RADIATION EXPOSURE LEVELS AND THEIR POTENTIAL EFFECTS ON DOMESTICATED ANIMALS IN WEST POKOT, KENYA

BY

MBISHEI H. MOTUM

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DECLARATION

Declaration by Student

This thesis is my original work and has not been presented for a degree in any other University or elsewhere. No part of this thesis may be produced without the prior written permission of the author and / or University of Eldoret.

…….. ……

Mbishei Motum Date

SC/PGC/035/14

Declaration by Supervisors

This thesis has been submitted for examination with our approval as University supervisors

…… ……..

Prof. Samuel Lutta Date

Department of Chemistry & Biochemistry

University of Eldoret, Kenya

…… ……

Prof. Lusweti Kituyi Date

Department of Chemistry & Biochemistry

University of Eldoret, Kenya

…… ……

Dr. Stephen Barasa Date

Department of Chemistry & Biochemistry

University of Eldoret, Kenya

DEDICATION

I dedicate this work to my loving parents, Jonah Kipchumba and Rose Cherotich; wife Imelda Chematia and children Ingrid, Sandra, Mitchell and Samuel.

ABSTRACT

Radioactive matter in the earth's crust and celestial bodies are the main sources of natural radioactive exposure to man and animals. The main contribution to external exposure comes from gamma-emitting radionuclides present in trace elements in the soil. This study aimed at investigating absorbed dose and annual effective dose rate from radiations emitted by radionuclides from Atulya and Mtembur in West Pokot. Purposive sampling was used to identify points for soil sampling. A 500 g of each of the soil samples were collected. Rock samples were chipped off from caves and bones and hides collected from a slaughter house. The samples were then transported to the National Radiation Protection Board laboratory (Nairobi), for radioactivity analysis. Soil was ground with a grinder to powder then sieved through 100μm mesh wire. An LB 200 Bequerel Monitor, measured gamma activity ($Bqkg^{-1}$) in solid samples. The values were subjected to statistical analysis and from t- test results, the corresponding p-values of soil and rock licks were ($P=0.000$, $df=3$, $t=-41.288$) and ($P=0.005$, $df=3$, $t=7.398$) which differed significantly ($P\leq0.05$). However, the results of crushed rocks ($P=0.731$, $df=3$, $t=-0.378$) didn't differ significantly. Samples from Mtembur showed negative correlations between radiation activity levels within soil and leaves, rock licks and skin, rock licks and bones, leaves and skin and between leaves and bones, since $p>0.05$ and $r<1$. The same negative correlation was noted for Atulya except for a positive correlation between radiation activity levels within crushed rocks and bones (0.050, $p\leq0.05$). Ratemeter in counts per second results showed elevated radioactive exposure in soils 0.5651 mSv/y, rock lick 0.8599 mSv/y, animal parts 0.4029 mSv/y and crushed rock 0.7421 mSv/y. Leaf samples showed up to 0.573 mSv/y. Evidently, animals in West Pokot County are exposed to harmful radiations which could lead to deformities like fragile limbs, misplaced organs and multiple organs. This leads to poor economic returns to the pastoral community. The two areas showed exposure limits beyond the WHO standards and policy to reduce the exposure levels is recommended.

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ABBREVIATIONS AND ACRONYMS

cpm	counts per minute
EDTA	Ethylenediaminetetraacetic acid
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
NEMA	National Environmental Management Authority
NRC	Norwegian Refugee Council
UNEP	United Nations Environmental Program
UNSCEAR	United Nations Scientific Commission on the Effects of Atomic Radiations
US-EPA	United States Environmental Protection Agency
W.H.O.	World Health Organization

DEFINITION OF TERMS

µSv/h and mSv/y: Units that measure effective exposure to radiations

nGy/h: Unit that measures absorbed doses of radiations by an organism

X-ray jacket: A protective jacket worn while handling suspected radioactive materials

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

High energy in form of radiation is given off by matter in the form of rays or photons (Takahashi *et al*., 2010). Natural radioactivity from celestial sources and radioactive matter in the earth's crust is a source of constant radiation exposure to humans and animals (Garba *et al*., 2013). Human beings are exposed to radiation from sources outside their bodies, mainly cosmic rays and gamma ray emitters in soils, building materials, water, food, and air.

