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Assessment of Natural Radioactivity Levels and Associated Dose Rates in Soil Samples from Al South Kordofan State–Dallanj Area

التحقق من مستوى الإشعاع الطبيعي ومعدل الجرعة الإشعاعية في عينة من التربة بمنطقة الدلنج ــ ولاية جنوب كردفان

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بسم الله الرحمن الرحيم

قال الله تعالى:

(الَّذِينَ يَذْكُرُونَ اللَّهَ قِيَامًا وَقُعُودًا وَعَلَى جُنُوبِهِمْ وَيَتَفَكَّرُونَ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ رَبَّنَا مَا خَلَقْتَ هَذَا بَاطِلًا سُبْحَانَكَ فَقِنَا عَذَابَ النَّارِ (191))

صدق الله العظيم

سورة آل عمران

Dedication

I dedicated this thesis to my Father who always supported in my life, my Mother who always give me the trust in myself, my Brothers and Sisters Who have provided me through moral and emotional Support In my life ,to All Friends and Teachers I dedicate this work With love

Acknowledgment

Prima facie, I am grateful to the Allah for having given me patience, strength, good health and wellbeing that were necessary to accomplish this work. My grateful thanks and deep appreciation to my Supervisor

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Abstract

In this study 15 soil samples were collected from Dallanj town where dividing the town into five parts (E, C, S, N and W) using GPS .Three samples were taken from each part. 500 grams of soil sample was weighed and closed in plastic containers for four weeks so as to have secular equilibrium for uranium. Our goal of this study was estimate Investigation of Radionuclides Soil Samples from South of Kordufan state (Western Sudan). Natural radioactivity concentrations in soil samples were measured by gamma-ray spectrometry a with a high purity germanium detector with 37% efficiency compared to the NaI (TI) detector .Calibration process carried out for gamma spectroscopy using MW652 as a reference source which recommended by the International Atomic Energy Agency (IAEA) including-source-Cs-137 and Co-60 with two energy levels . The study aimed to evaluate the levels of normal activity of radioactive elements .from the result was found that the concentration of potassium in the five parts in the range (325.66667 ± 259.954483-39.33333 ± 27) Bq/kg and the concentration of radium in the range (27.50000 ± 7.037755-13.13333 ± 1.404754) The average absorbed dose rate for each region was found to be 11.820793066 ± 2.849046 nGy / h of natural radioactivity of the region.

المستخلص

تم في هذه الدراسة أخذ 15عينة من تربة مدينة الدلنج بعد تقسيم المدينة إلي خمسة أجزاء (E,C,S,N and W) بإستخدام جهاز(GPS) ، وأخذت ثلاثة عينات من كل جزء ،وكان وزن كل عينة 500جرام. وقد تم وضع العينات في حاويات من البلاستيك لمدة أربعة أسابيع لكي يحدث إتزان لعنصر اليورانيوم .ولقد تم قياس النشاط الإشعاعي الطبيعي في عينات التربة بإستخدام جهاز قياس مطيافية غاما ذو كاشف الجرمانيوم عالي النقاء مع كفاءة 37% مقارنة مع كاشف ال NaI(Ti) وتمت معايرته بإستخدام MW (654) الذي أوصت به الوكالة الدولية للطاقة الذرية بإستخدامه كمصدر مرجعي بما في ذلك مصدري السيزيوم 137والكوبالت 60مع إثنين من مستويات الطاقة .

هدفت الدراسة إلي تقييم مستويات النشاط الطبيعي للعناصر المشعة. من خلال النتائج وجد أن تركيز البوتاسيوم في الخمسة أجزاء في المدى (27±39.33333-259.954483±325.66667) بيكريل /كجم و تركيز الريديوم في المدى(1.404754±13.13333-7.037755±27.50000) بيكريل /كجم أما تركيز الثوريوم (3.027100±24.76667 -15.521245±43.10333) بيكريل /كجم .وقد حسب متوسط معدل إمتصاص الجرعة لكل المنطقة وجد أنه يساوي (2.849046±11.820793066) نانوجراي / ساعة من النشاط الإشعاعي الطبيعي للمنطقة .وتعد هذه الدراسة أولية عن محتوى النشاط الإشعاعي في هذه المنطقة والتي يمكن إستخدامها في البيانات الأساسية اللازمة لبناء خرائط النشاط الإشاعي في السودان .

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LIST OF ABBREVIATION

Abbr.	Title
E	East
C	Center
S	South
N	North
W	West
K	Potassium
Th	Thorium
Ra	Radium
NORM	Naturally Occurring Radioactive Materials
OECD	Organization for Economic Cooperation and Development
HPGe	High Purity Germanium

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Human beings could be exposed to ionizing radiation through the emission of radionuclides in the contaminated soil .The internal hazard requires the incorporation of radioactive materials into the body through ingestion or inhalation. Once incorporated, the radionuclides are distributed in the body and irradiate living tissues at close quarters by alpha, beta particle emission, and gamma photons .The doses vary depending on the concentrations of the natural radionuclides of Uranium thorium, their daughter products and potassium, present in the soils and rocks, which in turn depend upon the local geology of each region in the world .In recent time, there has been an increasing interest in the study of radioactivity in various soil, oil sludge, sand, etc.

However, the study areas have not been assessed for radiation contamination, hence the need to investigate specific activity of Radon ,Uranium ,thorium in soil and water of the affected areas using Sodium Iodide detecting technique. Since Naturally Occurring Radioactive Materials (NORMs) can contaminate the environment and may pose a risk to human health [1]. It therefore becomes necessary to assess the level of enhancement of radionuclides of Radon, thorium and potassium in the soil.

1.2 Radioactivity

Radioactivity can be explained as a result sources. All these Emissions are capable of ionizing air with different of spontaneous emission of Particles or rays resulted from nuclear fission. This indicates that the chemical Elements are not internally immutable and can be Trans formed in to one another by emitting such rays .The property of spontaneous emission of rays is known as radioactivity. Detailed investigations revealed that ,these spontaneously

emitted Rays are of five kinds :alpha(a) ,particles ,beta(P) particles ,gamma(y) rays , x-rays and neutrons which are considered recently as a radiation sources . All these Emissions are capable of ionizing air with different power .The ionizing power has been utilized in radioactivity measurements and other related phenomena. Most spontaneous radioactive nuclei decayed by emitting these rays, in addition to capturing an orbital electron.

1.3 Classification of Radioactivity Elements

Radioactive elements that are presented in the environment can be classified into three groups according to their origin: territories, Cosmo genic and man-made. The territories radionuclides include the three primordial actinide Parent nuclides, ^{238}U , ^{232}Th and ^{235}U and their respective decay products and the long-lived primordial nuclides of elements coexisting in the environment with stable counter parts. The important members in this latter category include ^{40}K and. A unique feature of the three Primordial nuclides and their respective decay products is that each independent decay. Two most important natural decay series, the uranium (4n+2) and the thorium (4n) series are named after their parent nuclides .The third series headed by ^{235}U is called the actinide series (4n+3).If the radio nuclides in these series are left undisturbed, they attain a state of radioactive equilibrium in which the activity of each member of the series is the same as that of the parent [2].

1.3.1 Naturally Occurring Radioactive Materials

Naturally occurring radioactive materials (NORM) existing in soil could pose potential health risk especially if assisted by natural processes such as weathering, deposition and wind erosion. NORM can be found in many geological formation and may be brought to the surface during Oil and Gas drilling and abstraction .Human beings are exposed outdoors to the natural terrestrial radiation that originates predominantly from the upper 30cm of the soil [3]. Elevated radon and gamma exposures in dwellings are known to be

caused primarily by enhanced concentrations of naturally occurring radionuclide in building materials and soil. The use of soil as building material could therefore cause radiation exposure to man due to inhalation of gaseous daughters of Uranium and thorium decay series in the indoor air. It can also lead to an external exposure due to gamma radiation from the primordial radio nuclide present in the soil [4].

