.14 Calculated doses for site Ub3A

Description	Measurement Points								
points	1	2	3	4	5	6	7	8	9
ADR nGy/h	80.39	76.29	83.65	79.14	67.68	69.88	83.97	88.68	105.16
AEDE mSv/yr	0.10	0.09	0.10	0.10	0.08	0.09	0.10	0.11	0.13
$ELCR \times 10^{-3}$	0.35	0.33	0.36	0.34	0.29	0.30	0.36	0.38	0.45

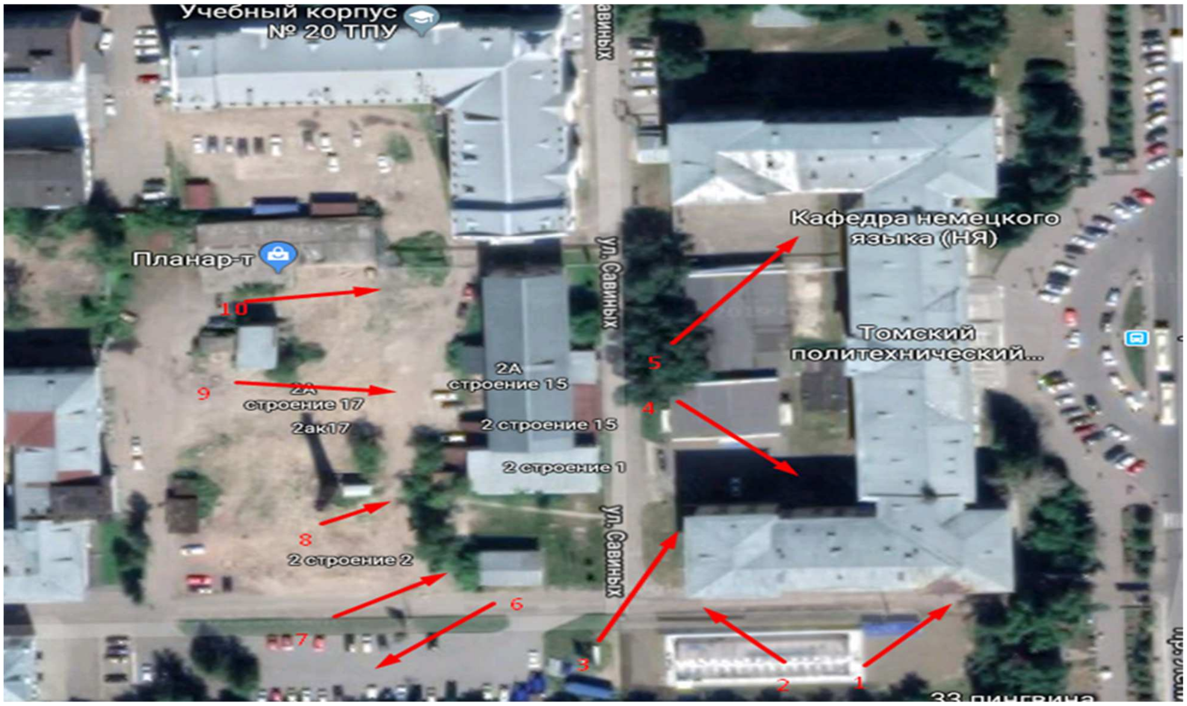

Figure 3.21 Location of measurements behind university building No. 10 site Ub3B

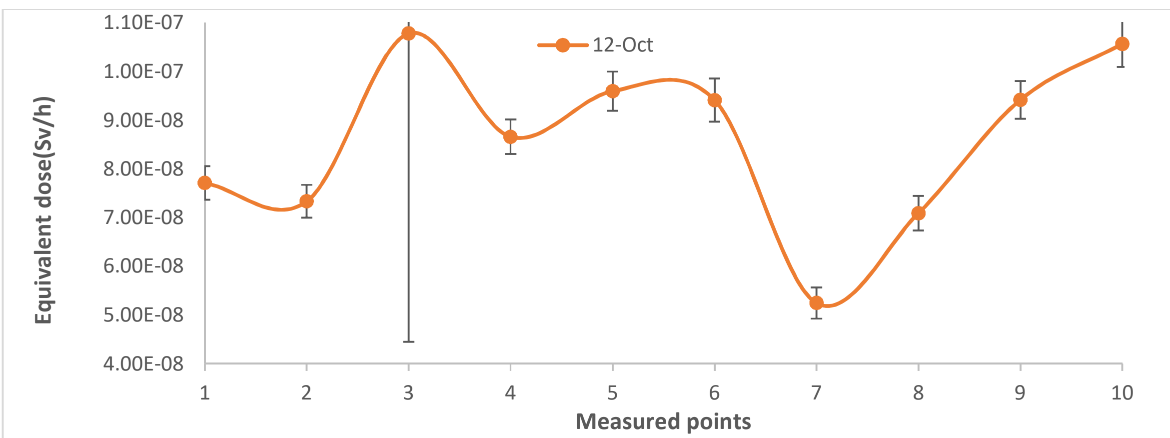

Figure 3.32 – Change in ambient Equivalent Dose from point 1-10 at site Ub3B

A plot of equivalent dose against the number of points shows how gamma background radiation changes from point 1 to 9. The background radiation increases at point 3 then decrease sharply at point 7 then increases sharply at point 10. The increase at point 10 and 3 is due to the proximity of the point to the technoshere objects. Points 1 and 2 have low background despite their proximity to the technoshere object.

Table 3.15 Gamma ambient equivalent dose at site UB3B

Measurements	Place of measurement	Date of measurement							Ambient temperature
БДКГ-03	Behind university building No.10 (site Ub3B)	**12/10/19**							
Description	Measurement Points									
Number of points	1	2	3	4	5	6	7	8	9	10
Ambient Dose Equivalent Sv/h	7.71E-08	7.33E-08	1.08E-07	8.66E-08	9.60E-08	9.41E-08	5.25E-08	7.09E-08	9.42E-08	1.06E-07
Dose error %	4.5	4.6	58.7	4.1	4.2	4.7	6.1	5	4.1	4.5
Impulse Imp/s	42.481	41.148	60.484	51.311	56.371	57.208	60.451	51.152	58.941	65.307
Impulse error %	1.8	1.8	23.5	1.6	1.7	1.8	1.8	1.8	1.5	1.7
Impulse calculated Sv/h	7.31E-08	7.08E-08	1.04E-07	8.83E-08	9.70E-08	9.85E-08	1.04E-07	8.80E-08	1.01E-07	1.12E-07
Impulse accuracy	1.32E-09	1.27E-09	2.45E-08	1.41E-09	1.65E-09	1.77E-09	21.87E-09	1.58E-09	1.52E-09	1.91E-09
Dose accuracy	3.47E-09	3.37E-09	6.33E-08	3.55E-09	4.03E-09	4.42E-09	3.20E-09	3.55E-09	3.86E-09	4.76E-09

Table 3.16 Calculated doses for site UB3B

Description	Measurement Points									
points	1	2	3	4	5	6	7	8	9	10
ADR nGy/h	77.11	73.35	107.80	86.60	95.95	94.14	52.46	70.90	94.18	105.68
AEDE mSv/yr	0.095	0.090	0.132	0.106	0.118	0.115	0.064	0.087	0.115	0.130
ELCR$\times 10^{-3}$	0.33	0.31	0.46	0.37	0.41	0.40	0.23	0.30	0.40	0.45

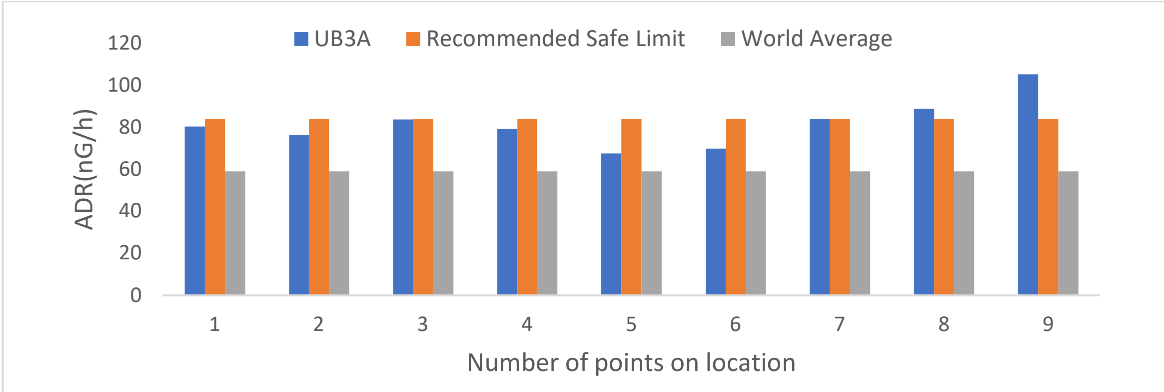

Figure 3.22 Absorbed dose rate at UB3A compared with world average and recommended safe limit

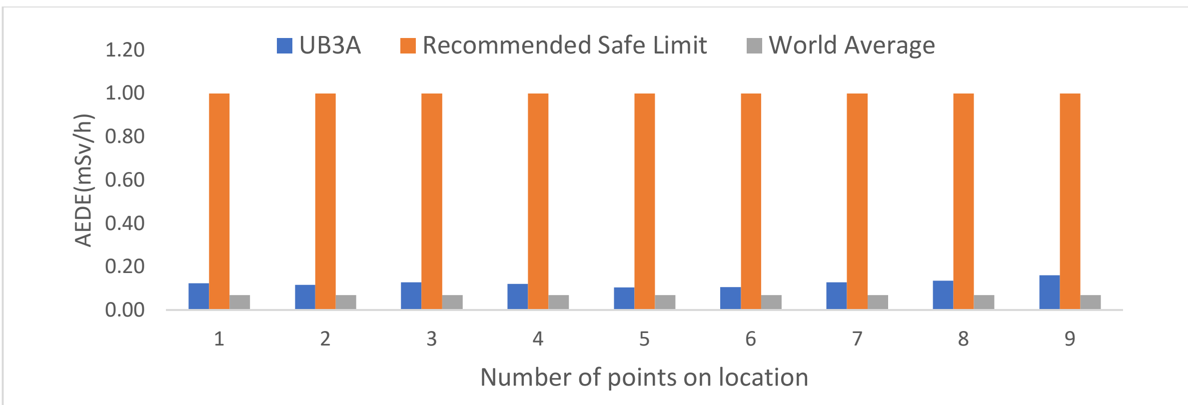

Figure 3.23 AEDE at site UB3A compared with world average and recommended safe limit

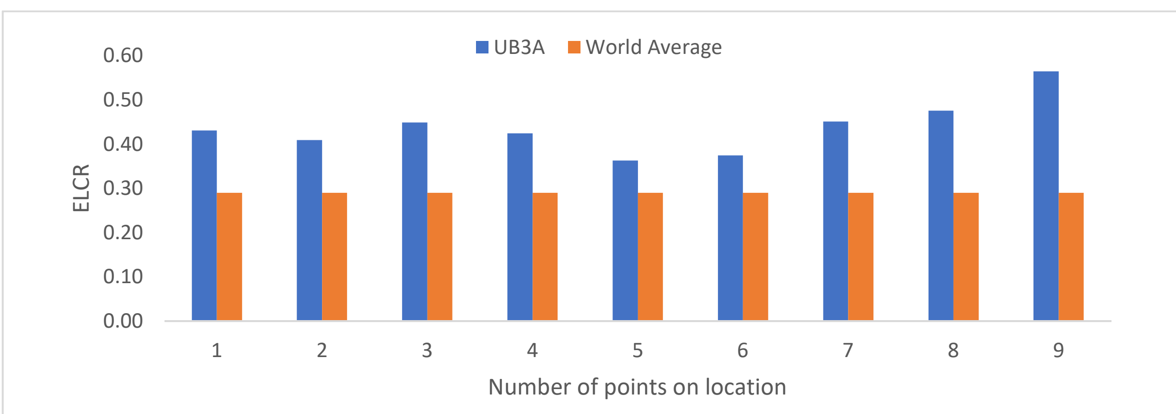

Figure 3.24 ELCR at site UB3A compared with world average and recommended safe limit

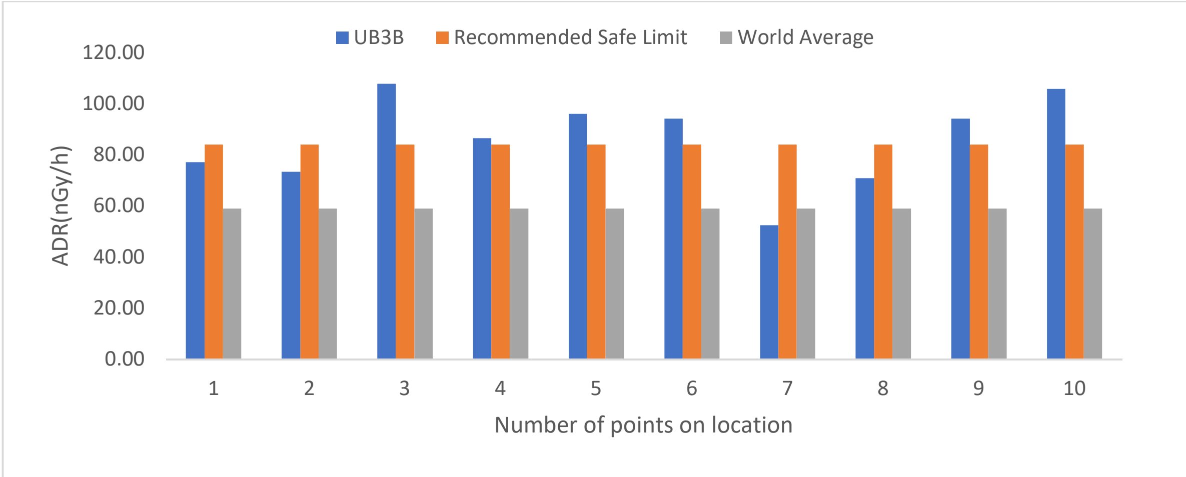

Figure 3.25 Absorbed dose rate at UB3B compared with world average and recommended safe limit

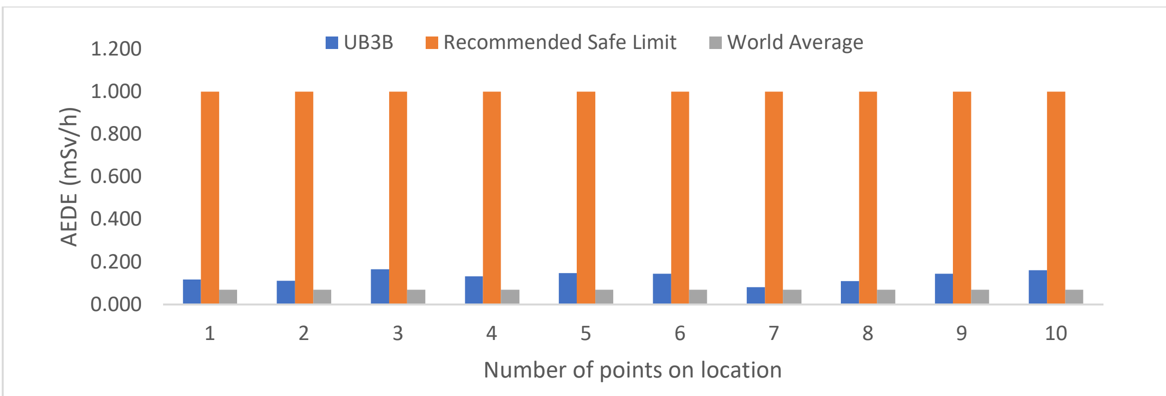

Figure 3.26 AEDE at site UB3B compared with world average and recommended safe limit