Radiation exposure comes both from extra-terrestrial sources and elements which are radioactive in the earth's crust (Alaamer, 2008). The main contribution to external exposure comes from gamma-emitting radionuclides present in trace elements in the soil, mainly K-40, U-238 and Th-232 families (UNSCEAR, 2011b). Natural background radiation mainly comes from the external terrestrial radiation, principally due to uranium and thorium decay chains, and by K-40, which is present in the earth's crust (Kinyua *et al.*, 2011; Xhixha *et al*., 2013). The radiological implication of this radionuclide is external radiation exposure by gamma rays and internal exposure due to inhalation of radon and its daughters (Singh *et al.*, 2009). The particles deposited after emission from industrial processes cause health and environmental problems as a result of accumulation of poisonous elements, for example, particles of dust or diluted particles in ground water (Lyons & Harmon, 2012). The levels due to the terrestrial background radiation are related to the types of rock from which the soils originate. Higher radiation levels are

associated to igneous rocks such as granite and lower levels from sedimentary rocks. There are some exceptions, however, since some shale and phosphate rocks have a relatively high content of radionuclides (Tzortzis *et al*., 2003; Abbady, 2005).

Residents in high intensity radiation environments are more likely to get exposed to abnormally high radiation levels over extended periods of time for subsequent generations (Faanu *et al.,* 2011). The increased background ionizing radiation can have negative side effects such as somatic and genetic effects, which can affect vital and radiosensitive organs and ultimately lead to death (Hashim *et al.,* 2001).

Rocks and soils from a number of areas underlined by carbonatite rocks in Kenya have been associated with high levels of natural background radioactivity. For instance, Mulwa *et al*. (2013) discovered that the radium equivalent activity for limestone rock samples obtained in Kitui South was less than the recommended limit of 370 $Bqkg^{-1}$, and that the hazard indices were also less than a unit.

Measurement of natural radioactivity is crucial in implementing precautionary measures whenever the source is found to exceed the recommended limit: 0.5 mSv/y and 30 nGy/h for effective and absorbed dose rates respectively (UNSCEAR, 2011b). The present study aimed at investigating naturally occurring radioactive elements and exposure levels to ionizing radiation at some selected parts in West Pokot region, Kenya. Rocks, soil and vegetation contamination by radioactive substances pose a major concern due to their toxicity and threat to both human and animal life. Radioactive nuclides are prevalent in

sand, granites, and in quarries (Gbadebo, 2011). Naturally occurring radioactive materials are also found within mine areas (Sroor *et al*., 2001; Mohanty *et al*., 2004; Lundquist & Varnedoe, 2006; Bahar *et al*., 2007), have also suggested presence of heavy metals and some radionuclide in salt caves where animals often lick to supplement their salt dietary requirements.

1.2 Statement of the problem

Livestock forms the basis of livelihood among the Pokot pastoral community in the North Rift region of Kenya. Livestock plays a major role in the community through supply of food in form of milk and meat; communal ceremonies like dowry payment; clothing (hides and skins); symbol status among other cultural values. However, this vital source of livelihood has been affected as shown by the animals collected at the Kitale nature conservancy, commonly called Ndura farm. This is an animal sanctuary that collects deformed animals with deformations ranging from misplaced organs to weak and fragile limps. The proprietor confirms that over 90% of the animals come from the neighbouring West Pokot County. The increase in incidences of disorders could be attributed to environmental exposure. Some disorders might have been biological and others radiological. It is apparent that the exposure to the naturally occurring radioactive materials is actually enhanced through mining/excavation works and the processing of minerals. Communities and livestock living near mineral sands mining operations may get exposed to about 100 times the normal background levels (approximately 2.4 $mSvy^{-1}$) (Leonard, 2014; Usman, 2015;). Heavy mineral sands usually contain high concentrations of uranium and thorium compared to the average levels in normal soils and rocks. Also,

environmental monitoring and assessment is vital in regulatory and advisory policy making for public safety due to radiation exposure. It is against this background that this research set out to analyze the radiation exposure to the livestock through the rocks they lick, the grass they graze on and the soil where the vegetation grows.