1.3.2 Man-Made Radioactivity

The equilibrium in the environment has become disturbed because of the expansion of technical civilization accompanied by intense application of chemicals.in the second part of our century violent growth of the population has increased food demand causing intensive use of fertilizer in agriculture .the continuous increase of applied chemicals has produced may problems due to its harmful influence on animals and human beings [5]. The natural radioactivity in the environment arises primarily from uranium and thorium, including the series of decay products, and from potassium .Today, the naturally occurring radioactivity is overlain by artificial radioactivity deposited with the debris from the atmospheric nuclear weapon tests during1950s and early 1960s. Most of this material, injected into the stratosphere, is deposited on a global scale according to a recognized latitudinal pattern. Possible emissions by the nuclear power industry, from reactors or processing plants and accidental releases can produce constituents similar to the radioactivity of the nuclear weapon fallout. However, the contributions from reprocessing, nuclear power plants or other sources, on a global scale, negligible and in the worst cases are detectable in limited areas in the vicinity of the source itself or on regional scale. Among the radioactive elements produced in atmospheric testing, only those of longer half-lives remain in ecosystem components at the present time [6]. Furthermore, the progressive development of the nuclear industry and other contaminating technologies and the widespread and ever increasing use of radiation in many

aspects of life has made it necessary to conduct radiological surveys to evaluate the background of natural radiation in order to detect the level of man-made contamination, assess its impact ,and implement appropriate countermeasures to protect the populace and the environment from radiation emergencies[7].Only radionuclides with half-lives comparable with the age of the earth or their corresponding decay products existing in terrestrial material such as $^{226}Ra,^{232}Th$ and^{40}K are of great interest .Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil and rock play an important role in radiation protection and measurement. Gamma radiation from these represents the main extern al source of irradiation to the human body and the concentrations of these radionuclides in soil are determined by the radioactivity of the rock and also nature of the process of the formation n of the soils. Therefore, radionuclides in soil generate a significant component of the background radiation exposure to the population. In Sudan, a program on environmental radioactivity monitoring was initiated in the late 1980s in the aftermath of the Chernobyl accident with the broad aim of producing a radiation map of the country and started in 1985.Since then a number of studies on environmental radioactivity measurements and assessments of public exposure have been conducted. The present study is a continuation of the national program on environmental radioactivity monitoring to contribute towards the broader aim of producing a radiation map for the country to be a reference against any radiological accident of regional or global dimension [8] .

1.4 Problem

The problem of search is that the radionuclides are not uniformly distributed, their distribution in the soil plays an important role in protection against radiation and measurement. Therefore, the researcher wanted to know the presence of radionuclides in the soil samples of South Kordufan state (Dallanj locality).

1.5 Objectives

The objective in this thesis was divided in two types

1.5.1 General Objective

To identify external exposure from terrestrial radiation in the study area and added to radiation map of the Country.

1.5.2 Specific Objectives

1. To assess the activity concentration of the natural radio nuclides in Dallanj Area locality ted in South Kordufan State, central Sudan.

2. To compare corresponding dose rates with the available data in the literature.

1.6 Thesis Lay Out

This thesis Included five Chapter. Chapter one Introduction, Chapter Two Literature Review, Chapter Three Theoretical Background, Chapter Four Material and Method and Chapter Five Results Discussion and Conclusion.

CHPTER TWO

LITERATURE REVIEW

2.1 Previous of Studies

In reviewing of literature in locally and internationally there are some published studies regarding the Measurement of some radioactive elements in Soil Samples by many researchers who they are mentioned below:

Aman Jeet, et al (2017). Have been determined the natural radioactivity levels in surface Soil samples collected from the historical city Panipat and its surrounding areas. By means gamma ray spectroscopy activity concentrations for ^{238}U (range from 14.82±0.26 to 42.82±0.84 Bq/kg), ^{232}Th (from 12.94±0.32 to 43.48±0.96 Bq/kg) and ^{40}K (from 238.05±0.28 to 348.50±0.95 Bq/kg). Radium equivalent activities are calculated to be in the range of 82.24-108.49 Bq/kg with an average value of 92.21 Bq/kg. Absorbed dose rates in air outdoors are measured in the range of 32.01-56.47 nGy/h with an average value of 44.16nGy/h. The corresponding effective dose rates (indoor and outdoor) 44.16nGy/h. The corresponding effective dose rates (indoor and outdoor) are calculated to be in the range of 0.09 to158 mSv/y and 0.039-0.069 mSv/y respectively. The internal and external hazard index varies from 0.234 to 0.339 and 0.207 to 0.286 respectively. The activities of radium equivalent in all the soil samples are lesser than the limit (370 Bq/kg) recommended in the Organization for Economic Cooperation and Development (OECD) report and the annual effective dose was within the safe limit of 1 mSv/y.

Anekwe, et al(Jun 2016) The activity concentrations of radionuclides of $^{226}_{.}Ra,\ ^{232}_{.}Th$ and $^{40}_{.}K$ were determined in soil sample collected from crude oil and gas environment in a selected part of the Niger Delta region of Nigeria using NaI detector based on gamma Spectroscopy .

The activity concentration of $^{226}_{.}Ra,\ ^{232}_{.}Th$ and $^{40}_{.}K$ in field1 ranged from15.87±6.6to48.08±4.63,38.29±1.82to83.71±2.39,116.50±7.62to243.39±10.73respectively.The activity concentration of $^{226}_{.}Ra,\ ^{232}_{.}Th$ and $^{40}_{.}K$ in field 2 ranged from 14.02±1.60to48.08±4.63,47.79±0.75to76.45±5.03 ,0.67 ±41.60 to227.65±14.14respectively.the activity concentration of $^{226}_{.}Ra,\ ^{232}_{.}Th\ and\ ^{40}_{.}K$ in field 3 ranged from from36.38±1.62 to101.83±9.85, 46.42±2.92 to 81.55±2.62, 125.17±6.22 to214.90±8.09respectively.

The activity concentration of $^{226}_{.}Ra,\ ^{232}_{.}Th$ and $^{40}_{.}K$ in field 4 ranged from10.54±2.62to62.33±4.40,50.69±2.05to64.44±186,115.69±3.59to252.53± 13.22 respectively. The activity concentration of $^{226}_{.}Ra,\ ^{232}_{.}Th$ and $^{40}_{.}K$ in field 5 ranged from 9.96±1.04 to 101.83±6.5, 35.92±1.71 to 85.24±4.25, 107.60±5.13 to274.34±11.42 respectively. In general, the average activity concentrations for the identified Radionuclides of $^{226}_{.}Ra,\ ^{232}_{.}Th$ and $^{40}_{.}K$ for soil samples ranged from 29.30 Bqkg^{-1} to 62.06 Bqkg^{-1}, 53.63 Bqkg^{-1} to 61.15 Bqkg^{-1} and 145.66 Bq$kg^{-1}$to 193.37 Bqkg^{-1} respectively. At different points, the specific activity concentration exceeded that of the control and world standard values, suggesting that the enhancement is as result of oil and gas activities. It then means that the host communities and oil companies operating in the area should take precautionary measure to curtail the possible health effect through consumption of farm produce from those areas.

Alshfia Hashiem (2015) .Study 40 soil and rock samples were collected from eight locations (A, B, C..... G) F present tow location,500 grams of soil and rock sample was weighed and closed in plastic containers for four weeks so as to have secular equilibrium for uranium. Our goal of this study

was estimate Investigation of Uranium-238 , Potassium -40 and Thorium-232 Level in Soil and Rock Samples from North and South of Kurd fan state(Western Sudan). Natural radioactivity concentrations in soil and rock samples were measured by gamma-ray spectrometry using Nal (TI). Calibration process carried out for gamma spectroscopy using MW652 as a reference source which recommended by the International Atomic Energy Agency (IAEA) including-source-Cs-137 and Co-60 with two energy levels The concentration of K-40 in location A was found to be range (347.78- 51.67)Bq/kg in location B was found to be range (169.90-125.54)Bq/kg in location C was found to be range (152.14-34.47)Bq/kg in location D was found to be range (396.26-49.90)Bq/kg in location E was found to be range (168.70-127.70)Bq/kg in location F was found to be range(432.5-200.1)Bq/kg and in location G was found to be range (684.41- 347.86)Bq/kg .The concentration ofU-238 in location A was found to be range (483.133-19.4)Bq/kg in location B was found to be range (50.24-24.94)Bq/kg in location c was found to be range (69.11 -10.58 Bq/kg in location D was found to be range (52.50-15.06)Bq/kg in location E was found to be range (56.66-49.6)Bq/kg in location F was found to be range (46.01-19.40)Bq/kg in location G was found to be range (180.36-116.15)Bq/kg and The concentration ofTh-232 in location A was found to be range (327.8-40)Bq/kg in location B was found to be range(88.62-40.04) Bq/kg in location c was found to be range (1 19.05-14.04)Bq/kg in location D was found to be range(51.62-16.96)Bq/kg in location E was found to be range (43.89 -39.84) Bq/kg in location F was found to be range (46.18-24.40)Bq/kg and in location G was found to be range (201.05-137.34)Bq/kg . The result explain that the activity concentration were Higher than the previous studies. There is need to expand the program to cover the whole region which requires effort to be made. We recommend to make more work in this field to make a complete database line on environmental and

natural radioactivity, also other researches on some region area by studying other environmental compartment such as foodstuff, drinking water, radon...