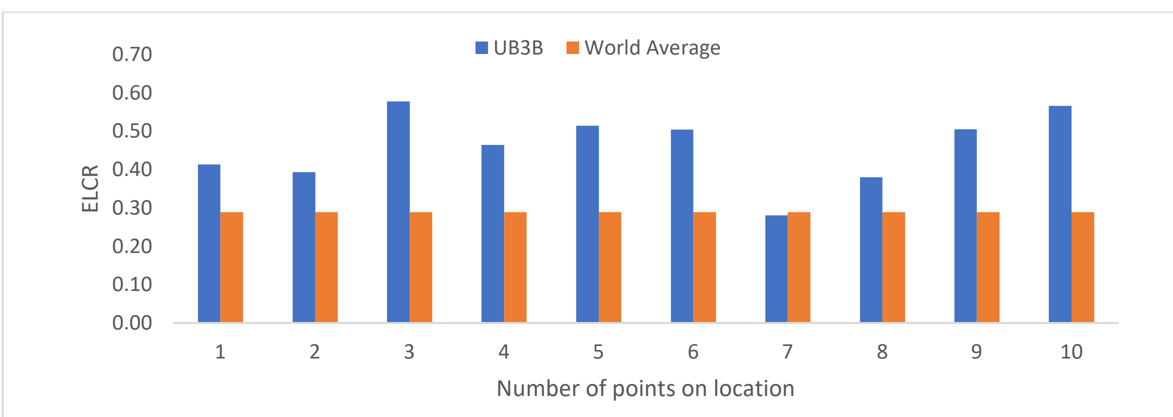

Figure 3.27 ELCR at site UB3B compared with world average and recommended safe limit

3.4 Absorbed dose, Annual effective dose equivalent, Excess life time cancer risk at Novo-Sobornaya Square (sites NO4A and N04B)

To determine the dependence between background radiation and distance away from the technoshere object. Measurements are made on site NO4A and NO4B. figure 3.28 shows the location of measurements and measured points. Measurements are made to determine the dose characteristic in soil area.

Figure 3.28 Location of measurements and number of points at site NO5A

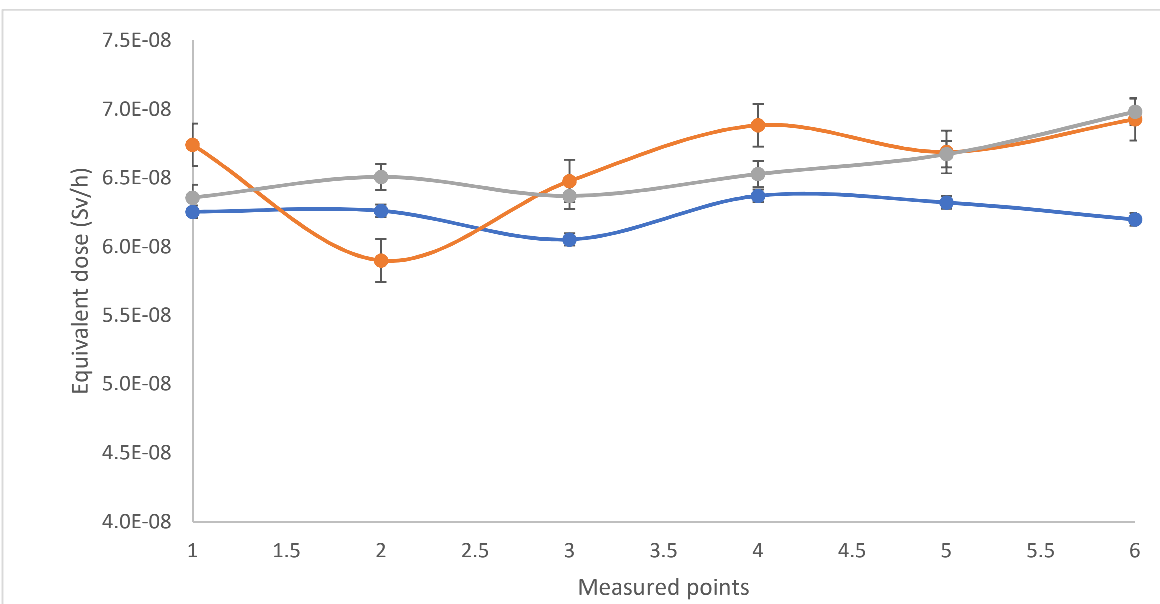

Figure 3.29 Change in Equivalent Dose at site NO5A

Table 3.17 Average equivalent dose at site NO5A

Measurements	Place of measurement	Date of measurement					Ambient temperature
БДКГ-03	Novo-Sobornaya Square (sites NO5A)	**30/10/2019 to 3/11/19**					
Description	Measurement Points (Points 10m apart)						
Number of points	1	2	3	4	5	6	
Ambient Dose Equivalent Sv/h	6.45E-08	6.22E-08	6.30E-08	6.59E-08	6.56E-08	6.70E-08	
Dose error %	5.1	5.0	5.0	4.8	4.8	4.8	
Impulse Imp/s	38.72	39.54	37.89	39.06	38.82	39.34	
Impulse error %	1.9	1.9	1.9	1.9	1.9	1.9	
Impulse calculated Sv/h	6.66E-08	6.81E-08	6.52E-08	6.72E-08	6.68E-08	6.77E-08	
Impulse accuracy Sv/h	1.29E-09	1.27E-09	1.24E-09	1.25E-09	1.25E-09	1.26E-09	
Dose accuracy	3.31E-09	3.09E-09	3.13E-09	3.14E-09	3.17E-09	3.22E-09	

Table 3.18 Calculated doses at site NO5A

Description	Measurement Points					
points	1	2	3	4	5	6
ADR nGy/h	64.51	62.23	63.00	65.94	65.61	67.02
AEDE mSv/yr	0.079	0.076	0.077	0.081	0.080	0.082
$ELCR \times 10^{-3}$	0.28	0.27	0.27	0.28	0.28	0.29

The background radiation is measured with a radius of 1m away from the technoshere object. Point 1 is 5cm, point 2 is 50cm and point 3 is 1m as shown in figure 3.30. The dose from the measured points is compared with dose at site NO4A.

Figure 3.30 Location of measurements and number of points at site NO5B

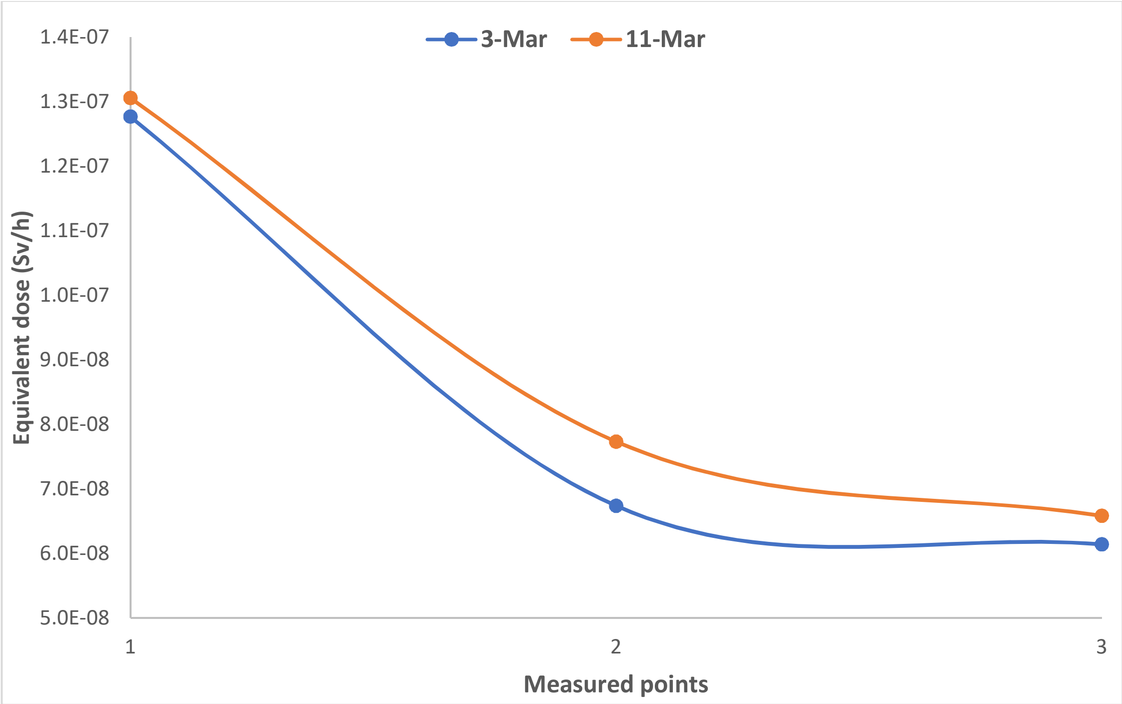

Figure 3.42 Dependence between dose and distance at site NO5B

A plot of equivalent dose against the number of points shows the dependence between background radiation and distance away from technoshere object.

Table 3.19 Average equivalent dose at site NO5B

Measurements	Place of measurement		**Date of measurement**	Ambient temperature
БДКГ-03	Novo-Sobornaya Square (site NO4B)		**03/03/20 to 11/03/20**	
Description	5cm	50cm	1m	
Number of points	1	2	3	
Ambient Dose Equivalent Sv/h	1.29E-07	7.24E-08	6.36E-08	
Dose error %	5.15	4.8	6	
Impulse Imp/s	56.5665	36.1235	33.028	
Impulse error %	2.25	2	2.45	
Impulse calculated Sv/h	9.735E-08	6.22E-08	5.68E-08	
Impulse accuracy Sv/h	2.19E-09	1.24E-09	1.39E-09	
Dose accuracy	6.65E-09	3.47E-09	3.82E-09	

Table 3.20 Calculated doses at site NO4B

Description	Measurement Points		
points	1	2	3
ADR nGy/h	129.16	72.37	63.64
AEDE mSv/yr	0.16	0.09	0.08
ELCR$\times 10^{-3}$	0.55	0.31	0.27

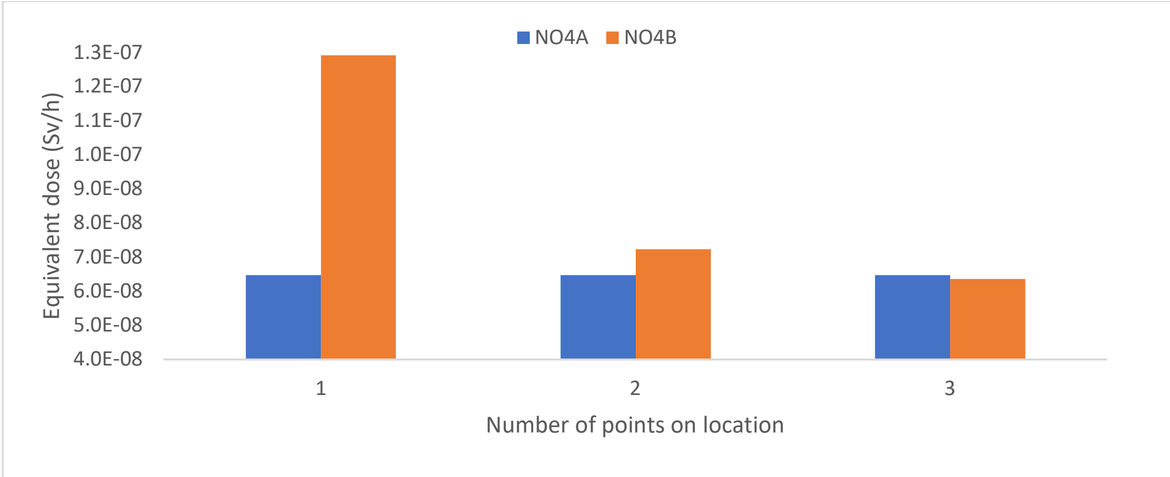

Figure 3.31 Dose comparison between site NO4A and NO4B

The background radiation increased at point 1 and 2 at NO5B as compared to the dose at site NO4A. Despite point 3 being near the monuments the dose measured was less than on site NO5A in soil area.

3.5 Absorbed dose, Annual effective dose equivalent and Excess life time cancer risk on Alley of Geologist (sites GL5A, GL5B, GL5C, GL5D and GL5E)

Figure 3.32 shows the location of measurements on geologist alley on a small monument Site GL5A. Points 1 is 5cm, 2 is 50cm and 3 is 1m away from the monument.

Figure 3.32 Location of measurements and number of points at site GL5A

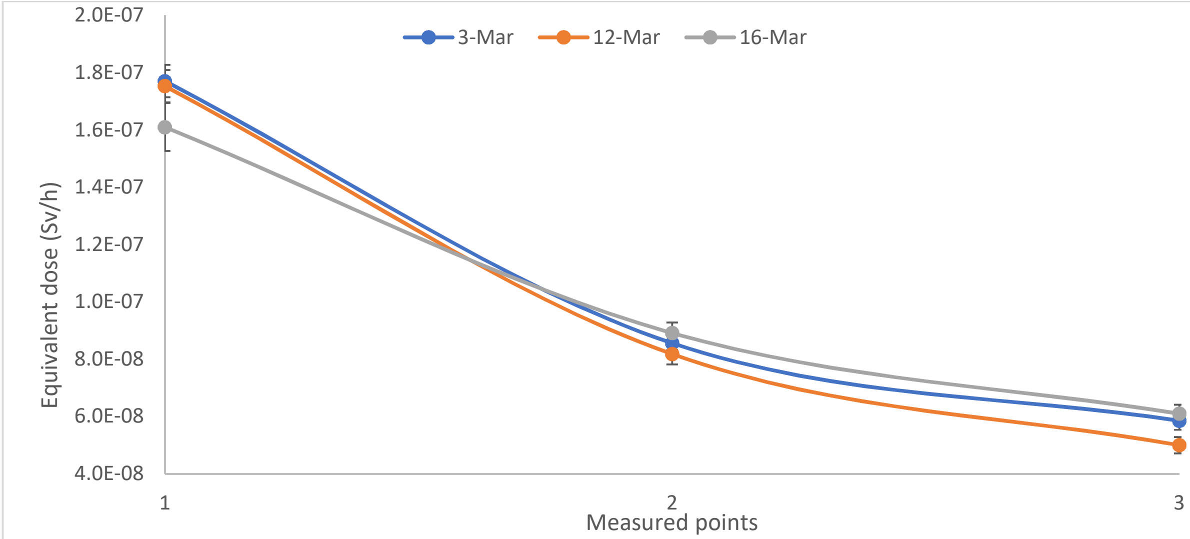

Figure 3.33 Dependence between dose and distance at site GL4A

Table 3.21 Average equivalent dose at site GL5A

Measurements	Place of measurement		Date of measurement		Ambient temperature
БДКГ-03	Alley of Geologist (site GL5A)		**03/03/20 to 16/03/20**		
Description	5cm	50cm	1m		
Number of points	1	2	3		
Ambient Dose Equivalent Sv/h	1.71E-07	8.55E-08	5.65E-08		
Dose error %	3.87	3.80	5.40		
Impulse Imp/s	73.01	42.53	31.16		
Impulse error %	1.77	4.20	2.17		
Impulse calculated Sv/h	1.26E-07	7.32E-08	5.36E-08		
Impulse accuracy Sv/h	2.22E-09	3.07E-09	1.16E-09		
Dose accuracy	6.62E-09	3.25E-09	3.05E-09		

Table 3.22 Calculated doses for site GL5A

Description	Measurement Points		
points	1	2	3
ADR nGy/h	171.12	85.49	56.48
AEDE mSv/yr	0.21	0.10	0.07
ELCR$\times 10^{-3}$	0.73	0.37	0.24

Figure 3.51 shows the location of measurements behind university building No. 10, at the monument of usova, “Alley of Geologists” site GL5B. Radiation doses are calculated for a person standing 50cm from the monument. Points 1 is 5cm, 2 is 50cm and 3 is 1m away from the monument.