1.3 Justification

There isn't a conclusive research that has been done in determining the radioactivity levels in Kenya besides the increasing numbers of industries, quarries, high-rise buildings and infrastructures. Actual data are required in construction and manufacturing industries to determine their environmental pollution in form of radiation. The building and construction materials that are used are not usually tested for radioactivity. This could pose danger to human health and can even result in death due to cancer (Anjos *et al*., 2005). Radiation exposure must be maintained below the WHO minimum exposure standards since even the lowest doses may cause cancer over a prolonged period of exposure. This study was carried out to determine the levels of radiation exposure from natural sources in mining areas, quarries and salt lick caves in Mtembur and Atulya sub locations of North Pokot. As Kenya aspires to attain vision 2030 on medium economic growth, there is an increase in technology and infrastructures which can result in an increase in the risks associated with radiation exposure. Thus there is need to provide data that can inform and guide the process of workplace safety as well as residential places. This research aimed at enlightening the West Pokot community and the Government agencies on the causes of livestock deformities which is affecting their production in terms of market value and products. It would also help further research in

this field so that long lasting solutions can be sought. Previous researches on causes of deformities (Tzortis *et al*., 2003; Tubiana *et al*., 2009 and Usman, 2015) have attributed this to ecological and poor management issues. Further, the belief that colostrum may harm the calf has been cited (Farah, 2004). In this thesis, an attempt to research on causes of genetic mutations that lead to the deformities is mentioned.

1.4 Objectives

1.4.1 General objective

To determine the presence of radionuclides in rocks, rock licks, soil, animal parts (skins and bones) and leaves in Mtembur and Atulya.

1.4.2 Specific Objectives

i. To determine the activity levels of the naturally occurring radionuclides Th-232, U-238, K-40 in soil, leaves, rocks and animal parts from West Pokot County.

ii. To approximate the activity concentration dose rates (absorbed and effective) from radionuclides contained in skins and bones.

iii. To determine the environmental safety of the radionuclides within the two areas.

iv. To correlate the activity values for Mtembur and Atulya.

1.4.3 Null Hypotheses

- H_{O1}

  The soils, leaves, rocks and animal parts from West Pokot County do not show any activity resulting from presence of natural radionuclides.

- H_{O2}

  Concentration of naturally occurring radionuclides U-238, Th-232 and K-40 does not cause deformities in domesticated animals in West Pokot County.

- H_{O3}

  The concentration of the naturally occurring radionuclides are below the WHO and NEMA standard.

- H_{O4}

  The correlation in activity values for the two areas is positive.

CHAPTER TWO

LITERATURE REVIEW

2.1 Radionuclide

Naturally occurring radionuclides (atoms that have excess nuclear energy, making them unstable) of terrestrial origin have existed in the earth's crust since its origin. These radionuclides have longer half-lives, for example, Potassium (K-40) with half-life of 1.248×10^{9} years, Uranium (U-238) with half-life of 4.468×10^{9} years and Thorium (Th-232) with half-life of 1.405×10^{10} years. These species have survived since the time of creation and have subsequently decayed to attain a state of stability in which they produce ionizing radiations. The distribution of naturally occurring radionuclides mainly U-238, Th-232 and K-40 and other radioactive elements depends on the distribution of rocks they originated from. The levels of radioactivity on earth vary from place to place. In some places they vary within narrow limits, but in some places deviations from normal levels are wider because of abnormally high levels of radioactivity (Allisy- Roberts & Burns, 2005).. Exposure to ionizing radiation from natural sources is a continuous and unavoidable process on earth. The major sources responsible for this exposure are due to the presence of naturally occurring radionuclides in the earth's crust (Mohanty *et al*., 2004; Bahar *et al*., 2007; Akhtar *et al*., 2005).

Rocks of volcanic origin, for example, granite and pumice contain radioactive elements (Hassan *et al*., 2010; Turhan *et al*., 2008). Radionuclides which occur naturally like uranium, radium and thorium can be present in many minerals that appear as crystals in

granite. It is common in soil originating from these rocks to have some number of radioactive samples. The weathering of these rocks and subsequent deposition as soil contributes to sediment pollution. The phosphate rocks used as raw materials in the manufacture of fertilizers are rich in uranium, thorium and their daughters (da Conceicao *et al.,* 2009). Therefore, the use of phosphate fertilizers can contribute to the radionuclide concentration in the environment.

2.2 Environmental Sources of Natural Radioactivity

Natural radioactivity refers to the rate of naturally occurring radionuclides in various environmental chambers. These origins can be classified into two types: cosmogenic (such as C-14 and H-3) and terrestrial (Sroor *et al.,* 2001).

The type of soil, geological characteristics, and geographical environments all influence exposure to terrestrial gamma rays (Sanusi *et al.,* 2014; Olarinoye *et al.,* 2010). Radionuclides are absorbed into the rock during the initial stages of rock formation and are emitted into the soil during weathering processes of the rock cycle (Belivermis *et al.,* 2010). In particular, increased amounts of radionuclide levels are consistent with igneous rocks such as granite, while lower levels are correlated with sedimentary rocks (Faanu *et al.,* 2011).