Trinh Van Giap, et al (2013) Setting up data base of natural radiation background serves for planning socio –economics development in a province as well as the whole country and estimating annual effective dose of population Beside external irradiation dose caused by the natural radioisotopes in the series $^{238}U, ^{232}Th$ and ^{40}K in soil population has been received internal dose caused by the above Radio isotopes taken in the body from several ways. In order to complete the database of national radiation background and go to estimate annual effective radiation dose of population in the whole country, this project focus to carry out the works as following: (i) Setting up database of radiation background in the whole country: 150 Soil samples that collected in the districts of 46 provinces have been analyzed. The average activity concentration of $^{238}U, ^{232}Th$ and ^{40}K are 37.86 Bq/kg, 58.88 Bq/kg and 462.78 Bq/kg, respectively. The outdoor, indoor and total annual effective doses are calculated: 0.036±0.087 mSv; 0.488±0.202 mSv and 0.576± 0.240 mSv, respectively. (ii) Setting up database of radiation background of province Ninh Thuan and Quang nam: The detailed database of radiation background of all villages in Ninh Thuan and Quang Nam has been established. 84 soil samples in Ninh Thuan and 311 in Quang Nam were collected for analyze. The indoor and outdoor radon Concentration at sampling positions has been measured. The average activities of $^{238}U, ^{232}Th$ ^{40}K , and ^{222}Rn isotopes in Ninh Thuan are reported: 33.50 Bq/kg, 55.43Bq/kg, 701.12Bq/kg and 12.1 $^{Bq}/_{m^3}$, 9.5 $^{Bq}/_{m^3}$ respectively. The outdoor, in door and total annual effective doses in Ninh Thuan are calculated: 0.095±0.029 mSv; 0.529±0.162 mSv and 0.624± 0.382 mSv respectively. The average activities of $^{238}U, ^{232}Th$ ^{40}K , and ^{222}Rn isotopes in Quang Nam are reported: 44.47 Bq/kg, 52.68 Bq/kg, 459.33 Bq/kg and 18.0 $^{Bq}/_{m^3}$ the outdoor, indoor and total annual effective doses are

calculated: 0.086±0.039 mSv; 0.482±0.216 mSv and 0.568± 0.254 mSv, respectively. The digital maps of radiation background on scale of whole country as well as the detailed for Ninh Thuan and Quang Nam provinces are established using Map in for software .The data of activity of $^{238}U, ^{232}Th, ^{40}K, ^{137}Cs$,and ^{222}Rn as well as the data of soil parameter at sampling position is founded in the map.

Rania Hamid et al (2012) study in Alkhwai area aiming at thorough investigations of natural environmental radioactivity. Considerable variation in soil radioactivity with location is observed. Results show that the average concentrations of $^{226}Ra, ^{232}Th$ and ^{40}K 238U,in soil were found to be 14.79± 2.43,20.71±3.59 and 162.09±21.19 respectively and have the range 10.0 - 21.98, 13.89 -28.55 and from 113.5to 219.45 respectively It is observed that there is strong correlation between Uranium -thorium. Between Uranium- Potassium and Thorium - Potassium. The average value of calculated gamma radiation dose rate in Alkhwai district was estimated to be (26.10) nGy h^{-1}comparable with the world average (59 nGy/h). The average dose from gamma radiation dose rate to an individual assuming a tropical rural setting is estimated to be 32.03μ.Sv/year ,which is considered to be within the normal range for doses from natural sources. Geological features of Sudan are needed to establish a more comprehensive database on the Relationship between gamma radiation dose and geological-soil information.

CHAPTER THREE

THEORETICAL BACKGROUND

3.1 Soil Analysis

The purpose of soil analysis is to evaluate the radioactive elements that are included in their components to monitor changes in the environment .This information is necessary to provide protection against pollution, to avoid the transfer of undesirable levels of certain elements into the environment and to ensure the safety of the products of that soil. Regular soil analysis should be carried out, every 3-5 years', should be undertaken as a vital part of good management practices [9].

3.2 Soil Radioactivity

Natural radioactivity is wide spread in the earth's environment and it exists in various geological formations in soils, rocks, plants, water and air. The main radioactivity materials are long lived radio nuclides such as $^{238}U, ^{232}Th$ and ^{40}K known as Natural Occurring Radionuclide Materials. Human beings exposed to ionizing radiation throw external sources (e.g. Terrestrial radiation and cosmic radiation) which irradiate the body with gamma photons whereas the internal hazard requires the incorporation of radioactivity. materials into the body through ingestion or inhalation Estimates of total radiation dose to the world population have shown that about 96% is from natural radioactivity and terrestrial gamma dose originated from NORM depend essentially on geological conditions. Hence, concentration of natural radioactivity in soil varies from one region to another in the world Soil acts as a source of continuous radiation exposure to human and as.a medium of migration for transfer of radionuclide's to the biological systems. Hence, causes the radiological contamination in the environment.

Hence, the soil radioactivity is usually important for the purpose of establishing baseline data for future radiation impact assessment, radiation protection and exploration [10] .

3.3 Natural Sources of Radiation

While many naturally occurring elements have radioactive isotopes, only potassium, and the uranium and thorium decay series, have radioisotopes that produce gamma rays of sufficient energy and intensity to be measured by gamma ray spectrometry. This is because they are relatively abundant in the natural environment. Average crustal abundances of these elements quoted in the literature are in the range 2-2.5% K, 2-3 ppm U and 8-12 ppm Th. Potassium 40 is the radioactive isotope of potassium, and occurs as 0.012 percent of natural potassium .This isotope decays to Argon 40 with the emission of gamma rays with energy 1.46 MeV. Since. Potassium 40 occurs as a fixed proportion of K in the natural environment, these gamma rays can be used to estimate the total amount of K present .The half-life of Potassium 40 is1.3×10^{9}years.Uranium occurs naturally as the radioisotopes Uranium 238 and Uranium 235 which give rise to decay series that terminate in the stable isotopes ^{206}Pb and ^{207}Pb respectively. The half-lives of Uranium 238 and Uranium 235 are 4.46×10^{9} and 7.13×10^{8} years, respectively. Thorium occurs naturally as the radioisotope ^{232}Th which gives rise to a decay series that terminates in the stable isotope ^{208}Pb . The half-life of ^{232}Th is 1.39×10^{10} years. Neither ^{238}U , nor^{232}Th emit gamma rays, and gamma ray emissions from their radioactive daughter products are used to estimate their concentrations [11].

3.3.1 Potassium

Potassium is a soft, silver-white metal. An important constituent of soil, it is widely distributed in nature and is present in all plant and animal tissues. Potassium is one of the most reactive metals in nature, and it forms a number

of compounds that have many commercial uses.Potassium-40 is a naturally occurring radioactive isotope of potassium. (An isotope is a different form of an element that has the same number of protons in the nucleus but a different number of neutrons).Two stable (nonradioactive) isotopes of potassium exist, p0tassium-39 and potassium-41. Potassium-39 comprises most (about 93%) of naturally occurring potassium, and potassium-41 accounts for essentially all the rest. Radioactive postassium-40 comprises a very small fraction (about 0.012%) of naturally occurring potassium [12].

3.3.2 Thorium

Thorium is a soft, very ductile, silver-grey, heavy, metallic element (Th) of the actinide series of elements. It is slightly radioactive. It is found in small amounts in most rocks and soils, where it is about three times more abundant than uranium. Soil commonly contains an average of around six parts per million of thorium. Thorium exists in nature in a single isotopic form, ^{232}Th, which the Earth) .Thorium oxide (ThO2), also called thoria , has one of the highest melting points of all oxides (3300°C) and thorium metal turnings ignite and burn brilliantly with a clear white light. Because of these properties, thorium has historically found applications in light bulb elements, lantern mantles, arc-light lamps, welding electrodes and heat-resistant ceramics. Glass containing thorium oxide has a high refractive index and dispersion, and is used in high quality lenses for cameras and scientific instruments. Thorium's use in most of these applications has generally decreased since the 1980s due to concerns about its naturally occurring radioactivity [13].