Figure 3.51-Location of measurements and number of measured points at site GL5B

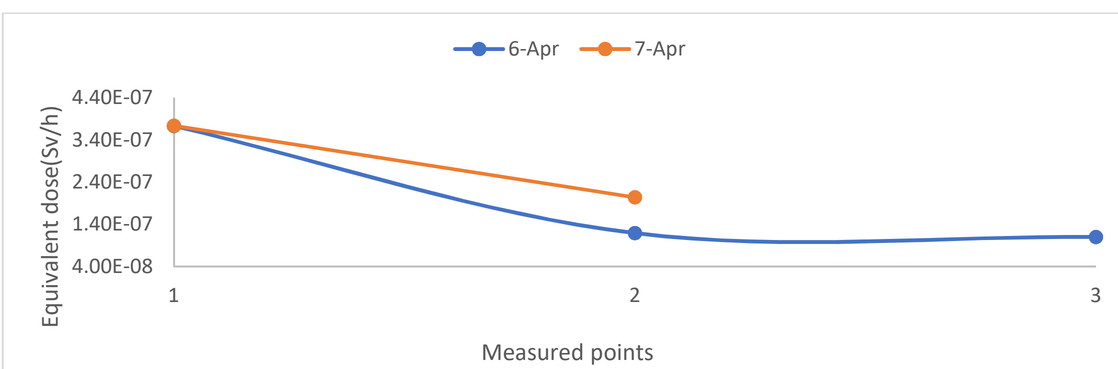

Figure 3.34 Change in Equivalent Dose at site GL5B

Table 3.23 Average equivalent dose at site GL5B

Measurements	Place of measurement		Date of measurement	Ambient temperature
БДКГ-03	Alley of Geologists (site GL5B)		**06/04/20 to 07/04/20**	
Description	5cm	50cm	1m	
Number of points	1	2	3	
Ambient Dose Equivalent Sv/h	3.74E-07	2.04E-07	1.10E-07	
Dose error %	2.15	2.7	3.8	
Impulse Imp/s	181.345	104.91	63.158	
Impulse error %	0.95	1.5	1.5	
Impulse calculated Sv/h	3.12092E-07	1.80548E-07	1.08694E-07	
Impulse accuracy Sv/h	2.96487E-09	2.70822E-09	1.63041E-09	
Dose accuracy	8.03477E-09	5.50233E-09	4.17924E-09	

Table 3.24 Calculated doses at GL5B

Description	Measurement Points		
points	1	2	3
ADR nGy/h	373.71	203.79	109.98
AEDE mSv/yr	0.57	0.31	0.17
ELCR$\times 10^{-3}$	2.01	1.09	0.59

Figure 3.35 Location of measurements and number of points measurements at site GL5C

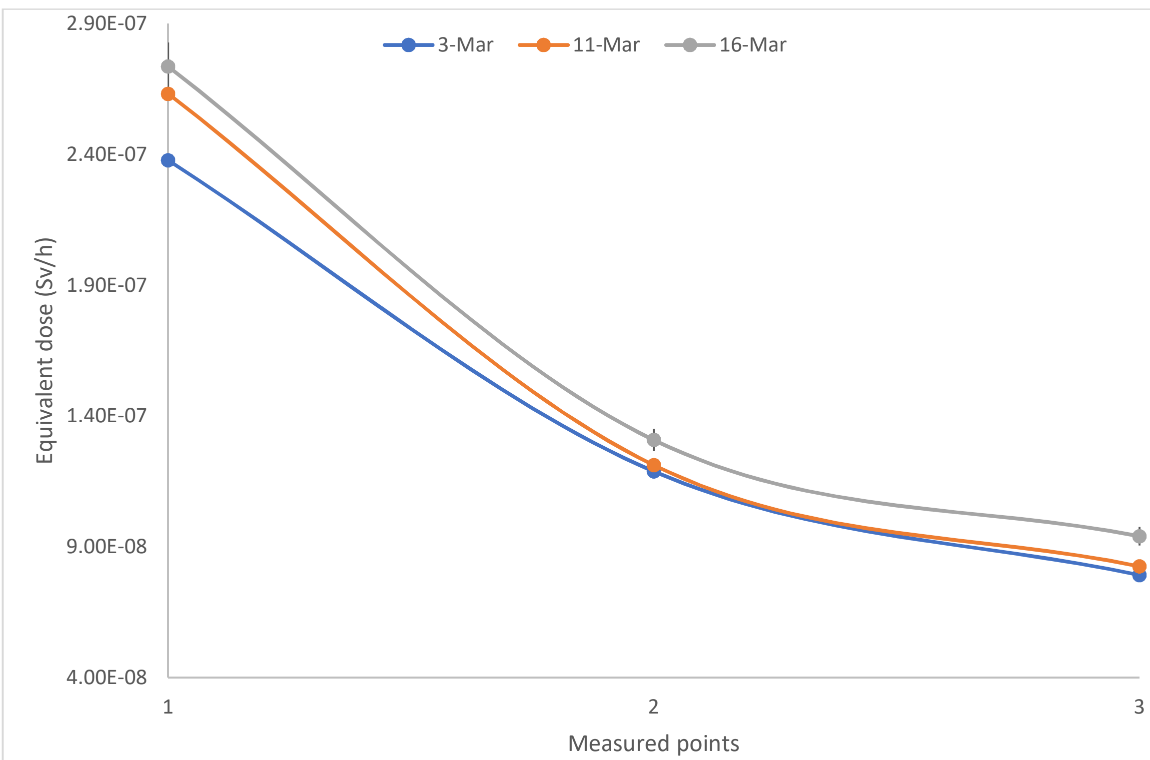

Figure 3.36 Dependence between dose and distance at site GL5C

Table 3.25 Average equivalent dose at site GL4C

Measurements	Place of measurement	Date of measurement	Ambient temperature
БДКГ-03	Alley of Geologist (site GL5C)	**03/03/20 to 16/03/20**	
Description	5cm	50cm	1m
Number of points	1	2	3
Ambient Dose Equivalent Sv/h	2.58E-07	1.24E-07	8.53E-08
Dose error %	3.03	3.53	4.33
Impulse Imp/s	122.43	69.19	50.62
Impulse error %	1.30	1.43	1.67
Impulse calculated Sv/h	2.11E-07	1.19E-07	8.71E-08
Impulse accuracy Sv/h	2.74E-09	1.71E-09	1.45E-09
Dose accuracy	7.83E-09	4.37E-09	3.70E-09

Table 3.26 Calculated doses at site GL5C

Description	Measurement Points		
points	1	2	3
ADR nGy/h	258.23	123.66	85.29
AEDE mSv/yr	0.32	0.15	0.10
ELCR$\times 10^{-3}$	1.11	0.53	0.37

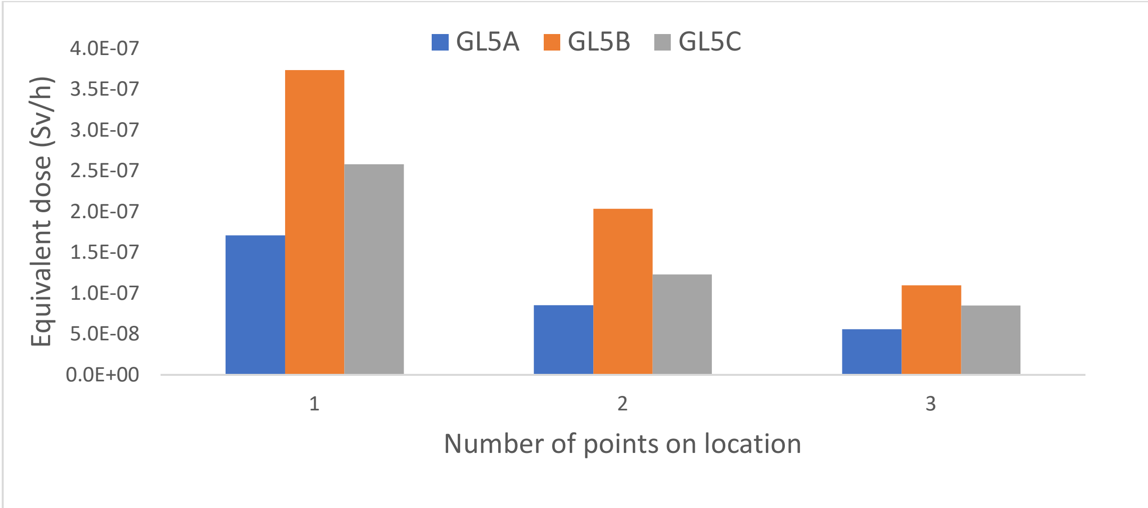

Table 3.27 Dose comparison site GL5A, GL5B and GL5C

Within a radius of 1m, site GL5B has the highest dose despite all the objects being made from the same material. At 5cm equivalent dose at site GL5B is 2.2 time higher than dose at site GL5A and 1.4 times higher than the dose at site GL5C. at 50cm the dose at site GL5B is 2.4 times higher than the dose at site GL5A and 1.6 times higher than the dose at site GL5C. at 1m the dose at site GL5B IS 1.9 times higher than the dose at site GL5A and 1.3 times higher than the dose at site GL5C.

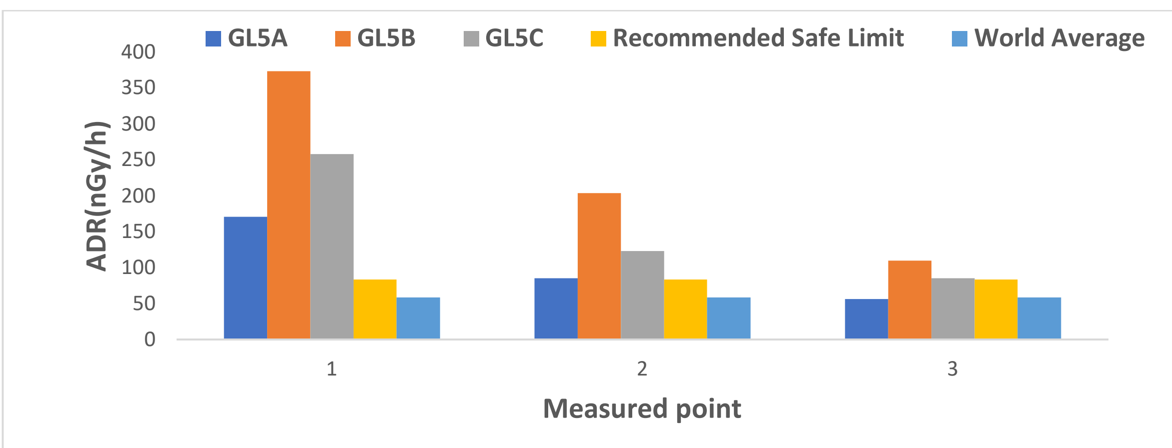

Figure 3.37 ADR at site GL5A, GL5B and GL5C compared with world average and recommended safe limit

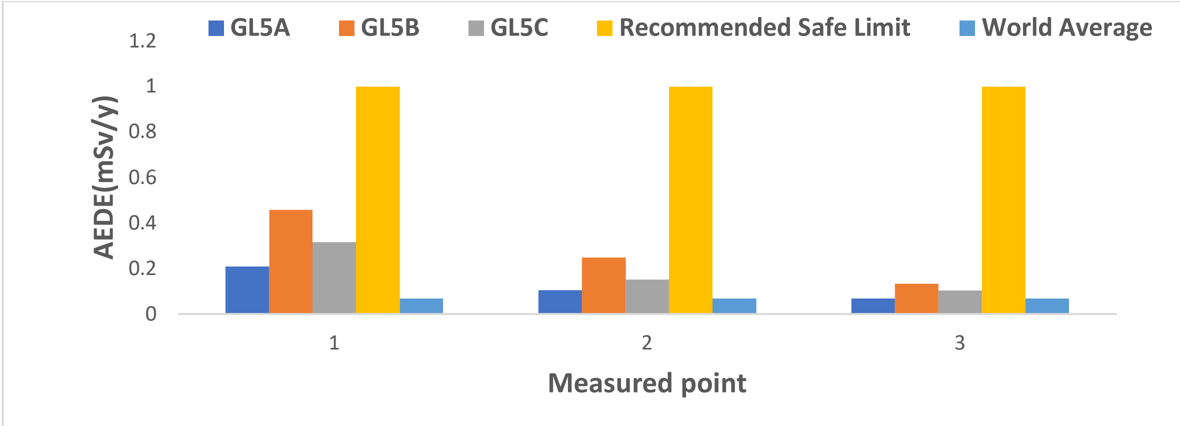

Figure 3.38 AEDE at site GL5A, GL5B and GL5C compared with world average and recommended safe limit

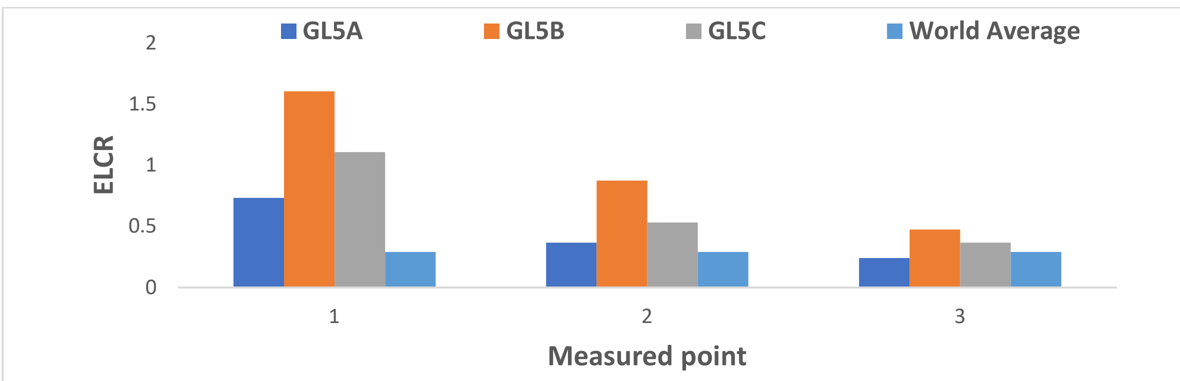

Figure 3.39 ELCR at site GL5A, GL5B and GL5C compared with world average and recommended safe limit

At 5cm absorbed dose rate (ADR) is 4.4 times higher than the recommended safe limit and 6.3 times higher than world average value. At 50cm ADR is 2.4 times higher than recommended safe limit and 3.5 times higher than world average. At 1m ADR is 1.3 times higher than recommended safe limit and 1.9 times higher than world average. Within the radius of 1m AEDE is lower than recommended safe limit but 6.5 times higher than world average at 5cm, 3.6 times higher at 50cm and 1.9 times higher at 1m. ECL is 6.5 times higher at 5cm, 3.6 times higher at 50cm and 1.9 times higher at 1m. A person standing 50cm from the technoshere object at site GL5B will receive a dose which is 2.4 times higher than the recommended safe limit.