Aside from radioactive potassium (K-40), terrestrial radionuclides include those found in four known decay series: uranium, thorium, actinium, and neptunium, which begin with U-238, Th-232, U-235, and Np-237, respectively (Atwood, 2013).

The radionuclides produced as a result of the collision of the primary cosmic rays with the elements of the Earth's atmosphere are known as cosmogenic radionuclides. C-14, H-3, and Be-7 are a few examples. Primordial radionuclides are those that are believed to have existed before the earth's formation and U-235, U-238, Th-232, and K-40 are among them (Ješkovský *et al.,* 2019).

The other group of exposures is technologically advanced natural exposure, which is marked by long half-lives in the order of hundreds of thousands of years. There are radiation exposures caused by normal sources that are caused by human activity (Chapman and Hooper, 2012). Exposures of cosmic rays during air and space travel are examples of technologically advanced exposures. At 10 km altitude, for example, aircraft crews and regular travelers are exposed to radiations varying from 1 - 2.5 Sv/h near the equator and 4 to 6 Sv/h above 50^{o}N. Mining operations in the phosphate sector, refining of monazite sands for rare earth extraction, the oil and gas industry, and coal-fired power plants are other examples of elevated emissions (Cook *et al.,* 2018).

2.3 Worldwide studies on natural activity

Studies have shown that the average radiation exposure dosage rate is approximately 2.4 mSv a year with background radiation accounting for 1.1 mSv of this dose and radon exposure accounting for an equivalent contribution (Vano *et al.,* 2006; UNSCEAR, 2000a).

Bajwa *et al*., (2017), studied natural radioactivity in water and soil samples from the Indian state of Punjab studied and obtained values in the range of 0.61 to 1.27 g/g. The activity levels of Ra-226, Th-232, and K-40 were determined using a gamma spectroscopic method, yielding 43.9, 55.9, and 101.7 Bq/kg, respectively.

Saad and Al-Azmi (2002) conducted analyses of radioactive material concentrations in sediments and their similarity to coastal structure in Kuwait. For the southern coastline, the average activity concentrations for U-238, Th-232, Ra-226, K-40, and Cs-137 were 13.56.2, 2.30.8, 18.47.5, and 110.340.7 Bq/kg, respectively, and 66.519.25, 11.24.0, 59.85.9, 384.4133, and 2.161.25 Bq/kg, respectively. The level of Cs-137 sample was observed to be below the detection level for the southern coastline.

Around 200 samples taken were obtained from various geological formations in Jordan's northern highlands to assess the activity concentrations of U-238, Ra-226, Th-232, and K-40 (Al-Hamarneh & Awadallah, 2009). Zarqa had the largest activity concentrations of Ra-226 and U-238, which were 1040 and 943.1 Bq/kg, respectively. This could be attributed to the presence of an old phosphate mine in the area (Al-Jundi *et al.*, 2008).

Analysis of natural radioactivity in coastal sediments from the north coast of Tamilnadu, India, discovered that the highest activity concentrations of U-238 and Th-232 in Mahabalipuram beach were 30.42 $Bqkg^{-1}$ and 218.64 $Bqkg^{-1}$, respectively. In Kovalam beach, the highest activity concentration for K-40 was 423.43 $Bqkg^{-1}$ (Ramasamy *et al.*, 2009). The estimated absorbed gamma dose rate was 30.15 $nGyh^{-1}$, which is less than the

global average of 51 $nGyh^{-1}$, and the annual effective dose rate was 0.15 mSv, which is less than the global average of 0.48 mSv (UNSCEAR, 2000a).

Júnior *et al.,* (2010) used high resolution (hyper pure germanium) gamma ray spectrometry to determine the radium equivalent and annual effective dose from geological samples from Pedra, Pernambuco, Brazil. The study discovered activity concentrations that were smaller than the overall recommended limit of 370 $Bqkg^{-1}$.

A study on radioactivity in soils in Malaysia's Johor state discovered that the level of naturally occurring radionuclide uranium-238 was in the range of (58.8 -484.88 $Bqkg^{-1}$) and that of thorium-232 was in the range of (59.68 -1203 $Bqkg^{-1}$) (Ramli *et al.,* 2005). The mean levels of U-238, Th-232, and K-40 in the samples were 207.0311.3 $Bqkg^{-1}$, 500.720.3 $Bqkg^{-1}$, and 805.320.7 $Bqkg^{-1}$, respectively, which are above the global values and the region is considered a high natural background field, according to an analysis of natural radiations from surface soils around Mrima Hill in Kenya (Kebwaro *et al.,* 2011).