3.3.3 Uranium

Is a silvery-white metallic chemical element in the actinide series of the periodic table, with atomic number 92.The uranium nucleus binds between 141 and 146 neutrons, establishing six isotopes (U-233 through U-238), the

most common of which are and uranium-235(143neutrons).All isotopes are unstable and uranium is weakly radioactive, uranium lias the second highest atomic weight of the naturally occurring elements, lighter only than p.utonium-244 [14].

The element uranium is very widely distributed throughout the crust of the earth .Almost all type of rocks contains at least some amount of uranium. Natural waters including sea water also contain uranium in very small quantity. It is estimated that the average concentration of uranium in earth's crust is about 3gms per tonne of rock and in sea water, it is about 1gm per thousand tonnes. About 1.3 x 10^{14} tonnes of uranium exist in the earth's crust . The element uranium with Atomic number 92 is positioned last in the periodic table amongst naturally occurring elements. It is radioactive and its atomic weight is 238 . Uranium is known to occur in three isotopic forms in nature. Their approximate relative natural abundance is as follows . U238 –99.27 *%* , U235 – 0.724% and U234- 0006 % the proportion of these isotopes is constant in nature regardless of the type of mineral or deposit in which the uranium is found. (Another isotopic form of uranium is U233, which is artificially produced in nuclear reactors).

Uranium does not occur in native state. It has affinity for oxygen and occurs in nature mostly as oxides, phosphates, sulphates, van dates, arsenates, carbonates and silicates . There are about more than 100 uranium bearing minerals known. But of these, only a few occur in economic concentration for commercial purpose. Uraninite, pitchblende and davidite are some of the primary uranium minerals. These minerals are refractory in nature. Naturally occurring some common secondary uranium min-erals are autonite and meta-autonite, torbernite and meta- torbernite, carnotite, uranophane etc. These minerals are normally bright and occur in different colour shades. In nature, uranium ions occur normally in 4 and 6 oxidation states. Sometimes the 5 oxidation state does occur in some environments but it is probably transitory. In hexavalent state, uranium is easily soluble in water [15].

3.4 Radioactive Decay

The atomic nuclei of some isotopes have a surplus of energy, are unstable, and disintegrate to form more stable nuclei of a different isotope. This process is accompanied by the emission of particles or energy, termed nuclear radiation. Nuclides with this feature are called radionuclides, and the process is called nuclear decay or disintegration.

3.4 .1 Methods of Radioactive Decay

Rather than considering what happens to individual nuclei it is perhaps easier to consider a hypothetical nucleus that can undergo many of the major forms of radioactive decay.

Didn't know what they really were. We found out that one type of these radiations had a double positive charge and it was not until sometime later that we learnt that they were in fact nuclei of helium-4. In the initial period of their discovery this form of radiation was given the name alpha rays (and the other two were called beta and gamma rays), these terms being the first three letters of the Greek alphabet. We still call this form of radiation by the name alpha particle for historical purposes. Calling it by this name also contributes to the specific jargon of the field and leads outsiders to think that the subject is quite specialized! But notice that the radiation really consists of a helium-4 nucleus emitted from an unstable larger nucleus. There is nothing strange about helium since it is quite an abundant element on our planet. So why is this radiation dangerous to humans? The answer to this question lies with the energy with which they are emitted and the fact that they are quite massive and have a double positive charge. So when they interact with living matter they can cause substantial destruction to molecules which they encounter in their attempt to slowdown and to attract two electrons to become a neutral helium atom. An

example of this form of decay occurs in the uranium-238 nucleus. The equation which represents what occurs is:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He \qquad (3.1)$$

Here the uranium-238 nucleus emits a helium-4 nucleus (the alpha particle) and the parent nucleus becomes thorium-234. Note that the Mass Number of the parent nucleus has been reduced by 4 and the Atomic Number is reduced by 2 which is a characteristic of alpha decay for any nucleus in which it occurs [16].

3.4 .1.1 Alpha Decay

Alpha decay is the emission of alpha particles (helium nuclei) which may be represented as either $^{4}_{2}He$ or $^{4}_{2}\alpha$. When an unstable nucleus ejects an alpha particle, the atomic number is reduced by 2 and the mass number decreased by 4. An example is uranium-234 which decays by the ejection of an alpha particle accompanied by the emission of a 0.068 MeV gamma.

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He \qquad (3.2)$$

The combined kinetic energy of the daughter nucleus (Thorium-230) and the α particle is designated as KE. The sum of the KE and the gamma energy is equal to the difference in mass between the original nucleus (Uranium-234) and the final particles (equivalent to the binding energy released, since m = BE). The alpha particle will carry off as much as 98% of the kinetic energy and, in most cases, can be considered to carry off all the kinetic energy.

3.4 .1.2 Beta Decay

Beta decay is the emission of electrons of nuclear rather than orbital origin. These particles are electrons that have been expelled by excited nuclei and may have a charge of either sign. If both energy and momentum are to be conserved, a third type of particle, the neutrino, +, must be involved. The neutrino is associated with positive electron emission, and its antiparticle, the

antineutrino, - , is emitted with a negative electron. These uncharged particles have only the weakest interaction with matter, no mass, and travel at the speed of light. For all practical purposes, they pass through all materials with so few interactions that the energy they possess cannot be recovered. The neutrinos and antineutrinos are included here only because they carry a portion of the kinetic energy that would otherwise belong to the beta particle, and therefore, must be considered for energy and momentum to be conserved. They are normally ignored since they are not significant in the context of nuclear reactor applications Negative electron emission, represented as ${}_{-1}^{0}\mathrm{e}$, ${}_{-1}^{0}\beta$, or simply as e^{-} or β^{-} . Effectively converts a neutron to a proton, thus increasing the atomic number by one and leaving the mass number unchanged. This is a common mode of decay for nuclei with an excess of neutrons, such as fission fragments below and to the right of the neutron-proton stability. An example of a typical beta minus-decay reaction is shown below.

$$ {}_{53}^{131}\mathrm{I} \rightarrow \quad {}_{54}^{131}\mathrm{Xe} + \quad {}_{-1}^{0}\mathrm{e} \qquad (3.3) $$

Positively charged electrons (beta-plus) are known as positrons. Except for sign, they are nearly identical to their negatively charged cousins. When a positron, represented as ${}_{+1}^{0}e$, ${}_{+1}^{0}\beta$, or simply as e^{+}, β^{+} is ejected from the nucleus, the atomic number is decreased by one and the mass number remains unchanged. A proton has been converted to a neutron. An example of a typical positron (beta-plus) decay is shown below [17].

$$ {}_{11}^{22}\mathrm{Na} \rightarrow \quad {}_{10}^{22}\mathrm{Ne} + {}_{+1}^{0}\mathrm{e} \qquad (3.4) $$

3.4 .1.3 Gamma Decay

Gamma decay involves the emission of energy from an unstable nucleus in the form of Electromagnetic radiation. You should remember from your high school physics that electromagnetic radiation is the biggest physical phenomenon we have so far discovered. The radiation can be characterized in

terms of its frequency, its wavelength and its energy. Thinking about it in terms of the energy of the radiation very low energy electromagnetic radiation called radio waves, infra-red radiation at a slightly higher energy, visible light at a higher energy still, then ultra- violet radiation and the higher energy forms of this radiation are called X-rays and gamma-rays . Also remember that these radiations form what is called the Electromagnetic Spectrum. Before proceeding it is useful to pause for a moment to consider the difference between X-rays and gamma-rays .These two forms of radiation are high energy electromagnetic rays and are therefore virtually the same. The difference between them is not what they consist of but where they come from. In general we can say that if the radiation emerges from a nucleus it is called a gamma-ray and if it emerges from outside the nucleus from the electron cloud for example, it is called an X-ray .One final point is of relevance before we consider the different forms of gamma-decay and that is what such a high energy ray really is .It has been found in experiments that gamma-rays (and X-rays for that matter!)Sometimes manifest themselves as waves and other times as particles .This wave particle duality can be explained using the equivalence of mass and energy at the atomic level .When we describe a gamma ray as a wave it has been found useful to use terms such as frequency and wavelength just like any other wave .In addition when we describe a gamma ray as a particle we use terms such as mass and electric charge. Furthermore the term electromagnetic photon is used for these particles. The interesting feature about these photons however is that they have neither mass nor charge! There are two common forms of gamma decay:

(a)Isomeric Transition

A nucleus in an excited state may reach its ground or unexcited state by the emission of a gamma ray. An example of this type of decay is that of technetium-99m-which by the way is the most common radioisotope used for diagnostic purposes today in medicine .The reaction can be expressed as:

$$^{99}_{43}Tc \rightarrow {}^{99}_{43}Tc + \gamma \quad (3.5)$$

Here a nucleus of technetium-99 is in an excited state that is it has excess energy. The excited state in this case is called a metastable state and the nucleus is therefore called technetium-99m (m for metastable). The excited nucleus loses its excess energy by emitting a gamma-ray to become technetium- 99.