Figure 3.40 shows the location of measurements behind University building No.1, at site GL5D on Alley of Geologists. The data from these measurements is used to compute ADR, AEDE and ECLR for a person standing 50cm from the small monument at point 4, sitting down on the bench at point 2 and or smoking at point 3.

Figure 3.40 Location of measurements and number of measured points at site GL5D

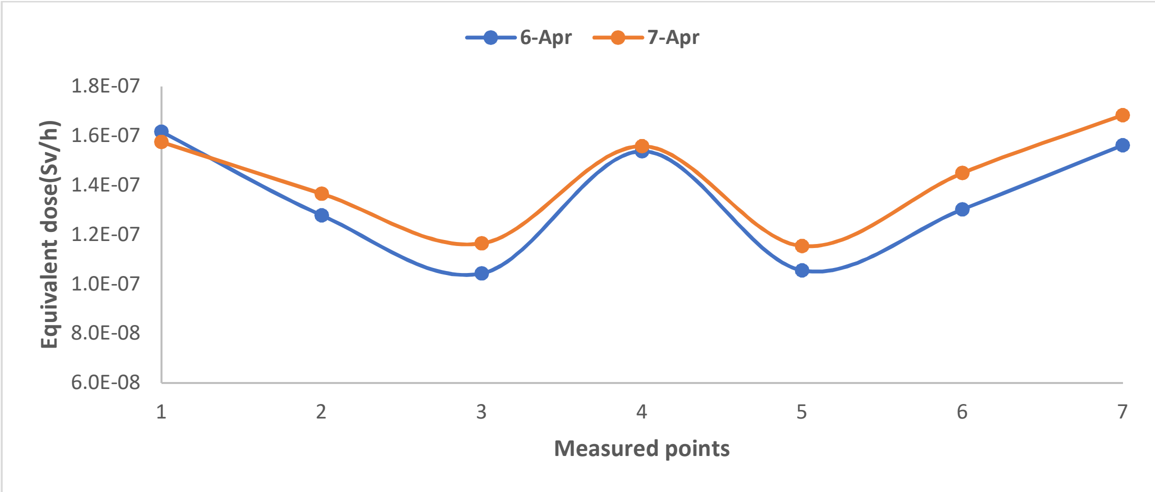

Figure 3.41 Change in Equivalent Dose at site GL5D

A plot of equivalent dose against the number of points in figure 3.41 shows how background radiation changes from point 1 to 7. The highest doses are recorded at point 1 and 7, 5cm away from the object on each side of the square and at point 4 50cm away from the small monument.

Table 3.28 Average equivalent dose at site GL5D

Measurements	Place of measurement		Date of measurement					Ambient temperature
БДКГ-03	Alley of Geologists (site GL5D)		**6/04/20 to 7/04/20**					
Description	Measurement Points (Points1, 5cm: 2, 25cm: 3, 1m: 4, 50cm: 5, 1m: 6, 25cm: 7, 5cm way from objects)							
Number of points	1	2	3	4	5	6	7	
Ambient Dose Equivalent Sv/h	1.60E-07	1.32E-07	1.10E-07	1.55E-07	1.10E-07	1.38E-07	1.62E-07	
Dose error %	3.35	3.45	3.65	4.50	3.65	3.40	3.15	
Impulse Imp/s	76.51	67.32	62.32	90.06	63.72	68.99	77.51	
Impulse error %	1.45	1.40	1.50	1.25	1.50	1.45	1.35	
Impulse calculated Sv/h	1.31672 E-07	1.15851 E-07	1.07254 E-07	1.54984 E-07	1.09664 E-07	1.18726 E-07	1.33395 E-07	
Impulse accuracy Sv/h	1.90925 E-09	1.62191 E-09	1.60881 E-09	1.9373E -09	1.64497 E-09	1.72153 E-09	1.80083 E-09	
Dose accuracy	5.34576 E-09	4.56004 E-09	4.02741 E-09	6.9633E -09	4.03033 E-09	4.67636 E-09	5.11245 E-09	

Table 3.29 Calculated doses at site GL5D

Description	Measurement Points						
points	1	2	3	4	5	6	7
ADR nGy/h	157.48	136.53	116.39	155.79	115.35	144.89	168.39
AEDE mSv/yr	0.19	0.17	0.14	0.19	0.14	0.18	0.21
ELCR$\times 10^{-3}$	0.68	0.59	0.50	0.67	0.50	0.62	0.72

To compare dose with site GL5D measurements were made at site GL4E. Dose are calculated for a person sitting at point 2 and 4 or passing at point 3. The calculated doses are compared with doses for a person sitting on a bench on paint 2 or 6 at site GL5D.

Figure 3.42 Location of measurements and number of points at site GL5E

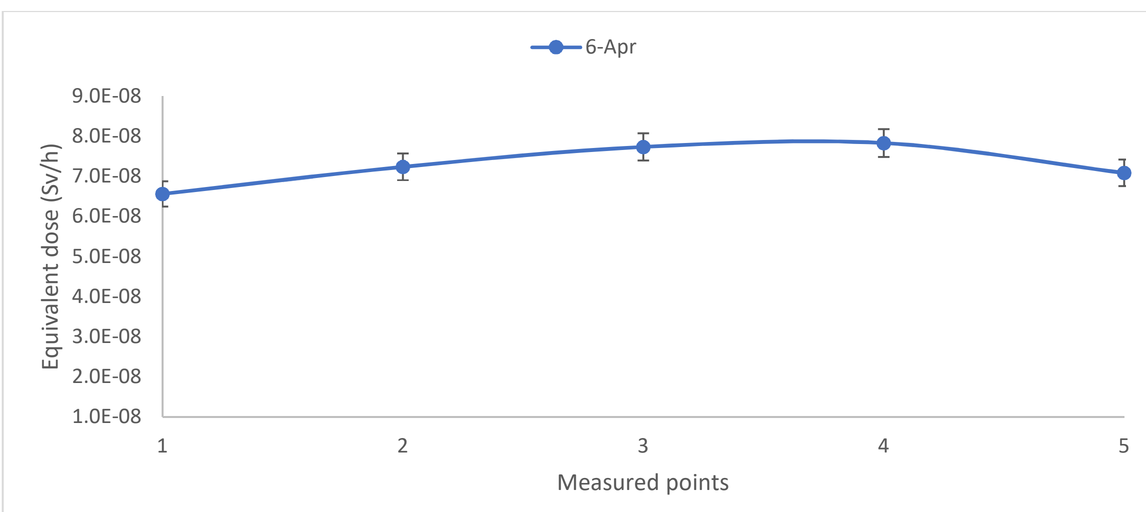

Figure 3.43 Change in Equivalent Dose from point 1 to 5 at site GL5E

Table 3.30 Equivalent dose at site GL5E

Measurements	Place of measurement	Date of measurement	Time of Start of measurements	Time of end of measurements	Ambient temperature
БДКГ-03	Alley of Geologists (site GL5E)	6/04/2030	14:45:47	15:10:36	

Description	Measurement Points					
Number of points	1	2	3	4	5	
Ambient Dose Equivalent Sv/h	6.56E-08	7.24E-08	7.73E-08	7.83E-08	7.09E-08	
Dose error %	4.8	3.4	4.6	4.4	4.7	
Impulse Imp/s	42.039	41.278	45.091	43.306	40.791	
Impulse error %	1.8	1.8	1.7	1.8	1.8	
Impulse calculated Sv/h	7.23484E-08	7.10387E-08	7.76008E-08	7.45289E-08	7.02006E-08	
Impulse accuracy Sv/h	1.30227E-09	1.2787E-09	1.31921E-09	1.34152E-09	1.26361E-09	
Dose accuracy	3.14928E-09	3.32856E-09	3.40278E-09	3.44476E-09	3.33004E-09	

Table 3.31 Calculated doses at site GL5E

Description	Measurement Points				
points	1	2	3	4	5
ADR nGy/h	65.61	72.36	77.34	78.29	70.85
AEDE mSv/yr	0.080	0.089	0.095	0.096	0.087
$ELCR \times 10^{-3}$	0.28	0.31	0.33	0.34	0.30

Since the dose fluctuation in very minimal on site on site GL5E we calculate the average dose from the points and assume the person setting at points 2 or 4 will receive a dose of $7.29 \cdot 10^{-8} \pm 5.16 \cdot 10^{-9} Sv/h$. The dose comparison is shown on figure 3.44. A person sitting on a bench at point 2 or 6 on site GL5D will receive a dose which is 2 times higher than the person sitting on a bench at site GL5E.

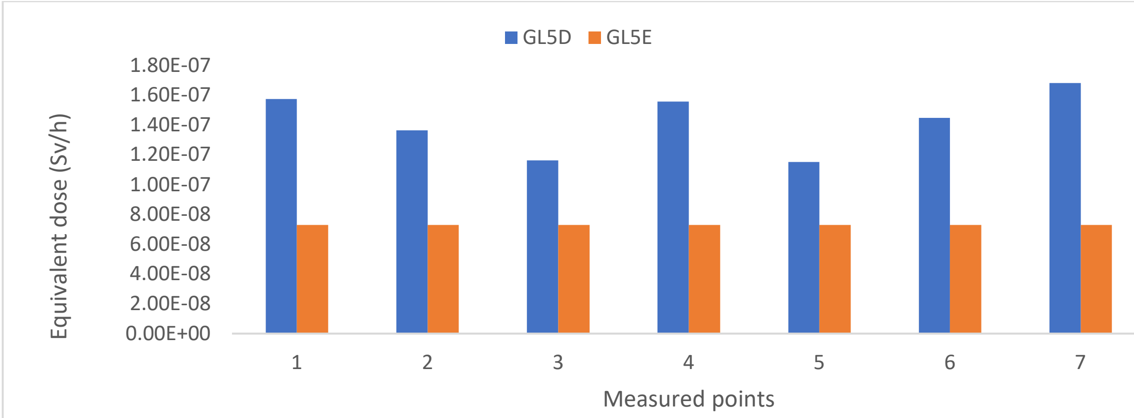

Figure 3.44 Dose comparison between site GL5D and GL5C

To assess the radiological health effects associated with the doses, the calculated doses are compared with recommended safe limit and world average values as shown in figure 3.45 to figure 3.47. for a person sitting on a bench at site GL5D at point 2 or 6, ADR is 1.7 time higher than the recommended safe limit of 84nGy/h and 3.4 times higher than world average value of 59nGy/h, but for a person sitting on a bench at site GL5E on point 2 or 4, ADR is 1.2 times lower than recommended safe limit and 1.2 times higher than world average. AEDE at both sites is lower than recommended safe limit but 2.5 times higher than world average value at point 2 or 6 on site GL5D and 1.3 time higher than world average value at site GL5E. ECLR is 2 times higher than world average at point 2 or 6 and 1.1 times higher than world average at site GL5E.

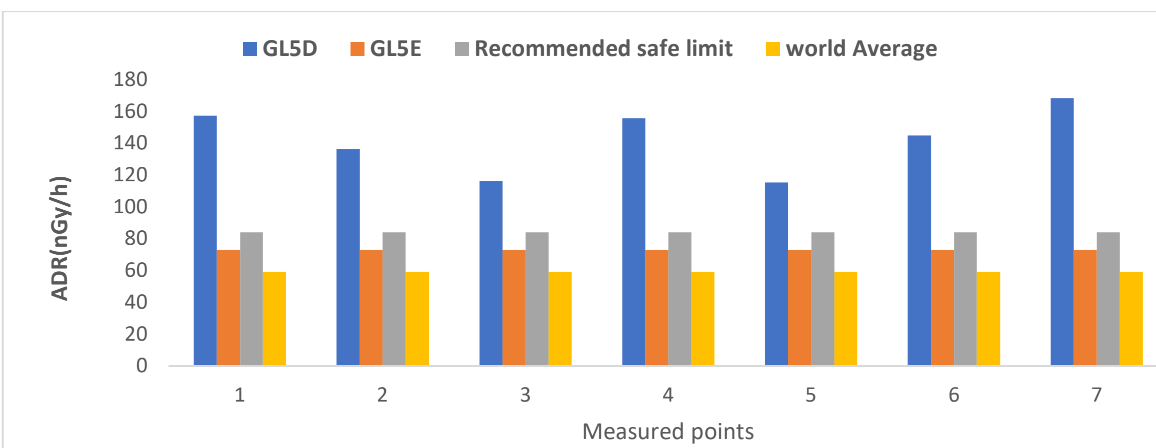

Figure 3.45 ADR at site GL5D and GL5E compared with world average and recommended safe limit