The absorbed dose was 440.716.8 $nGyh^{-1}$, which was higher than the world average of 60 $nGyh^{-1}$, and the annual effective dose was 1.11 $mSvy^{-1}$ (Kebwaro *et al.,* 2011). The findings of this study add to our understanding of the concentration levels of naturally occurring radionuclides in Kenya, as well as the health risks posed by radiation.

Oktay *et al.,* (2010) used gamma ray spectrometry to measure natural radioactivity and radiological risks in building products used in Elazig, Turkey. The calculations revealed that bricks had the lowest (36.5 $Bqkg^{-1}$) radium equivalent occurrence and concrete had the largest (405.2 $Bqkg^{-1}$). The particular behaviour varied between 1.6 and 4928 $Bqkg^{-1}$. The estimated indoor radon concentration in the newly built floor was 364.3 Bqm^{-3}, which was greater than the global mean amount.

In Western Haryana India, Xinwei (2005) established that average concentration for 238U, 232Th and 40K in the soil samples were 18.78, 47.35 and 361.57 $Bqkg^{-1}$respectively. A similar study by Faanu *et al.,* (2011) showed activities lower than the limit set in the Organization for Economic Cooperation and Development (OECD) report (370 $Bqkg^{-1}$), equivalent to external gamma dose of 1.5 mSv yr^{-1}.

A research on natural radioactivity at Minjingu phosphate rocks in Tanzania revealed high concentrations of Ra-226 of 5760 ± 107 $Bqkg^{-1}$in phosphate rock, waste rock 4250 ± 98 $Bqkg^{-1}$, 650 ± 11 $Bqkg^{-1}$ in wild leaf vegetation, edible leaf vegetation 393 ± 9 $Bqkg^{-1}$, and chicken feed 4.0 ± 0.1 $Bqkg^{-1}$which suggest a radiation health risk particularly when the samples are ingested (Banzi *et al.,* 2000). The radiation dose from ambient air over five years at the phosphate mine averaged 1415 $nGyh^{-1}$.

Studies on radiations in sediments have been carried out in different parts of the world in areas of economic interests like mining and tourism attraction areas. The level of radioactivity in sediment samples in ponds and oxbow lakes in the district of Jessore,

Bangladesh showed average values of 42.9 $Bqkg^{-1}$, 47.85 $Bqkg^{-1}$and 502.73 $Bqkg^{-1}$for Ra-226, Th-232 and K-40 respectively. The average absorbed dose rate of 71.71±18.4 $nGyh^{-1}$was obtained (Kabir *et al.,* 2009). The values are above the world averages even though they are within acceptable limits.

A high natural radiation zone was investigated for the first time in a geothermal region of Eastern Ghats Mobile Belt (EGMB) of Orissa state in India (Baranwal *et al.,* 2006). Soil and rock samples collected from the high radiation zone were analyzed by ɤ-ray spectrometry (GRS) using Nal (Tl) detector. The average concentration of U-238, Th-232 and K-40 were found to be 33 ppm, 459 ppm and 3 ppm, respectively, in soils and 312 ppm, 1723 ppm and 5 %, respectively in the granitic rocks. Maximum concentration of U-238, Th-232 and K-40 were found to be 95 ppm, 1194 ppm and 4 ppm respectively in soils and 1434 ppm, 10590 ppm and 8 %, respectively in the granitic rocks. The absorbed gamma dose rate in air and external annual dose rate of the high radiation zone were calculated to be 2431 nGy/h and 3.0 mSv /y, respectively.

2.4 Studies on natural radioactivity in Kenya

Maina *et al.,* (2002) reported elevated concentrations of Ra-226 and Th-232 in soils samples from different areas in Kenya. The study assessed human exposure to natural radiation in Kenya. Samples collected (geological materials and water), from various terrains, especially in the densely populated areas like Nairobi, Kiambu, Bungoma and Trans Nzoia districts were studied. The overall mean activity concentrations of K-40, Ra-226 and Th-232 in the collected samples were found to be 705, 65 and 163 $Bqkg^{-1}$,

respectively while the approximated effective dose as a result of external exposure to terrestrial gamma radiation differed from 0.06 to 2.00 $mSvy^{-1}$ with an average of 0.76 $mSvy^{-1}$. Concentrations of radon in different sources of water were reported to be higher than the accepted world average of 37.1 $Bqkg^{-1}$.