(b)Internal Conversion

Here the excess energy of an excited nucleus is given to an atomic electron, e.g. a K-shell electron [16].

3.4 .2 Radioactive Decay Low

The rate of decay (number of disintegrations per unit time) is proportional to the number of radioactive nuclei (N) in the sample:

$$\frac{dN}{dt} \propto -N \quad (3.6)$$

The negative sign signifies that N is decreasing with time. λ Is called the decay constant or probability per unit time that a given radioactive nucleus will decay. Equation (3.6) can be integrated to give:

$$N(t) = N_o e^{-\lambda t} \quad (3.7)$$

Here N_o = number of radioactive nuclei at t= 0.

3.4 .3 Activity And Half-Life

Activity is Number of disintegrations per unit time

$$A(t) = N(t) = N_o e^{-\lambda t} = A_o e^{-\lambda t} \quad (3.8)$$

Substituting $N_o = \frac{N_o}{2}$ and $t = t_{\frac{1}{2}}$ into Eq (2.8) gives

$$t_{\frac{1}{2}} = \frac{ln2}{\lambda} \qquad (3.9)$$

$t_{\frac{1}{2}}$ Is half-life of each radionuclide which it is the time for half – life radioactive nuclei in the sample to decay. This has the same exponential fell off with time as N (t).

3.4 .4 Decay Chanains

When nuclei A decay into stable nuclei B, the number of each nuclei present at time t is:

$$N_A(t) = N_A(0)e^{-\lambda t} \text{ And } N_B(t) = N_A(0)\left(1 - e^{-\lambda t}\right) \qquad (3.10)$$

Where only nuclei A are present initially. The number of nuclei A (parent nuclei) decreases with time, while the number of nuclei B (daughter nuclei) increases from zero and approaches$N_A(0)$. A St λ_t All the parent nuclei eventually become daughter nuclei. The total number of nuclei is constant:

$$N_A(t) + N_B(t) = N_A(0) \qquad (3.11)$$

If nuclei B are also radioactive, the above equations do not apply, since, as nuclei B are produced, they also decay. The daughter nuclei of B may also be radioactive and a decay chain is set up:

A >> B >> C >> etc.

3.4 .5 Decay Series

The number of atoms of each member of a radioactive series at any time (t) can be obtained by solving a system of differential equations, with relates each product A,B, c,... with corresponding disintegration constants λ A, λ B, λ C,...etc. Each series begins with a parent nuclide A, which has a rate of transformation

$$\frac{dN_A}{dt} = -\lambda_A N_A \qquad (3.12)$$

The second nuclide in a radionuclide series will be produced at a rate of $\lambda_A N_A$ due to the transformation of N_A , but as soon as atoms of A fexist, they also can undergo transformation if they are radioactive. Thus, the rate of change of atoms of $N_B$is the rate of production minus the rate of removal $of\ N_B$ atoms, or:

$$\frac{dN_B}{dt} = \lambda_A N_A - \lambda_B N_B \qquad (3.13)$$

Where λ_A and λ_B are the decay constants ofN_A andN_B, respectively. Substituting Eq. (3.12) into (3.13) and rearranging yields:

$$\frac{dN_B}{dt} + \lambda_B N_B - \lambda_A N_A \ \ e^{-\lambda tA} \qquad (3.14)$$

The solution of Eq. (2-14) is:

$$N_B = N_A\left(e^{-\lambda A\ tA} - e^{-\lambda B\ tB}\right) \qquad (3.15)$$

And it can be verified by substitution into Eq. (3-14). In Eq. (3-15), the first term on the right reflects the production of N_B by decay of N_A and the loss of $N_B$by decay .The second term on the right represents the contribution from any initial $N_B$in the system. If λB is zero, that is,$N_B$is a stable nuclide.

3.5 High Purity Germanium Spectrometer

3.5 .1 Detector Type

The first gamma ray spectrometer is the one dimensional High Purity Germanium spectrometer . The detector type is High Purity Germanium, which is a semiconductor that must be temperature controlled with liquid Nitrogen to 77 K due to excessive leakage current at higher temperatures because. The issue with leakage current only applies during operation, HPGe detectors can be stored at room temperature as long as there is no contamination in the Germanium from residual vapors. The Cal Poly HPGe used in this experiment is always kept at liquid Nitrogen temperatures in order

to mitigate this risk . One of the requirements for detecting high energy gamma rays is that the detector must have a depletion depth of at least 10 mm in order to absorb the energy .Germanium crystals can achieve this depth, but they must have a level of impurity of 10^{10}atoms/cm^3 in order to reach a resistance high enough. This is an extremely low impurity level, which gives the detector its name of high purity Germanium . These requirements for low operation temperature retaining purity of the Germanium are the two primary challenges for integration on a spacecraft. The operating temperature range of HPGe detectors is usually between 72 K and120 K, although the sensitivity efficiency decreases as temperatures decreases. The two primary options for attaining this temperature range for operation is through using active cryogenics or passive cooling through the use of sun shielding and radiators. Choosing between active and passive cooling is based on the application of the detector. For example, an application that requires the HPGe detector to point at the sun to measure radiation might need to use active cooling because passive cooling might not be adequate for reaching the correct temperature. On the other hand, an application that requires a long duration test for each sample may make the use of cryogenics unpractical because it would need to be used all the time. Additionally, HPGe detectors have the challenge of retaining purity by protecting against contaminants. First, the launch environment poses a major challenge due to the high g-loading and vibrations. The detector must be adequately isolated and designed in order to ensure that loose particles moving around during launch do not contaminate the Germanium crystal. The other contaminant in the space environment is from cosmic rays with charged particles and neutrons. When exposed for long periods of time, this radiation damages the detector and causes a loss in resolution. The damage varies with operation temperature and whether the crystal is a p-type or n-type semiconductor. Because of this problem, HPGe detectors must additionally be designed for the duration of the mission. Short duration missions do not need to account for this as much as long term

interplanetary missions that last several years. The 2001 Mars Odyssey mission, which used an HPGe detector over a long period, preserved the life of the crystal by periodically raising its temperature to 100°C to anneal the radiation damage.

3.5 .2 Configuration

The thermal requirements of the HPGe detector severely limit the configuration options for gamma ray spectroscopy experiments. Each detector needs its own bulky vacuum enclosure for the liquid nitrogen cooling system, so it is extremely difficult to incorporate additional HPGe detectors to make arrays or add anticoincidence shielding. Because of this and the high cost of each HPGe detector and cooling system, this experiment used a single HPGe detector in coaxial orientation. The coaxial shape is a cylinder with a hole for the electrical connection cut out in the middle. The detector is 45 mm in diameter and 46 mm high, and the active volume of the crystal is 68 cm^3 . The crystal cylinder is a p-type semiconductor, while the outer surface is a thin, lithium diffused n-type semiconductor layer that serves as one n^+ electrical contact. The other electrical contact is a p^+ contact made on the inner surface. Additionally, the spectrometer is surrounded by 0.102 meter thick bricks of low-radioactivity lead shielding.

3.5.3 Electronic Hardware

The electronic hardware for the HPGe spectrometer is a package purchased from Canberra Instruments, Model PCA-3 Third Generation Personal-Computer Analyzer. The signal from the detector goes to a card connected to an IBM computer. This card consists of a microprocessor, memory, and an internal A/D converter. The microprocessor runs at 10 MHz and the memory consists of about 65,000 bytes . Additionally, the maximum number of counts that can be stored to a histogram is 3 bytes of data, or about 16 million counts. The internal A/D converter is a 100 MHz Wilkinson, which has a conversion gain capable of 8K to 256. This card provides the data to the software on the computer. The advantages of this system are that all of the hardware is in one place and the A/D converter can be controlled by the computer [17].

CHAPTER FUOR

MATERIAL AND METHODOLOGY

4.1 The Study Area

The study area is located in South Kordufan State in the Western part of Sudan is located on the circle of width 12.045941°N and latitudes 29.651048° E. The exact locations are show in (figur**e** 4.1) shows the location and appendix 1 shows the names with their coordinates in concentration of radio nuclide.