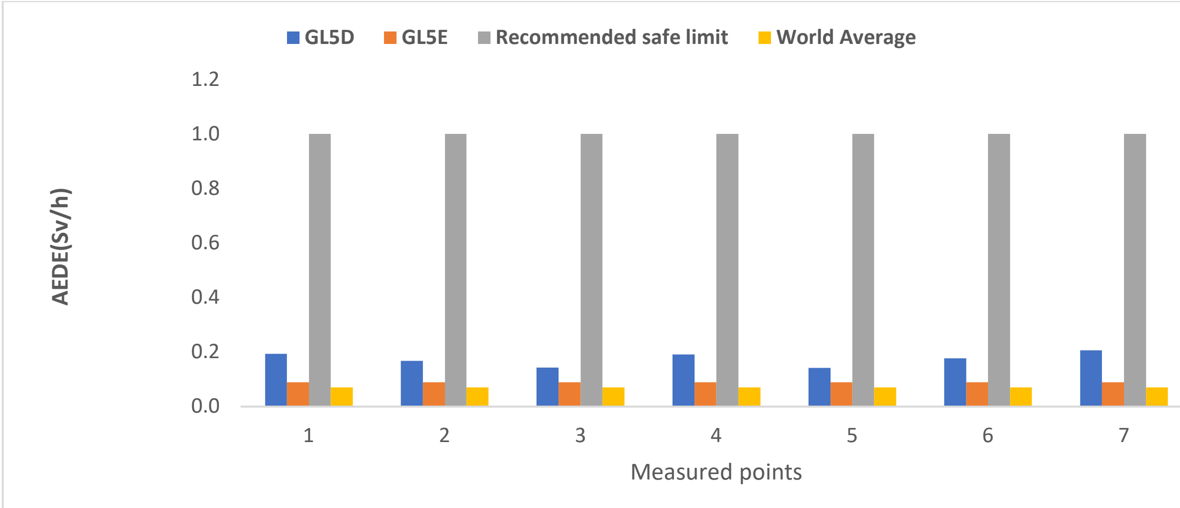

Figure 3.46 AEDE at site GL5D and GL5E compared with world average and recommended safe limit

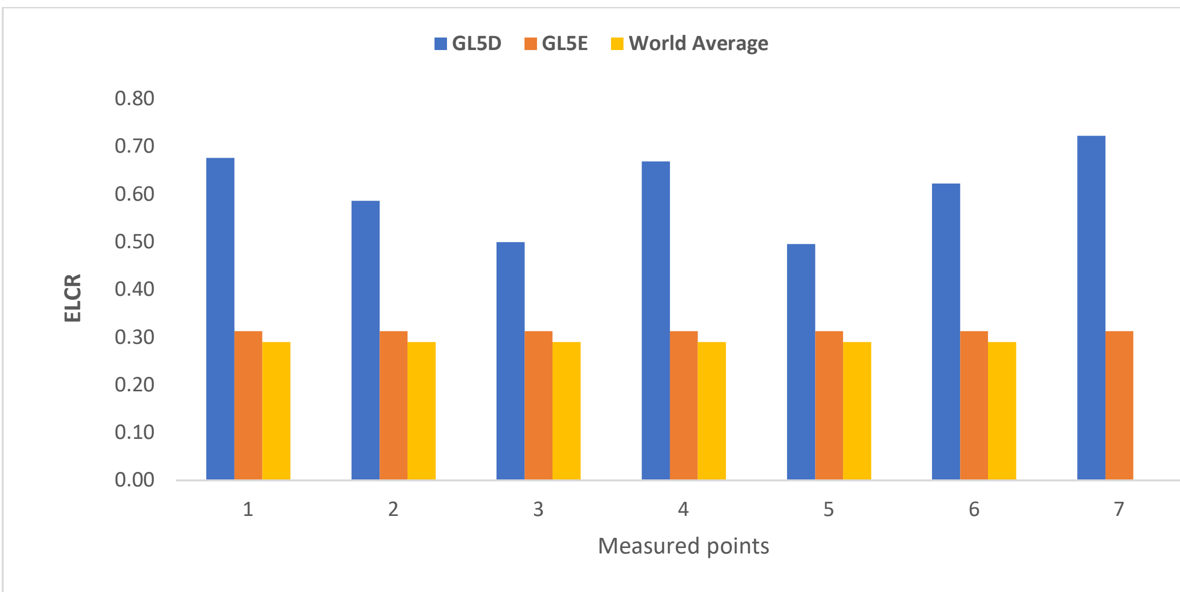

Figure 3.47 ELCR at site GL5D and GL5E compared with world average and recommended safe limit

Chapter 4 Financial management, resource efficiency and resource conservation

Accessing finance is often a major problem to the successful implementation of resource efficiency projects and, ultimately, the business benefits that these projects can deliver. When planning a resource efficiency project in any organization there need to access finance. A business case has to be prepared in order to support the proposed project as well as a strong case for investment to senior management or external lenders has to be presented. With this research work, an investigation of changes in gamma background radiation due to Technosphere object was carried. The background radiation was studied using highly sensitive gamma detectors BDKG-03. Hence, the aim of the section "Financial Management, Resource Efficiency and Resource savings" is to measure the prospects and success of a research project in order to design a mechanism for managing and acquiring special supports during the implementation stage of the project to enhance productivity. In addition, Financial Management means planning, organizing, directing and controlling the financial activities such as procurement and utilization of funds of the enterprise. It means applying general management principles to financial resources of the enterprise.

4.1 Financial Management

Financial management is one of the most important aspects in any research undertaking. In order to start up or even run a successful project, you will need excellent knowledge in financial management. Financial management refers to the strategic planning, organizing, directing, and controlling of financial undertakings in an organization or an institute. It also i includes applying management principles to the financial assets of an organization, while also playing an important part in fiscal management.

Business concern needs finance to meet their requirements in the economic world. Any kind of business activity depends on the finance. Hence, it is called as lifeblood of business organization. Whether the business concerns are big or small, they need finance to fulfil their business activities. In the modern world, all the activities are concerned with the economic activities and very particular to earning profit through any venture or activities. The entire business activities are directly related with making profit. (According to the economics concept of factors of production, rent given to landlord, wage given to labor, interest given to capital and profit given to shareholders or proprietors), a business concern needs finance to meet all the requirements. Hence finance may be called as capital, investment, fund etc., but each term is having different meanings and unique characters. Increasing the profit is the main aim of any kind of economic activity. (Paramasivan, n.d.)

Therefore, the purpose of the section "Financial Management, Resource Efficiency and Resource Savings" is to determine the prospects and success of a research project, to develop a mechanism for managing and supporting specific project solutions at the implementation stage of the project lifecycle which is in this case of an investigation of the changes of background radiation in urban atmosphere due to Technosphere.

4.2 Competitiveness analysis of technical solutions

It is important to realistically assess the strengths and weaknesses of the development of competitors. The analysis of competitive technical solutions from the standpoint of resource efficiency and resource saving makes it possible to evaluate the comparative effectiveness of scientific development and determine the directions for its future enhancement. This analysis was carried out using the evaluation map and three competitive developments have been selected. Criteria for comparison and assessment of resource efficiency and resource saving, given in Table 1.41 selected based on the selected objects of comparison, considering their technical and economic features of development, creation and operation. One of the best strategies for environmental management and sustainability can be characterized as the harmonization of environmental conservation and economic competitiveness by the pursuit of eco-efficiency. This is in keeping with the concept of Ecological Modernization, a conceptualization of a shift in environmental policy and management. Many solutions and strategies have been put in place on making sure that mapping of radiation levels in different countries is achieved, this has been taking place in order to control/monitor the amount of dose taken by the living organism in earth which has negative impact when the dose is higher compared to the allowable dose intake per year. However, the cost associated on undertaking such studies is higher as well as accuracy of the analysed data has been low, therefore different technological approaches has been implemented in order to lower cost of undertaking such studies. With this research the three technical solution includes the use:

- In situ ambient dose measurement-P_f
- Gamma ray laboratory-P_{i1}
- Real-time radiation monitoring in the environment-P_{i2}

First of all, it is necessary to analyze possible technical solutions and choose the best one based on the considered technical and economic criteria. Evaluation map analysis presented in Table 1.4.1 The position of my research and competitors has been evaluated for each indicator based on a five-point scale, where 1 is the weakest position and 5 is the strongest. The weights of indicators determined in the amount 1. Analysis of competitive technical solutions is determined by the formula:

$$C = \sum W_i \cdot P_i , \tag{4.1}$$

C - the competitiveness of research or a competitor;

Wi– criterion weight;
Pi – point of i-th criteria.

Table 4.1 Evaluation card for comparison of competitive technical solutions.

Evaluation criteria ***example***	**Criterion weight**	**Points**			**Competitiveness**		
		P_f	P_{i1}	P_{i2}	C_f	C_{i1}	C_{i2}
1	2	3	4	5	6	7	8
Technical criteria for evaluating resource efficiency							

1. Energy efficiency	0.1	3	4	4	0.3	0.4	0.4
2. Reliability	0.2	4	3	5	0.8	0.6	1
3. Safety	0.2	4	4	5	0.8	0.8	1
4. Functional capacity	0.1	5	5	5	0.5	0.5	0.5
Economic criteria for performance evaluation							
1. Development cost	0.1	4	4	5	0.4	0.4	0.1
2. Market penetration rate	0.1	5	4	3	0.5	0.4	0.3
3. Expected lifecycle	0.2	4	4	5	0.8	0.8	1
Total	**1**	**29**	**28**	**32**	**4.1**	**3.9**	**4.3**

In the existing state systems of radiation monitoring is measured only one parameter which is the dose rate of γ-radiation. In situ ambient dose measurement is the best alternative to investigate the changes in gamma background radiation due to Technosphere objects. The developed methodology is simple and economical in comparison with other competitive method for measuring radiation.

4.3 SWOT Analysis

A SWOT analysis evaluates the internal strengths and weaknesses, and the external opportunities and threats in an organization's environment. The internal analysis identifies resources, capabilities, core competencies and competitive advantages, using a functional approach to review finance, management, infrastructure, procurement, production, distribution, marketing, reputational factors and innovation. The internal analysis is critical in identifying the source of competitive advantage. It pinpoints the resources that need to be developed in order to remain competitive. The external analysis identifies market opportunities and threats by looking at the competitors' environment, the industry environment and the general environment. The competitors' environment is an analysis of the resources and functions of each rival firm. The industry environment is reviewed through the five forces framework of competitive rivalry, new entrants, suppliers, buyers and product substitution. The external environment is analysed in terms of political, economic, sociocultural, technological, ecological, demographic, ethical, and regulatory implications. The objective of a SWOT analysis is to use the knowledge an organization has about its environments and to formulate its strategy accordingly. (Sammut-Bonnici & Galea, 2015)

Table 4.2 SWOT Analysis of the research work

	Strengths: S1. The detector is highly sensitive and intelligent; S2. Results are displayed in real time; S3. Competitiveness.	**Weaknesses:** W1. Need technical know-how on to use the equipment.; W2. Sometime software takes time to respond W3. A lot of time needed In field to collect data.
Opportunities: O1. Radiation levels can be easily mapped in large areas; O2. Data can be used in construction industry; O3. The data can be applicable to city planning authorities; O4. Data can be used to improve public safety	***Strategy which based on strengths and opportunities:*** 1. Obtain a lot of measurements with the specified period which can be used to improve public safety which can in turn attract funding for future research.	***Strategy which based on weaknesses and opportunities:*** 1. work with a large number of engineers to collect a lot of data from various location within the city of Tomsk
Threats: T1. Budget overrun if project goes beyond schedule T2. Public perception of scientists carrying out measurements in their premises T3 Change in weather conditions can affect the accuracy of the results	***Strategy which based on strengths and threats*** 1. Spend minimum time outdoors but ensure that the accuracy and quality of data is maintained, this will ensure the technology remains competitive.	***Strategy which based on weaknesses and threats:*** 1 Follow the schedule of the project and to collect data in two different location in the same day.

4.4 Initiation of the Project

The gamma-background of the urban atmosphere is formed to a greater extent by the radiation of radionuclides contained in the soil, building materials, and the atmosphere. The influence of various objects of the Technosphere has practically not been studied by anyone. It is not known which objects will increase the total urban gamma background, and which ones will decrease. The foregoing determined the main goal of this work - the study of the influence of Technosphere objects on the gamma background of the urban environment. This work is important in the sense that knowing the level by which Technosphere objects have increased background radiation can help protect the public from the dangers of ionizing radiation.

4.4.1 Project stakeholders and Participants include

Table 4.3 Stakeholders of the project.

Project stakeholders	**Stakeholder expectations**
TPU	Provide necessary equipment and funding to ensure completion of the project.
ICRP	Develops dosimetric methodology for the assessment of internal and external radiation exposures
IAEA	Guidelines of radiological assessment of public environment

4.4.2 Objectives and Outcomes of the Project

Table 4.4 Purpose and results of the project.

Purpose of project:	• To investigate the changes in background radiation due to Technosphere objects in the urban environment.
Expected results of the project:	• Variations in gamma background radiation due to Technosphere objects. • Increase or decrease in absorbed dose within a radius of 1m from Technosphere objects. • Increase or decrease in Excess life time cancer risk within a radius of 1m from Technosphere objects
Criteria for acceptance of the project result:	Agreement between the results of project and the results of other authors on the similar subject or related subject area.
	Industrial applicability.

Requirements for the project result:	Significance for research

The organizational structure of the project is the most appropriate a temporary organizational structure that includes all its participants and is created to successfully achieve the project's objectives.

Table 4.5 The organizational structure of the project

№	Participant	Role in the project	Functions	Labor time, **hours.**
1	Engineer	Executor	Selection of main evaluation and scientific literatures studies. Collection of data and analyzing collected data	122
2	Supervisor	Head of project	Formulation of research topic and direction of research Verification work through weekly meetings Control of deadlines and objectives in the research.	28

4.4.3 Limitations and Assumptions of the Project

Project constraints - are all factors that can serve as a limited degree of freedom of members of the project team, as well as the "project boundary".

Table 4.6 Constraints and budget for the project

Factors	**Limitations / Assumptions**
3.1. Project's budget	**328666.11Rubles**
3.1.1. Source of financing	Internal TPU
3.2. Project timeline:	01/09/2019 to 12/05/2020
3.2.1. Date of approval of plan of project	01/09/2019

3.2.2. Completion date	20/05/2020

4.4.4 Project Schedule

This research demands that a working calendar graph is drawn to represent activities undertaken during the course of the project. This was used to monitor and guide the progress of work.

Table 4.7 Project Schedule

Job title	Duration, days	Start date	Date of completion	Participants
Development of technical specifications	4	1.02.2020	4.02.2020	Scientific supervisor
Drafting and approval of the Terms of Reference	3	4.02.2020	7.02.2020	Scientific supervisor
Research Direction	4	7.02.2020	11.02.2020	Scientific supervisor, Engineer
Collection and study scientific technical literature	25	11.02.2020	7.03.2020	Engineer
Data collection	35	7.03.2020	12.04.2020	Engineer
Analysis of the obtained experimental data	15	6.04.2020	21.04.2020	Engineer Scientific supervisor
Summary and assessment of results	2	21.04.2020	23.04.2020	Scientific supervisor, Engineer
Compilation of results for report preparation	15	1.04.2020	15.04.2020	Engineer
Preparation of the results and report submission.	6	20.04.2020	26.04.2020	Engineer
Defense preparation	20	30.04.2020	20.05.2020	Engineer

The Gantt chart was used to map the distribution of the work carried out. Gantt chart is a type of bar charts which is used to illustrate the planned schedule of project, in which the works can be shown the extensive length of time, characterized by the dates of beginning and end of the implementation of these works. Calendar schedule of R&D on the topic:

Table 4.8 work breakdown structure Gantt chart

№	Activities	Participants	T_c, days	Duration of the project													
				February			March			April			May			June	
				1	2	3	1	2	3	1	2	3	1	2	3	1	2
1	Development of technical specifications	Scientific supervisor	4														
2	Drafting and approval of the Terms of Reference	Scientific supervisor	3														
3	Research Direction	Scientific supervisor, Engineer	4														
4	Collection and study scientific technical literature	Engineer	25														
5	Data collection	Engineer	35														
6	Analysis of the obtained experimental data	Engineer	15														
7	Summary and assessment of results	Scientific supervisor, Engineer	2														
8	Compilation of results for report preparation	Engineer	15														
9	Preparation of the results and report for submission.	Scientific supervisor, Technician	6														
10	Defense preparation	Technician	20														

– Scientific supervisor, – Engineer

4.5 Scientific and technical research budget

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

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

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

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

4.5.1 Calculation of material costs

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

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

where

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

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

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

k_T – coefficient taking into account transportation costs.