Agola (2006), also reported mean activity concentrations of U-238 series, Th-232 series, Ra-226 series and K-40 as 73.72 ± 7.4, 149.33 ± 17.0, 163.81 ± 18.6, and 1,095.20 ± 53.2 $Bqkg^{-1}$, respectively in the Olkaria geothermal area. Radon (Rn-222) mean activity concentrations in water ranged from 1.95 ± 0.4 to 8.63 ± 0.1 $KBqm^{-3}$ with an overall mean value of 5.56 ± 0.5 $KBqm^{-3}$. The radon values obtained from water sources, (Agola, 2006), were therefore within the recommended level of 10 $KBqm^{-3}$ in water (UNSCEAR, 2011a). The overall mean concentration for radon in water was also be far below the permissible level of 11 $KBqm^{-3}$. Radon activity concentration for the indoor environments ranged from 5.13 ± 0.7 to 83.47 ± 0.1 Bqm^{-3} with a mean value of 41.05 ± 3.2 Bqm^{-3} with a value below the reference levels of 200-600 Bqm^{-3}.

Langat, (2012), reported the average activity to be 708.3±33.2 $Bqkg^{-1}$ for K-40, 43.5±3.8 $Bqkg^{-1}$ for Th- 232 and 36.9±9.1 $Bqkg^{-1}$ for U-238, a dose rate of 71.97 $nGyh^{-1}$ and an annual effective dose rate (outdoor) of 0.088±0.007 $mSvy^{-1}$ which is less than the safety limit to public exposure of 1 $mSvy^{-1}$ at the shores of Lake Nakuru, which is a tourist attraction site. The results indicated that the site is safe for public from the effects of radiations.

A research done by Daniel (2015), on spectrometric analysis of gamma rays of radionuclides that occur naturally in soil samples collected in Migori county on the shores of Lake Victoria, found that the average concentrations of U-238, Th-232 and K-40 in the samples analyzed in this study are 64.5±3.3 $BqKg^{-1}$,146.0±4.4 $BqKg^{-1}$ and 1222.8±43.3 $BqKg^{-1}$, respectively. It was found that activity concentration was above world estimated average values. An estimation was also done on absorbed dose rate in air above 1 m from the ground.

In a similar study, Hashim *et al.,* (2001), reported concentration levels of U-238, Th-232 and K-40 on the south coast of Mombasa was measured and results show the average activities are 22.8±1.8 $Bqkg^{-1}$, 26.2±1.7 $Bqkg^{-1}$ and 479.8±24.2 $Bqkg^{-1}$, respectively. The annual effective dose rate will be found to have a mean of 0.12±0.01 $mSvy^{-1}$.

Kipngeno (2015), assessed the spectroscopic analysis for gamma rays in tea leaves and soils in Kericho county and the research findings showed an average activity of 66±8 $Bqkg^{-1}$ for U-238, 55±2 $Bqkg^{-1}$, for Th-232 and 819±9 $Bqkg^{-1}$ for K-40 for Kericho tea estate soil, 51±5 $Bqkg^{-1}$ for U-238, 51±4 $Bqkg^{-1}$ for Th-232 and 724±9 $Bqkg^{-1}$ for K-40 for Mau soil, 48±5 $Bqkg^{-1}$ for U-238, 43±2 $Bqkg^{-1}$ for Th-232 and 667±8 $Bqkg^{-1}$ for K-40 for Kericho tea leaves and 53±3 $Bqkg^{-1}$ for U-238, 40±4 $Bqkg^{-1}$ for Th-232 and 558±7 $Bqkg^{-1}$ for K-40 for Mau leaves. An annual outdoor dose rate of 0.12±0.06 $mSvy^{-1}$ and 0.09±0.005 $mSvy^{-1}$ was found for tea and soil, values which are lower than the standard safety limit exposure to the public estimated at 1 $mSvy^{-1}$. When the activity

concentrations in the two ecosystems were compared, it was found that the environment in Kericho had higher pollution than the environment in Mau. This is associated with human activities in the tea estates showing a higher population of persons in Kericho than in Mau.

Kinyua *et al.,* (2011) discovered that the activity concentrations of Th-232, Ra-226, and K-40 ranged from 38.6-271.7, 43.1-360, and 245-1780 $Bqkg^{-1}$, respectively, in the soapstone quarries of Tabaka area of Kisii county. The average absorbed dose rate was 541.4 $nGyh^{-1}$ at a height of 1m above ground level, while the measured overall absorbed dose rate was 177.6 $nGyh^{-1}$below the surface. This is about four times greater than the global average of 43$nGyh^{-1}$.