4.2 Sample Collection

Soil samples were collected from various sites of the Dallanj town South Kordufan state (Western Sudan) see figur**e** (4.1) .which is showing high radiation background. This sample were collected from north, east, south, west and central town. The total of 15 samples were collected. Soil samples from the top layer were collected from different depths 10 cm, 20 cm and 40 cm each. These samples were then transferred to the powder and processed into plastic containers.

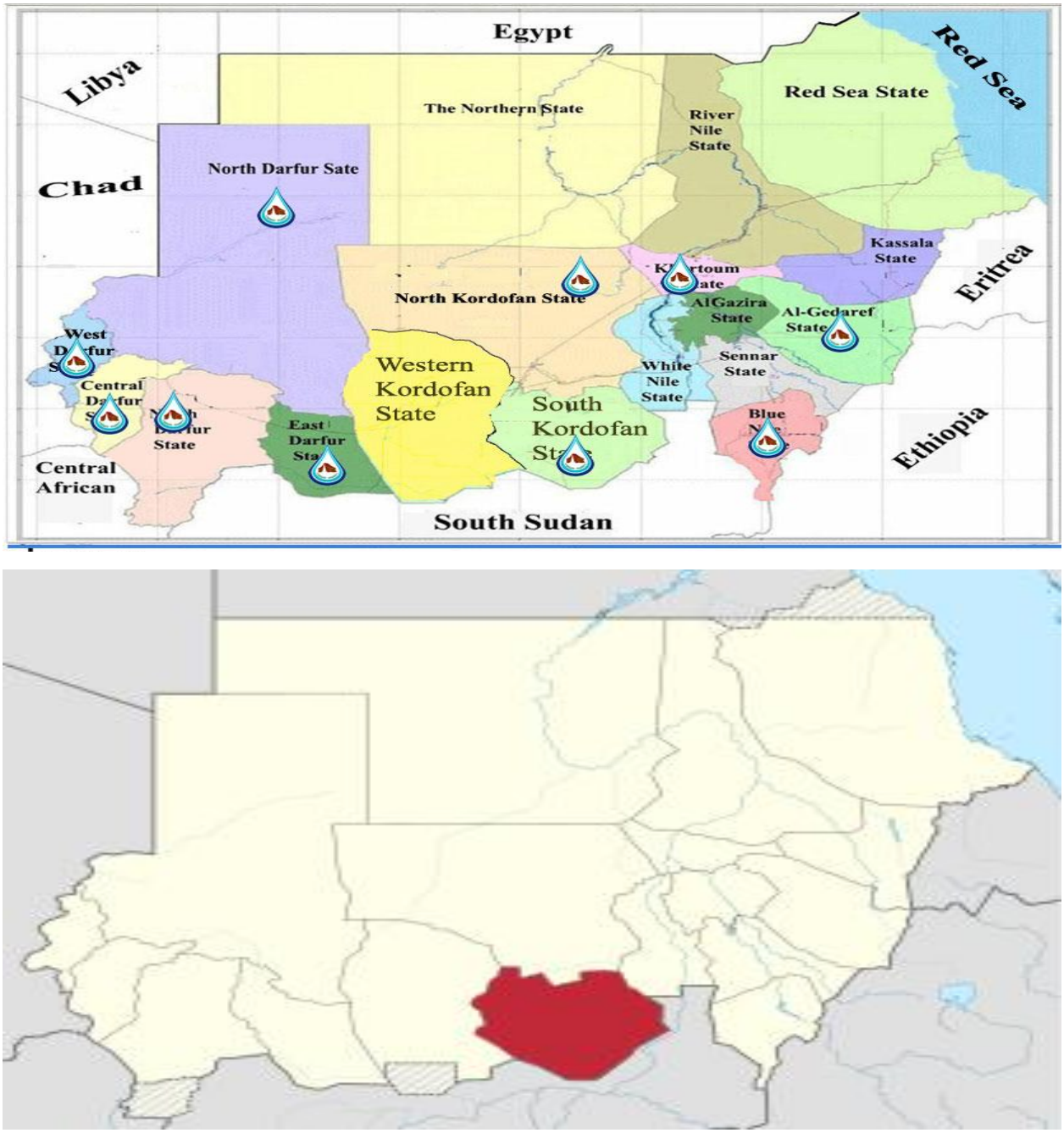

Figure 4.1 Study Area

4.3 Sample Preparation and Measurement

The samples after crushing were performed in the laboratories of the Ministry of Higher Education and scientific Research (Sudan Atomic Energy Commission (Radiation and Nuclear Safety Institute)) and weighed in a digital weighing balance with a precision of ± 0.0lg. After pretreatment, the samples were sealed in 500 ml Marinelli beakers and stored for more than four weeks before counting, in order to allow of secular equilibrium of radiation series with its short-lived progeny to take place before analysis with Gamma-Spectrometer(shown in figure 4.2) .The gamma-counting equipment was a Canberra vertical High purity germanium (HpGe) crystal detector and coupled to a Canberra Multichannel Analyzer (MCA) computer system.

The quantification of radionuclide present in soil samples was obtained through accurate energy. The (MCA) was calibrated so as to display gamma photo peaks in the applied energy range for radionuclide of interest identified with reliable regularity. The counting time was 36000 s. Each sample was placed onto detector and measured for at least three hours. The radio nuclide concentration was determined.

Figure 4.2 Gamma-Spectrometer

4.4 Marinelli Beakers

Environmental samples of low-level radioactivity are often measured in Marinelli beakers (shown in figure 4.3). They made from chemically resistant polypropylene and are available for .gamma spectral analysis of a variety of liquid solutions or solid samples. These Mlarinelli beakers are advantageous for the following reasons:

1. Higher counting efficiencies.
2. Lighter weight.
3. It requires mini storage space.
4. Seamless, thin-wall construction eliminates leakage and minimizes gamma ray Attenuation.

Figure 4.3 Marinelli Beakers

4.5 Calibration

The methods based on gamma-ray measurements are frequently applied for the determination of activity or for nuclide identification. For precise determinations these methods must be validate in conformity to national, regional or international standards or in the absence of the above on the base of validated calibration methods [19].The validation of the measurement method is based on the determination of the performance parameters of the

global method. These parameters are obtained during the development of the method and the inter-laboratory study, or by obeying internal validation protocols [20] [21]. As it is known, the calibration of a gamma-ray spectrometry system evolves three main aspects:

(1) The energy as a function of the number of the channel.

(2) FWHM as a function of the number of the channel.

(3) The efficiency as a function of the energy correlated with the acquisition geometry of the radiation.

In addition to these aspects, in the case of applied geometries the correlation with the coincidental standard (TCC) can be made. The energy as a function of the number of the channel and the FWHM as a function of the number of the channel do not interfere with the initial calibration in efficiency of the measuring system [22].

4.5 .1 Energy Calibration

If a gamma spectrometer is used for identifying samples of unknown composition, its energy scale must be calibrated first. Energy calibration sources was performed using cesium -137 or cobalt-60. Because the channel number is proportional to energy, the channel scale can be converted to an energy scale. If the size of the detector crystal is known, one can also perform an intensity calibration ,so that not only the energies but also the intensities of an unknown source or the amount of a certain isotope in the source can be determined .

4.5.2 Efficiency Calibration

In general, the analysis of a sample by gamma spectroscopy is considered to be non -destructive, certain sample/source preparation steps are essential for precise measurements. For example , it is necessary that the sample to be completely homogenized and measurement are carried out in the same

geometry on used in the efficiency calibration .Ideally, the calibration source and the samples to be measured should have the same chemical composition and density ,this is not the case, correction must be made for differences in the degree of self- attenuation ,corrections may also have to be made for coincidence summing, which occurs with radionuclide which remit gamma ray cascade and which is particularly important for low source-detector resistances. To suppress background radiation and this improve sensitivity, a passive shield made from 'aged' lead must surround all gamma detectors [23].

This study detector efficiency calibration was performed using a mixed radionuclide sources (MW652) in 500 ml Marinelli beaker geometry. The container was placed on the detector. The spectrum was stored in the computer, and analyzed using the software.