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

Table 4.9 Material costs

Name	Unit	Amount	Price per unit, rub.	Material costs, rub.
Office supplies	-	1	800	800
Total				800

4.5.2 Calculation of the depreciation

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

$$A = \frac{(C_{прв} \cdot H_a)}{100} \qquad 4.3$$

Where

H_a - annual amount of depreciation;

$C_{перв}$ - initial cost of the equipment;

rate of depreciation;

$$H_a = \frac{100}{T_{сл}} \qquad 4.4$$

where

$T_{сл}$ - life expectancy.

In this research work, the special equipment necessary for conducting experimental work includes gamma detector BDKG-03 detector which cost 60000rubles and life time expectancy of 10years and computer connected to detector which cost 24000rubles and life time expectancy of 5years

Detector:

$$C_{dp} = \frac{C_{eq}}{T} \qquad (4.5)$$

$$C_{dq} = {60000}\!\!\diagup\!{10 \times 365} = 16.438 rubles / day$$

The equipment was used for 68 days, the cost of equipment:

$$C_{eq} = 16.438 rub / day \cdot 68 days = 1117.80 rubles / day$$

Computer:

$$C_{dq} = {24000}\!\!\diagup\!{5 \times 365} = 13.15 rubles / day$$

The equipment was used for 68 days, the cost of equipment

$$C_{eq} = 13.150 rub / day \cdot 68 days = 894.2 rubles / day$$

Table 4.10 Depreciation

№	Equipment identification	Quantity of equipment	Total cost of equipment, rub.	Life expectancy, year	Depreciation for the duration of the project, rub.
1.	Gamma detector	1	60000	10	1117.808
2.	computer	1	24000	5	894,2
Total					2012

4.5.3 Basic salary

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

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

$$S_B = S_a \times T_W \qquad (4.6)$$

where S_b – basic salary per participant;

T_w – the duration of the work performed by the scientific and technical worker, working days;

S_a - the average daily salary of an participant, rub.

The average daily salary is calculated by the formula:

$$S_d = \frac{S_m \times M}{F_V} \qquad (4.7)$$

где S_m – monthly salary of an participant, rub .;

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

at holiday in 48 days, M = 11.2 months, 6 day per week;

F_v – valid annual fund of working time of scientific and technical personnel (251 days).

F_v

Table 4.11 Work time balance

Working time indicators	Scientific supervisor
Calendar number of days	365
The number of non-working days - weekend - holidays	 52 14
Loss of working time - vacation - sick absence	 48 –
The valid annual fund of working time	251

Monthly salary is calculated by formula:

$$S_{month} = S_{base} \cdot \left(k_{premium} + k_{bonus}\right) \cdot k_{reg} \qquad (4.8)$$

where

S_{base} – base salary, rubles;

$k_{premium}$ – premium rate;

k_{bonus} – bonus rate;

k_{reg} – regional rate.

Table 4.12 Calculation of the base salaries

Performers	S_{base}, rubles	$k_{premium}$	k_{bonus}	k_{reg}	S_{month}, rub.	W_d, rub.	T_p, work days	W_{base}, rub.
Supervisor	35000	–	–	1,3	4550	1885.3	28	52788.4
Engineer	17310				22503	932.4	122	113752.8
Total								166541.2

4.5.4 Additional salary

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

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

$$W_{add} = k_{extra} \times W_{base}, \quad (4.9)$$

where

W_{add} – additional salary, rubles;

k_{extra} – additional salary coefficient (10%);

W_{base} – base salary, rubles.

Table 4.13 Additional Salary

Participant	Additional Salary, rubles
Supervisor	5278.84
Engineer	11375.28
Total	16654.12

4.5.5 Labor tax

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

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

$$P_{social} = k_b \times (W_{base} + W_{add}) \quad (4.10)$$

where

k_b – coefficient of deductions for labor tax.

In accordance with the Federal law of July 24, 2009 No. 212-FL, the amount of insurance contributions is set at 30%. Institutions conducting educational and scientific activities have rate - 27.1%.

Table 4.14 Labor tax

	Project leader	**Engineer**
Coefficient of deductions	0.271	
Salary, rubles	58067.24	125128.08
Labor tax, rubles	15736.22	33909.71
Total	49645.93	

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

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

Overhead is calculated according to the formula:

$$C_{ov} = k_{ov} \times (W_{base} + W_{add}) \quad (4.11)$$

Where

k_{ov} =50% – overhead rate.

Table 4.15 Overhead

	Project leader	Engineer
Overhead rate	0.5	
Salary, rubles	58067.24	125128.08
Overhead, rubles	29033.62	62564.04
Total	91597.66	

4.5.6 Other direct costs

Energy costs are calculated by the formula:

$$C = P_{el} \cdot P \cdot F_{eq}, \qquad (4.12)$$

where

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

P – power of equipment, kW;

F_{eq} – equipment usage time, hours.

When performing the work, a stationary computer with an average power of 500 W (0.5 kW) was used. If we assume that all the work was done on it, then, all was spent:

$$E = Pel \cdot P = 0.5 \cdot 4 \cdot 122 = 244 kW \cdot h,$$

(four-hour work day)

Energy Costs:

$$C = 5.8 * 244 = 1415.2 rubbles$$

Table 4.16 Other direct costs

Name	Power of equipment, kW	Amount	Price per unit, rub.	Material costs, rub.
Energy costs	0.5	244	5.8	1415.2
Total				1415.2

4.5.7 Formation of budget costs

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

Determined budget for the scientific research is given in the table.

Table 4.17 Items expenses grouping

Name	Cost, rubles
1. Material costs	800
2. Depreciation	2012
3. Basic salary	166541.2
4. Additional salary	16654.12
5. Labor tax	49645.93
6. Overhead	91597.66
7. Other direct cost	1415.2
Total planned cost	**328666.11**

4.6 Evaluation of the comparative effectiveness of the project

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

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

The integral financial measure of development is defined as:

$$I_{\phi}^{p} = I_{\phi}^{p} \frac{\Phi_{\text{pi}}}{\Phi_{\max}}, \tag{4.13}$$

where I_{ϕ}^{p} – integral financial measure of development;

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

$\Phi_{\max}$ – the maximum cost of execution of a research project (including analogues).

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

Since the development has one performance, then $I_{\phi}^{p} = 1$.

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

$$I_m^a = \sum_{i=1}^{n} a_i b_i^a \ , I_m^p = \sum_{i=1}^{n} a_i b_i^p \qquad (4.14)$$

where

I_{T} – integral indicator of resource efficiency for the i-th version of the development;

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

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

n – number of comparison parameters.

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

Table 4.18 Evaluation of the performance of the project

Criteria	**Weight criterion**	**Points**
1. 1. Energy efficiency	0.1	3
2. Reliability	0.2	4
3. Safety	0.2	4
4. Functional capacity	0.1	5
Economic criteria for performance evaluation		
1. The cost of development	0.1	4
2. Market penetration rate	0.1	5
3. Expected life	0.2	4
Total	1	4.1

The integral indicator of the development efficiency ($I^{p}_{\text{финр}}$) is determined on the basis of the integral indicator of resource efficiency and the integral financial indicator using the formula:

$$I^{p}_{\text{финр}} = \frac{I^{p}_{m}}{I^{p}_{\text{ф}}},\ I^{\text{а}}_{\text{финр}} = \frac{I^{\text{а}}_{m}}{I^{\text{а}}_{\text{ф}}} \text{ and etc.} \quad (4.15)$$

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

$$\text{Э}_{\text{ср}} = \frac{I^{\text{р}}_{\text{финр}}}{I^{\text{а}}_{\text{финр}}}. \quad (4.16)$$

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

Table 4.19 Efficiency of development

№	**Indicators**	P_f	P_{i1}
1	Integrated Financial Development Indicator	1	0.78
2	Integral indicator of resource efficiency of development	4.1	3.9
4	Integral indicator of the development efficiency	4.1	5

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

4.7 Conclusion on chapter

From Financial management, resource efficiency and resource saving analysis It can be concluded that the big piece of financial resources goes into paying salaries which takes a share of 166541.2rubles in basic salaries plus 16654.12rubles in additional salary. The total budget of the project was calculated at 328666.11rubles. In every scientific undertaking financial management, resource efficiency and serving is a very import aspect to ensure successful completion of project.

Chapter 5 Social responsibility

5.1 Introduction

Naturally occurring radioactive materials are ubiquitous throughout the earth's crust but Human manipulation of the environment for economic and social means has led to what is known as "technologically enhanced naturally occurring radioactive materials," often called TENORM. Technologically enhanced naturally occurring radioactive materials are present almost everywhere in the Technosphere in the form of Technosphere objects, hence the aim of the study to investigate the changes in background radiation due to technoshere objects in the urban environment.

5.2 Legal and organizational items in providing safety

Nowadays one of the main ways to radical improvement of all prophylactic work referred to reduce Total Incidents Rate and occupational morbidity is the widespread implementation of an integrated Occupational Safety and Health management system. That means combining isolated activities into a single system of targeted actions at all levels and stages of the production process.

Occupational safety is a system of legislative, socio-economic, organizational, technological, hygienic and therapeutic and prophylactic measures and tools that ensure the safety, preservation of health and human performance in the work process.

According to the Labor Code of the Russian Federation, every employee has the right: to have a workplace that meets Occupational safety requirements; to have a compulsory social insurance against accidents at manufacturing and occupational diseases; to receive reliable information from the employer, relevant government bodies and public organizations on conditions and Occupational safety at the workplace, about the existing risk of damage to health, as well as measures to protect against harmful and (or) hazardous factors; to refuse carrying out work in case of danger to his life and health due to violation of Occupational safety requirements; be provided with personal and collective protective equipment in compliance with Occupational safety requirements at the expense of the employer; for training in safe work methods and techniques at the expense of the employer; for personal participation or participation through their representatives in consideration of issues related to ensuring safe working conditions in his workplace, and in the investigation of the accident with him at work or occupational disease; for extraordinary medical examination in accordance with medical recommendations with preservation of his place of work (position) and secondary earnings during the passage of the specified medical examination; for warranties and compensation established in accordance with this Code, collective agreement, agreement, local regulatory an act, an employment contract, if he is engaged in work with harmful and (or) hazardous working conditions.

The labor code of the Russian Federation states that normal working hours may not exceed 40 hours per week, the employer must keep track of the time worked by each employee.

Rules for labor protection and safety measures are introduced in order to prevent accidents, ensure safe working conditions for workers and are mandatory for workers, managers, engineers and technicians.

5.3 Basic ergonomic requirements for the correct location and arrangement of researcher's workplace when working with PC

The workplace when working with a PC should be at least 6 square meters. The legroom should correspond to the following parameters: the legroom height is at least 600 mm, the seat distance to the lower edge of the working surface is at least 150 mm, and the seat height is 420 mm. It is worth noting that the height of the table should depend on the growth of the operator.

The following requirements are also provided for the organization of the workplace of the PC user: The design of the working chair should ensure the maintenance of a rational working posture while working on the PC and allow the posture to be changed in order to reduce the static tension of the neck and shoulder muscles and back to prevent the development of fatigue.

The type of working chair should be selected taking into account the growth of the user, the nature and duration of work with the PC. The working chair should be lifting and swivel, adjustable in height and angle of inclination of the seat and back, as well as the distance of the back from the front edge of the seat, while the adjustment of each parameter should be independent, easy to carry out and have a secure fit.

5.4 Work safety

A dangerous factor or industrial hazard is a factor whose impact under certain conditions leads to trauma or other sudden, severe deterioration of health of the worker. A harmful factor or industrial health hazard is a factor, the effect of which on a worker under certain conditions leads to a disease or a decrease in working capacity.

5.4.1 Analysis of harmful and dangerous factors that can be created by object of investigation

The objective of the study is investigation of changes in background radiation due to technoshere objects in the urban environment. Therefore, objective of investigation itself cannot cause harmful and dangerous factors it only seeks to determine the potential radiological health effects of increased background radiation due to technoshere objects.

5.4.2 Analysis of harmful and dangerous factors that can arise at workplace during investigation

The research work was carried on the pc in the room during analysis of results and also in the urban environment during data collection. working conditions in the workplace are characterized by the presence of hazardous and harmful factors, which are classified by groups of elements: physical, chemical, biological, psychophysiological. Since the research was carried out in two places at the work place in room during analysis of results and in the urban environment around technoshere objects. The main elements of the production process that form dangerous and harmful factors are presented below.

5.4.3 Analysis of harmful and dangerous factors that can arise at workplace during investigation

5.4.3.1 Deviation of microclimate indicators

The air of the working area (microclimate) is determined by the following parameters: temperature, relative humidity, air speed. The optimum and permissible values of the microclimate characteristics are established in accordance with and are given in Table 5.1

Table 5.1 Optimal and permissible parameters of the microclimate

Period of the year	Temperature, C	Relative humidity,%	Speed of air movement, m/s
Cold and changing of seasons	23-25	40-60	0.1
Warm	23-25	40	0.1

5.4.3.2 Excessive noise

Noise and vibration worsen working conditions, have a harmful effect on the human body, namely, the organs of hearing and the whole body through the central nervous system. It results in weakened attention, deteriorated memory, decreased response, and increased number of errors in work. Noise can be generated by operating equipment, air conditioning units, daylight illuminating devices, as well as spread from the outside. When working on a PC, the noise level in the workplace should not exceed 50dB.

5.4.3.3 Increased level of electromagnetic radiation

The screen and system blocks produce electromagnetic radiation. Its main part comes from the system unit and the video cable. According to, the intensity of the electromagnetic field at a distance of 50 cm around the screen along the electrical component should be no more than:

- in the frequency range 5 Hz - 2 kHz - 25 V / m;
- in the frequency range 2 kHz - 400 kHz - 2.5 V / m.

The magnetic flux density should be no more than:

- in the frequency range 5 Hz - 2 kHz - 250 nT;
- in the frequency range 2 kHz - 400 kHz - 25 nT

5.4.3.4 Abnormally high voltage value in the circuit

Depending on the conditions in the room, the risk of electric shock to a person increases or decreases. Do not operate the electronic device in conditions of high humidity (relative air humidity exceeds 75% for a long time), high temperature (more than 35 ° C), the presence of conductive dust, conductive floors and the possibility of simultaneous contact with metal components connected to the ground and the metal casing of electrical equipment. The operator works with electrical devices: a computer (display, system unit, etc.) and peripheral devices. There is a risk of electric shock in the following cases:

- with direct contact with current-carrying parts during computer repair;
- when touched by non-live parts that are under voltage (in case of violation of insulation of current-carrying parts of the computer);

- when touched with the floor, walls that are under voltage;
- short-circuited in high-voltage units: power supply and display unit.