From the foregoing studies it is clear that the presence of naturally occurring radionuclides in some parts of Kenya are above the world set standards hence endangering the lives of those who live in these areas. In addition, the presence of deformed domesticated animals in West Pokot County could also be proof for the existence of these substances. Therefore, this study set out to examine the concentration of U-238, Th-232 and K-40 and compare it with the world set standards. The results from this study will help agencies that monitor the environment such as WHO, NEMA and UNEP. Information about levels of concentration of radionuclides occurring naturally in Kenya and public safety on radiation effects will help to pave way for better policies on health risks resulting from exposure to radiations.

2.5 Radionuclide activity concentration in soil

Soil properties are classified primarily as physical (texture, structure, porosity, water, air, and heat regimen), chemical (chemical and mineralogical composition, pH, microelements, micronutrients, salinity (EC), cation exchange capacity (CEC), organic matter, and so on), and biological (macroflora, macrofauna (rodents, insects, woodlice, mite, snails, millipedes, spiders, worms) (Smičiklas, & Šljivić-Ivanović, 2016; Zeelie, 2012). Based on the contaminant type, all five critical features of the soil, including minerals, water, organic matter, gases, and microorganisms, have an effect on the attachment and preservation of contaminants of varying degrees (Ren *et al.,* 2018). Physical (reversible) sorption is controlled by uncompensated charges on the surface of soil particles, while chemical (principally irreversible) sorption is governed by high attraction, complex interactions, and the formation of covalent bonds (Smičiklas, & Šljivić-Ivanović, 2016). The key elements in sediment, mostly quarts and feldspar, are derived from the parent rock and account for the majority of the sand and silt fraction. Because of their low specific surface area, they play the smallest role in contaminant interaction, and connection occurs via reversible sorption (Wilson, 2004). Clay and other secondary minerals are formed as a result of physical, chemical, and biological weathering processes. Since structural ions have unbalanced charges, they are vectors of persistent surface charge, which, along with their small particle size and high specific surface area, makes them essential matrices for contaminant transport (Sarkar *et al.,* 2012).

Soil is made up of mineral or organic matter, water, and air that are organized in a complex physiochemical system that provides mechanical support for plants as well as nutritive support (Dhok, 2020). Based on the proportion of sand, silt, and clay, the inorganic component of surface soils can be classified into a variety of textural groups. Sand is mostly composed of primary minerals such as quartz, with particle sizes varying from around 2 mm to 60 mm. Silt consists of particles with diameters ranging from 2 mm to 60 mm, while clay particles have diameters less than 2 mm (White, 2013). The earth's crust contains significant concentrations of radionuclides. In reality, natural radioactivity is primarily responsible for the earth's interior being hot and molten (Vearrier *et al.,* 2009). The term radiometric fingerprinting refers to the process of identifying mineral species based on differences in radionuclide concentrations (Van Wijngaarden *et al.,* 2002).

Soil pollution with radioactive contaminants is a major source of risk for environmental and health protection, as well as for the economy (Manisalidis *et al.,* 2020). The use of nuclear weapons is a major source of waste. Radiation will penetrate and impact the atmosphere at any point of the nuclear fuel cycle, beginning with the extraction and refining of uranium ore and continuing with the manufacture and storage of nuclear fuels and ending with the processing and disposal of radioactive wastes (Chapman & Hooper, 2012). In the earth's surface, the normal uranium content is 2.8 mg/kg.

This radionuclide can be found in varying amounts in oxide, silicate, arsenate, vanadate, and phosphate minerals. Ores mined using traditional uranium extraction methods range from (>20 percent in Canada) to very low (0.01 percent in Namibia) (Smičiklas &

Šljivić-Ivanović, 2016). The hydrometallurgical process extracts uranium from the ore matrix, and the final product (the so-called yellowcake) used in the subsequent stages of nuclear fuel processing normally contains of 75–85 percent U-3O8. Studies on the impact of the uranium production process on air contamination and possible health threats have shown increased activity in towns near ore processing facilities and old mines, in particular (Xiang *et al.,* 2019; Brugge & Buchner, 2011; Hoag, 2005).