4.6 Calculations

4.6.1 Activity Concentration

The activity concentration of individual nuclides in the soil samples were calculated using the Following equation 4.1[24].

$$A = \frac{N_{net}}{I_\gamma \varepsilon m t}$$

(4.1)

Where:

A: calculated gamma activity (Bq/kg) ,N_{net}: Net peak area count subtract background of the sample (counts) ,ε : Absolute efficiency of the detector ,I: emission probability of a specific energy photo peak ,t: sample count time (sec) m: sample weight/volume .

This calculation was done by assuming that all correction factors are equal to unity. The distribution of the activity mass concentrations due to the radionuclides ^{226}Ra, ^{232}Th and ^{40}K is not uniform throughout the soils. The

incompatibility with radiation exposure has been defined in terms of exposure has been defined in terms of radium equivalent activity (Ra_{eq}) used to represent the specific activity value of the three radionuclides by only single quantity. It is calculated using the following equation (4. 2) [25, 26].

$$Ra_{eq} = CR_a + 1.43C_{Th} + 0.07C_K$$

(4.2)

Where:

Ra_{eq}: Radium equivalent activity in Bq/kg ,C_{Th}:Thorium Activity concentration in Bq/kg,CR_a : Radium Activity concentration in Bq/kg,C_K : Potassium Activity concentration in Bq/kg .While defining Ra_{eq}activity, it is assumed that 10 Bq/kg of $^{226}_{.}Ra$ 7Bq/kg of$^{232}_{.}Th$ and 130 Bq/kg of $^{40}_{.}K$ produce equal gamma ray dose [27].the maximum value of this parameter should not exceed 370 Bq/kg in order to limit the annual exposure 1.5 mGy. From previous studies.

4.6.2 External Gamma Absorbed Dose rate

The External gamma ab external gamma absorbed dose rate (D) in the air at 1 m above ground level was calculated using the factor 0.042 nGy/h per Bq/kg for $^{40}_{.}K$ 0.462 nGy/h per Bq/kg for$^{226}_{.}Ra$ and 0.604 nGy/h per Bq/kg for $^{232}_{.}Th$ The calculations were performed according to the following equation [28] .

$$D = 0.462CR_a + 0.604C_{Th} + 0.042C_K$$

(4.3)

Where D: External gamma absorbed dose rate in nGy/h.

To calculate the effective dose rate, the conversion coefficient for the dose rate absorbed to the effective dose rate and external occupancy factor should be taken into account. The absorbed dose rate found to be converted

into effective dose rate using 0.7 Sv/Gy conversion factor recommended by UNSCEAR (2000) and external occupancy factor of 0.2 assuming that the man spends 20% of their time outdoors.

4.6.3 Annual Effective

Annual effective doses are calculated using the following equation 4.4.

Annual effective dose (Sv) = D × 8760 × 0.7 × 0. 2 (4.4)

Where 0.7: conversion factor in Sv/Gy ,8760 time in a year (hour) ,0.2 external occupancy factor.

4.6.4 External Hazard

External hazard is an index hazard widely used in the study as it represents external exposure to humans. The value of this index must be less than unity (unity value = 1) in order to keep the radiation hazard insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of radium equivalent activity (370 Bq/kg) [11]. The external hazard indexes,H_{ex}, are calculated using the following equation 4.5.

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (4.5)$$

4.6.5 Internal Hazard Index

Radon and thorn are the decay products of natural radionuclides, which exist in soil are the reason of lungs cancer when inhaled by inhabitants. Henceforth, to determine of radon exposure, reported the equation for the internal hazard index:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (4.6)$$

The values of Hex and H_{in} indices must be less than 1 mSv/y In order to cause any harmful effect to population.

CHAPTER FIVE

RESULTS DISCUSSION AND CONCLUSION

5.1 Results Discussion

5.1.1 Activity Concentration

In this work, the Dallanj town was divided into 5 parts named E, C, S, N and W. The samples were then collected from these parts so that three samples were taken from each part and the total number of samples became 15 samples. Samples for five different location were analyzed .When the samples were analyzed, different types naturally occurring radionuclide appeared with different concentrations as in the table 5.1.

Table 5.1: The activity concentration (Bq/kg) level of radionuclide collected from all region.

location	sample	^{40}K Bq/kg	^{226}Ra Bq/kg	^{232}Th Bq/kg
1	E1 - E3	94.86667±30.214290	13.13333±1.404754	27.50000±4.033609
2	C1 - C3	325.66667±259.954483	26.36667±3.407834	42.13333±1.234234
3	S1 - S3	77.33333±15.695010	19.70000±3.122499	31.48333±6.303240
4	N1 - N3	39.33333±27.319102	21.83333±4.843897	24.76667±3.027100
5	W1 -W3	60.26667±33.185288	27.50000±7.037755	43.10333±15.521245

The result of these analysis is shown in table 5.1 in which the mean and the standard deviation are presented. The activity concentrations were range

$325.667 \pm 259.954 - 39.333 \pm 27.319\, Bq/kg$, $27.500 \pm 7.038 - 13.333 \pm 1.405\, Bq/kg$ *and* $43.103 \pm 15.521 - 24.767 \pm 3.027100\, Bq/kg$ *for* ^{40}K, ^{226}Ra *and* ^{232}Th respectively.

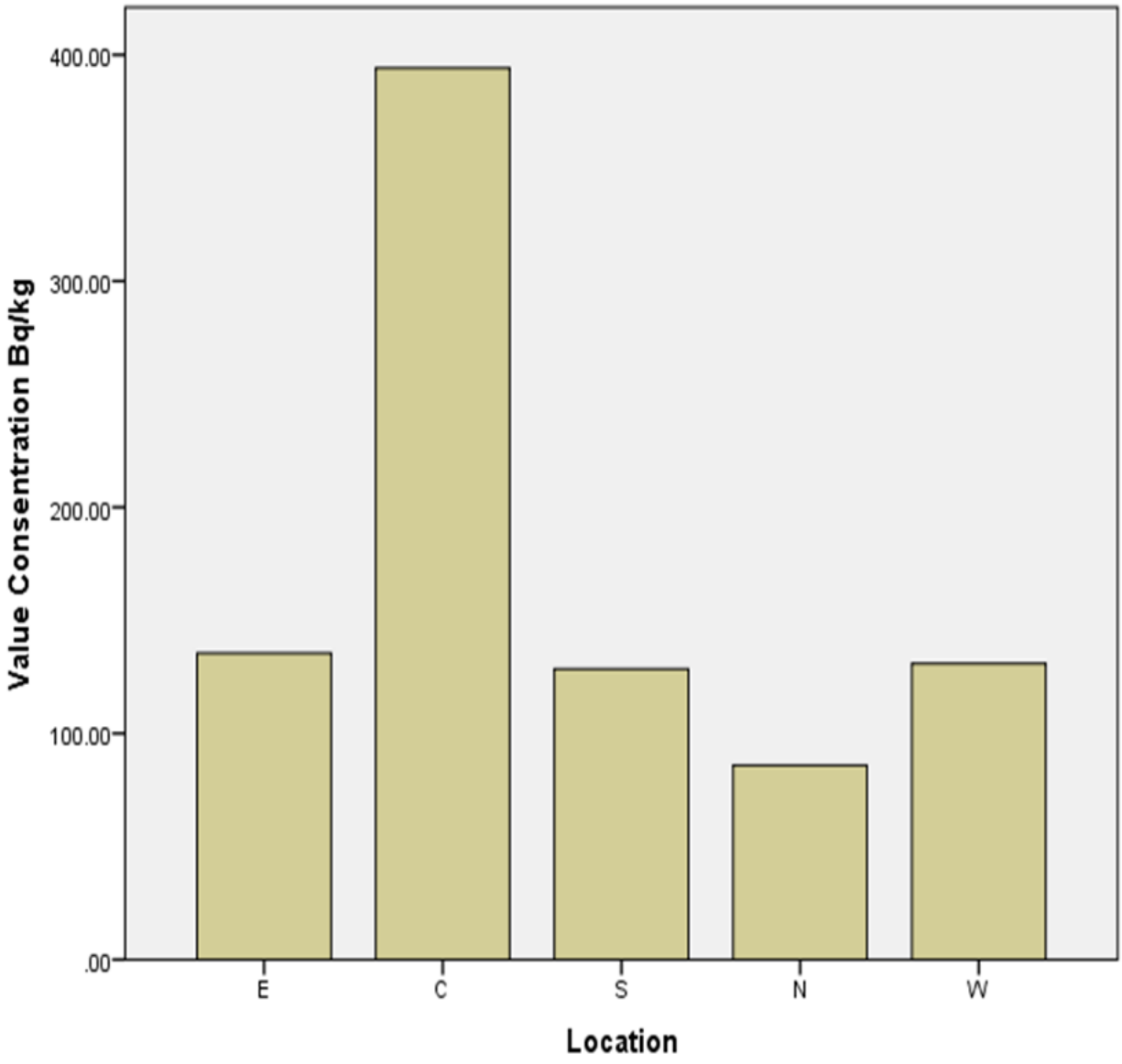

Figure 5.1Activity concentration

5. 1.2 Absorbed Dose Rate

The absorbed dose rate was calculated from the activity concentration of soil samples, according to Equation (4.3). The results of the calculations are presented in Table 5.2.