Table 5.2 Upper limits for values of contact current and voltage

	Voltage, V	Current, mA
Alternate, 50 Hz	2	0.3
Alternate, 400 Hz	3	0.4
Direct	8	1.0

5.4.3.5 Insufficient illumination of the working area

Light sources can be both natural and artificial. The natural source of the light in the room is the sun, artificial light are lamps. With long work in low illumination conditions and in violation of other parameters of the illumination, visual perception decreases, myopia, eye disease develops, and headaches appear.

According to the standard, the illumination on the table surface in the area of the working document should be 300-500 lux. Lighting should not create glare on the surface of the monitor. Illumination of the monitor surface should not be more than 300 lux.

The brightness of the lamps of common light in the area with radiation angles from 50 to 90° should be no more than 200 cd/m, the protective angle of the lamps should be at least 40°. The safety factor for lamps of common light should be assumed to be 1.4. The ripple coefficient should not exceed 5%.

5.4.3.6 Increased levels of ionizing radiation

Ionizing radiation is radiation that could ionize molecules and atoms. This effect is widely used in energetics and industry. However, there is health hazard. In living tissue, this radiation could damage cells that result in two types of effects. Deterministic effects (harmful tissue reactions) due to exposure with high doses and stochastic effects due to DNA destruction and mutations (for example, induction of cancer).

To provide radiation safety with using sources of ionizing radiation one must use next principles:

a) keep individual radiation doses from all radiation sources not higher than permissible exposure;
b) forbid all activity with using radiation sources if profit is low than risk of possible hazard;
c) keep individual radiation doses from all radiation sources as low as possible.

There are two groups of people related to work with radiation: personnel, who works with ionizing radiation, and population.

Table 5.3 Permissible dose limit

Quantity	Dose limits	
Effective dose	20 mSv per year in average during 5 years, but not higher than 50 mSv per year	1 mSv per year in average during 5 years, but not higher than 5 mSv per year
Equivalent dose per year in eye's lens	150 mSv	15 mSv
skin	500 mSv	50 mSv
Hands and feet	500 mSv	50 mSv

Effective dose for personnel must not exceed 1000 mSv for 50 years of working activity, and for population must not exceed 70 mSv for 70 years of life. In addition, for women from personnel of age below 45 years there is limit of 1 mSv per month of equivalent dose on lower abdomen. During gestation and breast-feeding women must not work with radiation sources. For students older than 16, who uses radiation sources in study process or who is in rooms with increased level of ionizing radiation, dose limits are quarter part of dose limits of personnel

5.4.4 Justification of measures to reduce the levels of exposure to hazardous and harmful factors on the researcher

5.4.4.1 Deviation of microclimate indicators

The measures for improving the air environment in the production room include: the correct organization of ventilation and air conditioning, heating of room. Ventilation can be realized naturally and mechanically. In the room, the following volumes of outside air must be delivered:

- at least 30 m 3 per hour per person for the volume of the room up to 20 m 3 per person;
- natural ventilation is allowed for the volume of the room more than 40 m 3 per person and if there is no emission of harmful substances.

The heating system must provide sufficient, constant and uniform heating of the air. Water heating should be used in rooms with increased requirements for clean air. The parameters of the microclimate in the laboratory regulated by the central heating system, have the following values: humidity 40%, air speed 0.1 m / s, summer temperature 20-25 ° C, in winter 13-15 ° C. Natural ventilation is provided in the laboratory. Air enters and leaves through the cracks, windows, doors. The main disadvantage of such ventilation is that the fresh air enters the room without preliminary cleaning and heating.

5.4.4.2 Excessive noise

In research audiences, there are various kinds of noises that are generated by both internal and external noise sources. The internal sources of noise are working equipment, personal computer, printer, ventilation system, as well as computer equipment of other engineers in the audience. If the maximum permissible conditions are exceeded, it is sufficient to use sound-absorbing materials in the room (sound-absorbing wall and ceiling cladding, window curtains). To reduce the noise penetrating outside the premises, install seals around the perimeter of the doors and windows

5.4.4.3 Increased level of electromagnetic radiation

There are the following ways to protect against EMF: increase the distance from the source (the screen should be at least 50 cm from the user); the use of pre-screen filters, special screens and other personal protective equipment. When working with a computer, the ionizing radiation source is a display. Under the influence of ionizing radiation in the body, there may be a violation of normal blood coagulability, an increase in the fragility of blood vessels, a decrease in immunity, etc. The dose of irradiation at a distance of 20 cm to the display is 50 µrem / hr. According to the norms, the design of the computer should provide the power of the exposure dose of x-rays at any point at a distance of 0.05 m from the screen no more than 100 µR / h.

Fatigue of the organs of vision can be associated with both insufficient illumination and excessive illumination, as well as with the wrong direction of light.

5.4.4.4 Increased level of electromagnetic radiation

There are the following ways to protect against EMF: increase the distance from the source (the screen should be at least 50 cm from the user); the use of pre-screen filters, special screens and other personal protective equipment. When working with a computer, the ionizing radiation source is a display. Under the influence of ionizing radiation in the body, there may be a violation of normal blood coagulability, an increase in the fragility of blood vessels, a decrease in immunity, etc. The dose of irradiation at a distance of 20 cm to the display is 50 µrem / hr. According to the norms, the design of the computer should provide the power of the exposure dose of x-rays at any point at a distance of 0.05 m from the screen no more than 100 µR / h.

Fatigue of the organs of vision can be associated with both insufficient illumination and excessive illumination, as well as with the wrong direction of light.

5.4.4.5 Increased levels of ionizing radiation

In case of radiation accident, responsible personnel must take all measures to restore control of radiation sources and reduce to minimum radiation doses, number of irradiated persons, radioactive pollution of the environment, economic and social losses caused with radioactive pollution.

Radiation control is a main part of radiation safety and radiation protection. It is aimed at not exceeding the established basic dose limits and permissible levels of radiation, obtaining the necessary information to optimize protection and making decisions about interference in the case of radiation accidents, contamination of the environment and buildings with radionuclides.

The radiation control is control of:

- Radiation characteristics of radiation sources, pollution in air, liquid and solid wastes.
- Radiation factors developed with technological processes in working places and environment.
- Radiation factors of contaminated environment.
- Irradiation dose levels of personnel and population.

The main controlled parameters are:

- Annual effective and equivalent doses
- intake and body content of radionuclides
- volume or specific activity of radionuclides in air, water, food products, building materials and etc.
- radioactive contamination of skin, clothes, footwear, working places and etc.
- dose and power of external irradiation.
- particles and photons flux density.

Radiation protection office establish control levels of all controlled parameters in according to not exceed dose limits and keep dose levels as low as possible. In case of exceeding control levels radiation protection officers start investigation of exceed causes and take actions to eliminate this exceeding.

during planning and implementation of radiation safety precautions, taking any actions about radiation safety and analysis of effectiveness of mentioned action and precautions one must value radiation safety with the following factors:

- characteristics of radioactive contamination of the environment;
- probability of radiation accidents and scale of accidents;
- degree of readiness to effective elimination of radiation accidents and its aftermath;
- number of persons irradiated with doses higher than controlled limits of doses;
- analysis of actions for providing radiation safety, meeting requirements, rules, standards of radiation safety;
- analysis of irradiation doses obtained by groups of population from all ionizing radiation sources.

5.4.4.6 Abnormally high voltage value in the circuit

Measures to ensure the electrical safety of electrical installations:

- disconnection of voltage from live parts, on which or near to which work will be carried out, and taking measures to ensure the impossibility of applying voltage to the workplace;
- posting of posters indicating the place of work;
- electrical grounding of the housings of all installations through a neutral wire;
- coating of metal surfaces of tools with reliable insulation;

- inaccessibility of current-carrying parts of equipment (the conclusion in the case of electroporating elements, the conclusion in the body of current-carrying parts).

5.4.4.7 Insufficient illumination of the working area

Desktops should be placed in such a way that the monitors are oriented sideways to the light openings, so that natural light falls mainly on the left. Also, as a means of protection to minimize the impact of the factor, local lighting should be installed due to insufficient lighting, window openings should be equipped with adjustable devices such as blinds, curtains, external visors, etc.

5.5 Ecological safety

5.5.1 Analysis of the impact of the research object on the environment

Human manipulation of the environment for economic and social means, such as mining, ore processing, fossil fuel extraction, construction and commercial aviation, may lead to what is known as "technologically enhanced naturally occurring radioactive materials," The existence of technologically enhanced naturally occurring radioactive materials results in an increased risk for human exposure to radioactivity. This rapid change in technological advances has put pressure on the ecosystem. This has led to global environmental issues, and the more humanity has developed, the bigger has negative impact been on the environment.

5.5.2 Analysis of the environmental impact of the research process

Process of investigation itself in the thesis do not have essential effect on environment. One of hazardous waste is fluorescent lamps. Mercury in fluorescent lamps is a hazardous substance and its improper disposal greatly poisons the environment.

Outdated devices go to an enterprise that has the right to process wastes. It is possible to isolate precious metals with a purity in the range of 99.95–99.99% from computer components. A closed production cycle consists of the following stages: primary sorting of equipment; the allocation of precious, ferrous and non-ferrous metals and other materials; melting; refining and processing of metals. Thus, there is an effective disposal of computer devices.

5.6 Safety in emergency

Analysis of probable emergencies that may occur at the workplace during research is an important undertaking. The fire is the most probable emergency in our life. Possible causes of fire:

- malfunction of current-carrying parts of installations;
- work with open electrical equipment;
- short circuits in the power supply;
- non-compliance with fire safety regulations;

presence of combustible components: documents, doors, tables, cable insulation, etc.
Activities on fire prevention are divided into: organizational, technical, operational and regime.

5.6.1 Substantiation of measures for the prevention of emergencies and the development of procedures in case of emergencies

Organizational measures provide for correct operation of equipment, proper maintenance of buildings and territories, fire instruction for workers and employees, training of production personnel for fire safety rules, issuing instructions, posters, and the existence of an evacuation plan.

The technical measures include compliance with fire regulations, norms for the design of buildings, the installation of electrical wires and equipment, heating, ventilation, lighting, the correct placement of equipment.

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

- elimination of the formation of a flammable environment (sealing equipment, control of the air, working and emergency ventilation);
- use in the construction and decoration of buildings of non-combustible or difficultly combustible materials;
- the correct operation of the equipment (proper inclusion of equipment in the electrical supply network, monitoring of heating equipment);
- correct maintenance of buildings and territories (exclusion of the source of ignition - prevention of spontaneous combustion of substances, restriction of fireworks);
- training of production personnel in fire safety rules;
- the publication of instructions, posters, the existence of an evacuation plan;
- compliance with fire regulations, norms in the design of buildings, in the organization of electrical wires and equipment, heating, ventilation, lighting;
- the correct placement of equipment;
- well-time preventive inspection, repair and testing of equipment.
- In the case of an emergency, it is necessary to:
- inform the management (duty officer);
- call the Emergency Service or the Ministry of Emergency Situations tel. 112;

These measures must be taken to eliminate the accident in accordance with the instructions

5.7 Conclusion on chapter

In this section about social responsibility the hazardous and harmful factors were revealed. All necessary safety measures and precaution to minimize probability of accidents and traumas during investigation are given. It could be stated that with respect to all regulations and standards, investigation itself and object of investigation do not pose special risks to personnel, other equipment and environment

Conclusion

Assessment of gamma background radiation within an urban environment is an important aspect of radiation protection. Investigation of changes in gamma background radiation due to technosphere objects in the urban environment found that;

Technosphere objects extremely influence background radiation and increase irradiation doses within an urban environment, which can result in increased probability of developing cancer over a life time of exposure.

Within a radius of 1m from certain technosphere objects the absorbed dose is 1.5 to 4.4 times higher than the UNSCEAR recommended safe limit.

The range of absorbed dose was $44nGy/h \pm 1.9nGy$ to $374nGy/h \pm 0.26nGy/h$.The calculated range of AEDE was $0.05mSv/y$ to $0.46mSv/yr$ and ELCR was 0.175×10^{-3} to 1.60×10^{-3}.

A person standing 50cm from certain technoshere objects would receive a radiation doses in the range of 86nG/h ± 2.1nGy/h to 204nGy/h ± 5.5nGy/h, which 1.02 to 2.4 higher than the recommended safe limit.

A person sitting on a bench (site GL5D) would receive an absorbed dose 1.7 time higher than the recommended safe limit and 3.4 times higher than world average.

The presence of an asphalted area at Lenta (site LE2A) resulted in a decrease in gamma background radiation.

Largernyy sad (site LA1A and LA1B) and Alley of Geologist (site GL5B and GL5C) are areas with the highest recorded gamma background radiation. The annual effective dose equivalent calculated indicates that the areas do not constitute any immediate radiological health effects on the general public but there exists a very high probability of one developing cancer over a life time of exposure.

However, there is need to determine the exact contribution of technoshere objects to the total background radiation therefore, in future further studies have to be carried out to determine the exact contribution.