Table 5.2 absorbed dose rates (nGy/h) from natural radiation in farm soil samples.

sample	^{40}K nGy/h	^{226}Ra nGy/h	^{232}Th nGy/h	Total
E	3.9844±1.2690	6.0676±0.64899	16.61±2.436	26.662±4.35399
C	13.6780±10.9181	12.18140±1.5744	25.4485±0.7430	51.3079±13.2355
S	3.247999±0.6592	9.1014±1.4426	19.0159±3.8072	31.365299±5.909
N	1.6519999±1.1474	10.086998±2.2379	14.9591±1.8284	26.6980979±5.2137
W	2.5312±1.3938	12.705±3.2514	26.0344±9.3783	41.2706 ±14.0235

From Table 5.2, it was shown that the absorbed dose rate due to the presence of ^{40}K , ^{226}Ra *and* ^{232}Th in each Sample Were 26.662±4.35399, 51.3079±13.2355, 31.365299±5.909,26.6980979±5.2137and 41.2706 ±14.0235 nGy/h respectively. The highest absorbed dose rate for region W for ^{232}Th had the highest values of absorbed dose rates of average (20.41358±3.63858) nGy/h while^{40}K had the least values of absorbed dose rates of average (5.0203196±3.0775)nGy/h and the ^{226}Ra had the value of absorbed dose rate (10.0284796±1.831058) nGy/ h. the calculated average absorbed dose rate for the all regions was found to be 11.820793066±2.849046 nGy/h. This is within the world average (20.41358±3.63858) nGy/h.

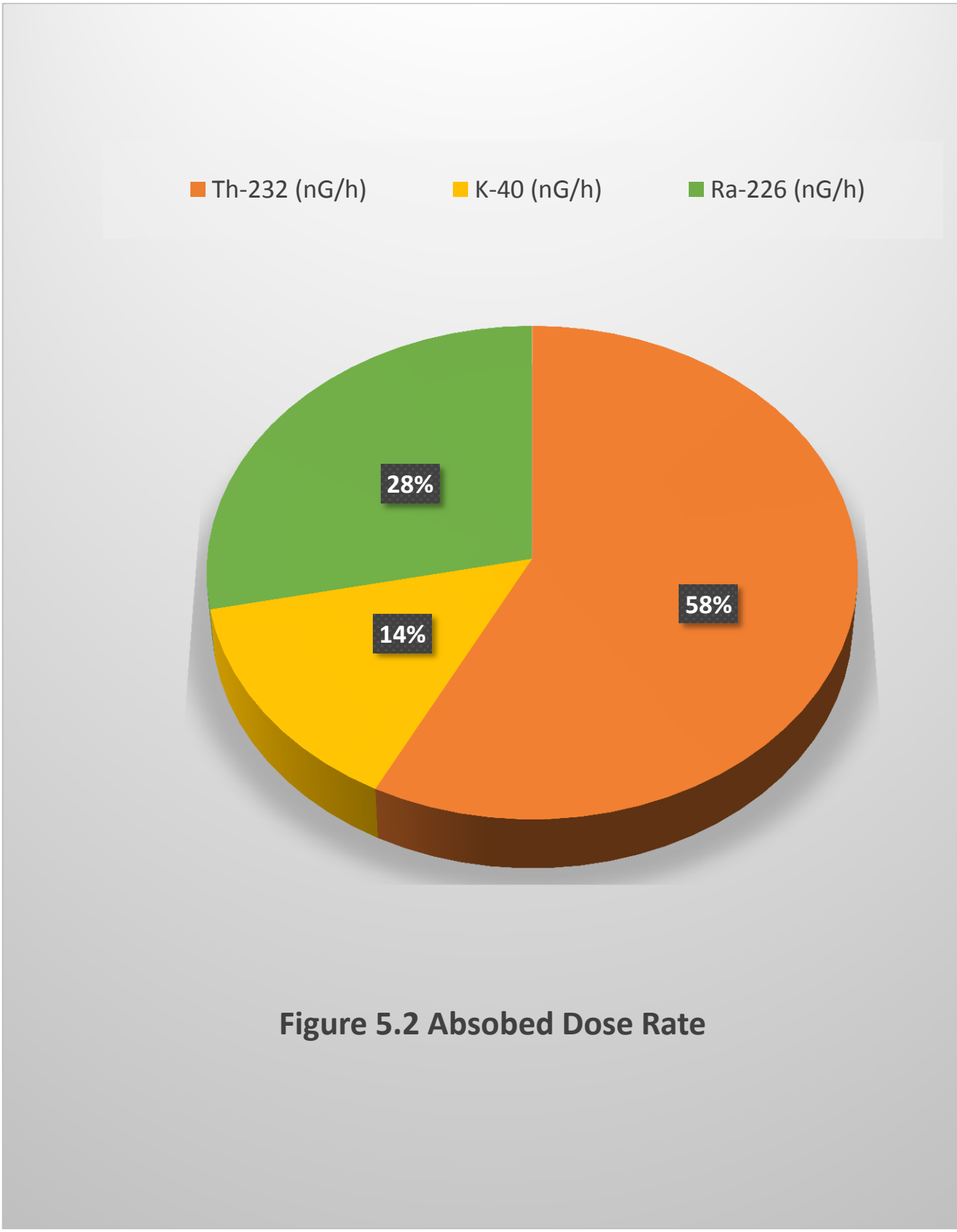

Figure 5.2 Absobed Dose Rate

5.1.3 Annual Effective Dose Rates, External (H_{ex}) and Internal (H_{in}) Hazard Indices

The annual effective dose rates were calculated by Equation (4.4).the annual effective dose rates effective in the five region from 62924.00656±16232.0172to32698.2768±533.9733336Sv(average=43489.099 ±9521.058) Sv. The external hazard index ($\boldsymbol{H_{ex}}$) was calculated using Equation (4.5).

The external hazard indices from all samples were within the acceptable average value of unity. The internal exposure to 222Rn and its radioactive progeny is controlled by the internal hazard index ($\mathbf{H_{in}}$) which is given by Equation (4.5). The internal hazard indices for all the samples were within the acceptable average value of unity .The calculated values of annual effective dose rates, external and internal hazard indices are presented in Table 5.3.

Table 5.3 annual effective dose rates in (Sv), external and internal hazard indices.

No	location	annual effective (Sv)	External index	Internal index
1	E	32698.2768±533.9733336	0.16185±0.02565	0.212664±0.027884
2	C	62924.00656±16232.0172	0.3016442±0.06802	0.226496±0.0776114
3	S	38466.40269±7246.7976	0.190878±0.036042	0.336869±0.04448
4	N	32742.54726±6394.08168	0.16281±0.081575	0.2218188±0.0435504
5	W	50614.26384±17198.4204	0.253276±0.085848	0.327600±0.104868

5.2 Conclusion

In this study the radioactivity of soil samples were investigated samples were taken from South kuordofan (Dallanj Town) .The city was divided into five parts: East, Central, South, North and West. Three samples were taken from each part.The activity concentration of natural radionuclides $^{226}Ra, ^{232}Th$ and ^{40}K of the samples obtained by using gamma spectrometry. The radioactivity of generally showed high level of ^{40}K in Central location of city, with concentration 325.67 Bq/Kg and the lowest concentration in the northern part 39.33 Bq/Kg. while high concentration of ^{232}Th found in Western part 43.10 Bq/Kg and the lowest concentration in the Eastrent part 27.50 Bq/Kg and high concentration of $^{226}Ra,$ found in Western part 27.5 Bq/Kg and the lowest concentration in the Eastrent part 13.13 Bq/Kg.

5.3 Recommendations

. There is need to expand the program to cover the whole region which requires effort to be made.

. We recommend to make more work in this field to make a complete database line on environmental and natural radioactivity, also other researches on some region area by studying other environmental compartment such as foodstuff, drinking water and radon.

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