References

1. *(11) (PDF) Effects of weather elements on the formation of background radiation in Bulgaria*. (n.d.). ResearchGate. Retrieved May 28, 2020, from https://www.researchgate.net/publication/315662074_Effects_of_weather_elements_on_the_formation_of_background_radiation_in_Bulgaria

2. Abbasi, A. (2017). Levels of Radon and Granite Building Materials. In F. Adrovic (Ed.), *Radon*. InTech. https://doi.org/10.5772/intechopen.69987

3. Abdullahi, S., Ismail, A. F., & Samat, S. (2019). Determination of indoor doses and excess lifetime cancer risks caused by building materials containing natural radionuclides in Malaysia. *Nuclear Engineering and Technology*, *51*(1), 325–336. https://doi.org/10.1016/j.net.2018.09.017

4. Al Kanti, H., El Hajjaji, O., El Bardouni, T., & Mohammed, M. (2019). An analytical fit and EGSnrc code (MC) calculations of personal dose equivalent conversion coefficients for mono-energetic electrons. *Applied Radiation and Isotopes*, *154*, 108906. https://doi.org/10.1016/j.apradiso.2019.108906

5. Alam, M. N., Miah, M. M. H., Chowdhury, M. I., Kamal, M., Ghose, S., & Rahman, R. (2001). Attenuation coefficients of soils and some building materials of Bangladesh in the energy range 276–1332keV. *Applied Radiation and Isotopes*, *54*(6), 973–976. https://doi.org/10.1016/S0969-8043(00)00354-7

6. Al-Azmi, D., Kumara, S., Mohan, M. P., & Karunakara, N. (2019). GAMMA DOSE RATES IN THE HIGH BACKGROUND RADIATION AREA OF MANGALORE REGION, INDIA. *Radiation Protection Dosimetry*, *184*(3–4), 290–293. https://doi.org/10.1093/rpd/ncz063

7. Al-Hamarneh, I. F., & Awadallah, M. I. (2009). Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan. *Radiation Measurements*, *44*(1), 102–110. https://doi.org/10.1016/j.radmeas.2008.11.005

8. Amin, R. M. (2015). A study of radon emitted from building materials using solid state nuclear track detectors. *Journal of Radiation Research and Applied Sciences*, *8*(4), 516–522. https://doi.org/10.1016/j.jrras.2015.06.001

9. Amrani, D., & Cherouati, D. E. (1999). Radon exhalation rate in building materials using plastic track detectors. *Journal of Radioanalytical and Nuclear Chemistry*, *242*(2), 269–271. https://doi.org/10.1007/BF02345552

10. Asaduzzaman, K., Mannan, F., Khandaker, M. U., Farook, M. S., Elkezza, A., Amin, Y. B. M., Sharma, S., & Abu Kassim, H. B. (2015). Assessment of Natural Radioactivity Levels and Potential Radiological Risks of Common Building Materials Used in Bangladeshi Dwellings. *PLOS ONE*, *10*(10), e0140667. https://doi.org/10.1371/journal.pone.0140667

11. Avdic, S., Demirovic, D., Kunosic, S., Pehlivanovic, B., Kadic, I., & Ilic, Z. (2020). A study of daily variations of the outdoor background radiation measured in continuous mode in Federation of Bosnia and Herzegovina. *Journal of Environmental Radioactivity*, *217*, 106212. https://doi.org/10.1016/j.jenvrad.2020.106212

12. Bala, P., Kumar, V., & Mehra, R. (2017). Measurement of radon exhalation rate in various building materials and soil samples. *Journal of Earth System Science*, *126*(2), 31. https://doi.org/10.1007/s12040-017-0797-z

13. Banzi, F. B., & Msaki, P. (2000). *Radioactivity in Products Derived from Gypsum in Tanzania*. https://doi.org/10.1093/oxfordjournals.rpd.a033251

14. Bibbo, G., & Piotto, L. (2014). Background ionising radiation: A pictorial perspective. *Australasian Physical & Engineering Sciences in Medicine*, *37*(3), 575–581. https://doi.org/10.1007/s13246-014-0286-5

15. Bou-Rabee, F., & Bem, H. (1996). Natural radioactivity in building materials utilized in the State of Kuwait. *Journal of Radioanalytical and Nuclear Chemistry Letters*, *213*(2), 143–149. https://doi.org/10.1007/BF02165246

16. Casanovas, R., Prieto, E., & Salvadó, M. (2016). Calculation of the ambient dose equivalent H*(10) from gamma-ray spectra obtained with scintillation detectors. *Applied Radiation and Isotopes*, *118*, 154–159. https://doi.org/10.1016/j.apradiso.2016.09.001

17. Dinh Chau, N., Dulinski, M., Jodlowski, P., Nowak, J., Rozanski, K., Sleziak, M., & Wachniew, P. (2011). Natural radioactivity in groundwater – a review.

Isotopes in Environmental and Health Studies, *47*(4), 415–437. https://doi.org/10.1080/10256016.2011.628123

18. *Dołhańczuk-Śródka2012_Article_EstimationOfExternalGammaRadia.pdf*. (n.d.).

19. *Earth's "technosphere" now weighs 30 trillion tons, research finds*. (n.d.). Retrieved May 21, 2020, from https://phys.org/news/2016-11-earth-technosphere-trillion-tons.html

20. Emelue, H. (2014). Excess Lifetime Cancer Risk due to Gamma Radiation in and Around Warri Refining and Petrochemical Company in Niger Delta, Nigeria. *British Journal of Medicine and Medical Research*, *4*(13), 2590–2598. https://doi.org/10.9734/BJMMR/2014/7180

21. Fujinami, N. (1996). Observational study of the scavenging of radon daughters by precipitation from the atmosphere. *Environment International*, *22*, 181–185. https://doi.org/10.1016/S0160-4120(96)00106-7

22. Hendry, J. H., Simon, S. L., Wojcik, A., Sohrabi, M., Burkart, W., Cardis, E., Laurier, D., Tirmarche, M., & Hayata, I. (2009). Human exposure to high natural background radiation: What can it teach us about radiation risks? *Journal of Radiological Protection*, *29*(2A), A29–A42. https://doi.org/10.1088/0952-4746/29/2A/S03

23. *ICRP*. (n.d.). Retrieved May 1, 2020, from https://www.icrp.org/publication.asp?id=ICRP%20Publication%20103

24. Jakubowska, T., & Długosz-Lisiecka, M. (2020). Estimation of effective dose using two ICRP criteria, applied to radiation protection of personnel in an unshielded PET cyclotron facility. *Radiation Physics and Chemistry*, *171*, 108688. https://doi.org/10.1016/j.radphyschem.2020.108688

25. Jo, L., & Jg, Y. (1998). Radioactive materials in recycled metals—An update. *Health Physics*, *74*(3), 293–299. https://doi.org/10.1097/00004032-199803000-00001

26. Keller, P. E., & Kouzes, R. T. (2009). Influence of Extraterrestrial Radiation on Radiation Portal Monitors. *IEEE Transactions on Nuclear Science*, *56*(3), 1575–1583. https://doi.org/10.1109/TNS.2009.2019618

27. Khan, K., & Khan, H. M. (2001). Natural gamma-emiting radionuclides in Pakistani Portland cement. *Applied Radiation and Isotopes: Including Data, Instrumentation and Methods for Use in Agriculture, Industry and Medicine*, *54*(5), 861–865. https://doi.org/10.1016/s0969-8043(00)00327-4

28. Krstić, D., Nikezić, D., Stevanović, N., & Vučić, D. (2007). Radioactivity of some domestic and imported building materials from South Eastern Europe. *Radiation Measurements*, *42*(10), 1731–1736. https://doi.org/10.1016/j.radmeas.2007.09.001

29. Liu, Z., & Sullivan, C. J. (2019). Prediction of weather induced background radiation fluctuation with recurrent neural networks. *Radiation Physics and Chemistry*, *155*, 275–280. https://doi.org/10.1016/j.radphyschem.2018.03.005

30. Livesay, R. J., Blessinger, C. S., Guzzardo, T. F., & Hausladen, P. A. (2014). Rain-induced increase in background radiation detected by Radiation Portal Monitors. *Journal of Environmental Radioactivity*, *137*, 137–141. https://doi.org/10.1016/j.jenvrad.2014.07.010

31. Mahat, R. H., & Amin, Y. M. (1990). Concentration of radon precursors in some malaysian building materials. *Journal of Radioanalytical and Nuclear Chemistry Letters*, *144*(5), 375–378. https://doi.org/10.1007/BF02218145

32. Mahmoud Pashazadeh, A., Aghajani, M., Nabipour, I., & Assadi, M. (2014). Annual effective dose from environmental gamma radiation in Bushehr city. *Journal of Environmental Health Science & Engineering*, *12*(1), 4. https://doi.org/10.1186/2052-336X-12-4

33. Mahur, A. K., Kumar, R., Sengupta, D., & Prasad, R. (2008). Estimation of radon exhalation rate, natural radioactivity and radiation doses in fly ash samples from Durgapur thermal power plant, West Bengal, India. *Journal of Environmental Radioactivity*, *99*(8), 1289–1293. https://doi.org/10.1016/j.jenvrad.2008.03.010

34. Maxwell, O., Adewoyin, O. O., Joel, E. S., Ehi-Eromosele, C. O., Akinwumi, S. A., Usikalu, M. R., Emenike, C. P., & Embong, Z. (2018). Radiation exposure to dwellers due to naturally occurring radionuclides found in selected commercial building materials sold in Nigeria. *Journal of Radiation Research and Applied Sciences*, *11*(3), 225–231. https://doi.org/10.1016/j.jrras.2018.01.007

35. Mercier, J.-F., Tracy, B. L., d'Amours, R., Chagnon, F., Hoffman, I., Korpach, E. P., Johnson, S., & Ungar, R. K. (2009). Increased environmental gamma-ray dose rate during precipitation: A strong correlation with contributing air mass. *Journal of Environmental Radioactivity*, *100*(7), 527–533. https://doi.org/10.1016/j.jenvrad.2009.03.002

36. Michael, F., Parpottas, Y., & Tsertos, H. (2010). Gamma radiation measurements and dose rates in commonly used building materials in Cyprus. *Radiation Protection Dosimetry*, *142*(2–4), 282–291. https://doi.org/10.1093/rpd/ncq193

37. Mitchell, A. L., Borgardt, J. D., & Kouzes, R. T. (2009). *Skyshine Contribution to Gamma Ray Background Between 0 and 4 MeV* (PNNL-18666, 990599; p. PNNL-18666, 990599). https://doi.org/10.2172/990599

38. Nagorskiy, Zenchenko, A., Pustovalov, N., Cherepnev, S., Yakovlev, A., & Yakovleva, S. (2017). THE INFLUENCE OF URBAN AREA (TECHNOSPHERE) ON VARIATIONS OF ELECTROPHYSICAL AND RADIATION QUANTITIES. *№4(20) (2017)*. https://doi.org/10.18454/2079-6641-2017-20-4-64-75

39. Nguyen, P. K., & Wu, J. C. (2011). Radiation exposure from imaging tests: Is there an increased cancer risk? *Expert Review of Cardiovascular Therapy*, *9*(2), 177–183. https://doi.org/10.1586/erc.10.184

40. Njinga, R. L., & Tshivhase, V. M. (2016). Lifetime cancer risk due to gamma radioactivity in soils from Tudor Shaft mine environs, South Africa. *Journal of Radiation Research and Applied Sciences*, *9*(3), 310–315. https://doi.org/10.1016/j.jrras.2016.02.003

41. Nowak, K. J., & Solecki, A. T. (n.d.). *Factors affecting background gamma radiation in an urban space*. 13.

42. Pierce, D. A., & Preston, D. L. (2000). Radiation-Related Cancer Risks at Low Doses among Atomic Bomb Survivors. *Radiation Research*, *154*(2), 178–186. https://doi.org/10.1667/0033-7587(2000)154[0178:RRCRAL]2.0.CO;2

43. Ramachandran, T. V. (n.d.). Background radiation, people and the environment. *People and the Environment*, 14.

44. Ramli, A. T., Hussein, A. W. M. A., & Wood, A. K. (2005). Environmental 238U and 232Th concentration measurements in an area of high level natural background radiation at Palong, Johor, Malaysia. *Journal of Environmental Radioactivity*, *80*(3), 287–304. https://doi.org/10.1016/j.jenvrad.2004.06.008

45. Rugani, B., Maes, J., Othoniel, B., Pulselli, F. M., Schaubroeck, T., & Ziv, G. (2018). Human-nature nexuses: Broadening knowledge on integrated biosphere-technosphere modelling to advance the assessment of ecosystem services. *Ecosystem Services*, *30*, 193–199. https://doi.org/10.1016/j.ecoser.2018.04.002

46. Saghatchi, F., Salouti, M., & Eslami, A. (2008). Assessment of annual effective dose due to natural gamma radiation in Zanjan (Iran). *Radiation Protection Dosimetry*, *132*(3), 346–349. https://doi.org/10.1093/rpd/ncn285

47. Salupeto-Dembo, J., Szabó-Krausz, Z., Völgyesi, P., Kis, Z., & Szabó, C. (2020). External radiation exposure of the Angolan population living in adobe houses. *Journal of Radioanalytical and Nuclear Chemistry*, *323*(1), 353–364. https://doi.org/10.1007/s10967-019-06920-z

48. Shahbazi-Gahrouei, D. (n.d.). *Annual background radiation in Chaharmahal and Bakhtiari province*. 6.

49. Shahbazi-Gahrouei, Daryoush, Gholami, M., & Setayandeh, S. (2013). A review on natural background radiation. *Advanced Biomedical Research*, *2*(1), 65. https://doi.org/10.4103/2277-9175.115821

50. Shea, M. A., & Smart, D. F. (2000). Cosmic Ray Implications for Human Health. In J. W. Bieber, E. Eroshenko, P. Evenson, E. O. Flückiger, & R. Kallenbach (Eds.), *Cosmic Rays and Earth* (Vol. 10, pp. 187–205). Springer Netherlands. https://doi.org/10.1007/978-94-017-1187-6_10

51. Speth, P., Christoph, M., & Diekkrüger, B. (Eds.). (2010). *Impacts of Global Change on the Hydrological Cycle in West and Northwest Africa*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-12957-5

52. Stojanovska, Z., Nedelkovski, D., & Ristova, M. (2010). Natural radioactivity and human exposure by raw materials and end product from cement industry used as building materials. *Radiation Measurements*, *45*(8), 969–972. https://doi.org/10.1016/j.radmeas.2010.06.023

53. Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., Hidiroglu, S., & Karahan, G. (2009). Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. *Journal of Environmental Radioactivity*, *100*(1), 49–53. https://doi.org/10.1016/j.jenvrad.2008.10.012

54. Temuujin, J., Surenjav, E., Ruescher, C. H., & Vahlbruch, J. (2019). Processing and uses of fly ash addressing radioactivity (critical review). *Chemosphere*, *216*, 866–882. https://doi.org/10.1016/j.chemosphere.2018.10.112

55. Ugbede, F. O., & Echeweozo, E. O. (2017). *Estimation of Annual Effective Dose and Excess Lifetime Cancer Risk from Background Ionizing Radiation Levels Within and Around Quarry Site in Okpoto-Ezillo, Ebonyi State, Nigeria*. 6.

56. United Nations (Ed.). (2000). *Sources and effects of ionizing radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2000 report to the General Assembly, with scientific annexes*. United Nations.

57. United Nations (Ed.). (2010). *Sources and effects of ionizing radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2008 report to the General Assembly, with scientific annexes*. United Nations.

58. Vearrier, D., Curtis, J. A., & Greenberg, M. I. (2009). Technologically enhanced naturally occurring radioactive materials. *Clinical Toxicology (Philadelphia, Pa.)*, *47*(5), 393–406. https://doi.org/10.1080/15563650902997849

59. Yang, Y., Wu, X., Jiang, Z., Wang, W., Lu, J., Lin, J., Wang, L.-M., & Hsia, Y. (2005). Radioactivity concentrations in soils of the Xiazhuang granite area, China. *Applied Radiation and Isotopes*, *63*(2), 255–259. https://doi.org/10.1016/j.apradiso.2005.02.011

60. Zalasiewicz, J., Williams, M., Waters, C. N., Barnosky, A. D., Palmesino, J., Rönnskog, A.-S., Edgeworth, M., Neal, C., Cearreta, A., Ellis, E. C., Grinevald, J., Haff, P., Ivar do Sul, J. A., Jeandel, C., Leinfelder, R., McNeill, J. R., Odada, E., Oreskes, N., Price, S. J., … Wolfe, A. P. (2017). Scale and diversity of the physical technosphere: A geological perspective. *The Anthropocene Review*, *4*(1), 9–22. https://doi.org/10.1177/2053019616677743