2.6 Radioactivity in Plants

Soil-plant-man is highlighted as a significant mechanism for radionuclide conversion to humans (Kritsananuwat *et al.*, 2015). The absorption of vital minerals in both edible and inedible plant parts is affected by soil composition, mineral concentrations, and bioavailability. Processes within the plant's biological system allow nutrients available for consumption, resulting in exposure (Wang *et al.*, 2015).

Fertilizers, particularly phosphate-based fertilizers, have a high uranium content, which is likely to lead to increased levels in vegetables grown with these fertilizers (El-Taher & Althoyaib, 2012). The plants obtain accumulated radionuclides from the soil, that is known as the soil-to-plant transfer factor (TF), which is widely used for measuring radiological human dose via the ingestion route. The soil-to-plant TF is considered as one of the most critical criteria in assessing the environmental quality of nuclear sites (Avwiri *et al.,* 2021).

The soil-to-plant TF, which is commonly used for calculating radiological human dose through the ingestion path, is obtained by the plants from the soil. The soil-to-plant TF is regarded as one of the most important metrics for evaluating the environmental sustainability of nuclear sites (Mollah, 2014).

The TF characterizes radionuclide absorption from soil to plant: it is the ratio of radionuclide concentration in plant to soil per unit mass (Abu Khadra *et al.,* 2009). The TF is commonly used to measure the environmental effects of radionuclide releases. Because of the expected long-term transition of radionuclides in the atmosphere due to their lifespan, knowledge of the geochemical and ecological cycles is also needed, since they contribute to the actions of not only radionuclides but also related elements (Campbell *et al.,* 2015).

Radionuclides and soil synergy rely upon the chemical form of the elements and different soil features, including the mineralogical content, pH, organic matter composition, supplement status Ca, K, and organic matter quality, plant species, and other environmental factors (Sohlenius *et al.,* 2013).

Various studies have shown that trees, vegetables, shrubs, weeds, lichens, fungi, and algae can absorb, retain, and store radionuclides (Mahiban, *et al.,* 2013).

2.7 Effects of Radiation in Plants

Radiation has a beneficial effect on plant growth at low concentrations and a negative effect at elevated amounts, according to the Health Physics Society, U.S. Plants use non-

ionizing radiation, such as sunlight, for photosynthesis. Though these sun rays are essential for plant life, certain types of non-ionizing and ionizing radiations are harmful to plants. Growth of plants and sprouting are affected by ultraviolet radiation (U.V.), and the amount of exposure is proportional to the amount of radiation produced. As a result of radiation exposure, soil may become compacted and lose nutrients necessary for plant growth (Gasmalla, 2014).

Studies in laboratories using screened lamps to provide U.V radiation to plants have shown that higher doses of radiation delivered to the plants were extremely harmful. Radiation causes stomatal tolerance to be disrupted. Stomata are tiny air holes within plant leaves that often regulate water levels. When there is excessive evaporation as a result of heavy radiation, the stomata close to save water. The plant's development is hampered if the stomata are unable to open for an extended period of time. Prolonged radiation exposure will permanently affect the stomata, causing the plant to die (Programme, 2017).

Plant cells produce genes, which are the genetic material responsible for plant reproduction. If the cell is severely affected by radiation, reproduction is hampered. Since UV rays kill cells, the likelihood of mutation increases. Plants that have been affected are mostly tiny and thin, with altered leaf patterns. Persistent exposure to radiation will totally kill a plant's vitality and cause it to die. The environment therefore becomes poisoned, which can preclude potential offspring from growing. According to studies, for several days after the tragic Chernobyl disaster, the herbs, trees, and soil of Sweden and

Norway were showered with radioactive rain, which penetrated the food chain via soil and eventually into the human body. Even now, radionuclides contaminate the lichens that people eat (Gill *et al.,* 2015).

Radionuclides also hasten the rate of plant mutation. Radioactive elements appear to collect in soil sediments, air, and water, eventually reaching humans. Plants are killed by intense radiation in various ways. The reactivity and exposure of trees and shrubs to radioactive contaminants vary. This variation is caused mostly by differences in their size and chromosome number. Sparrow indicated that plants with fewer chromosomes have a greater target for radiation attack than those with an abundance of small chromosomes (Gill *et al.,* 2015).

2.8 Sources and effects of Animals Environmental Radiation

Animals are exposed to radioactive contaminants as a result of chemical pollution, feeding on polluted forages, and consuming contaminated water (Dorea, 2006). Human practices that introduce heavy metals into an animal's habitat include, among other things, the use of rock phosphate fertilizers on croplands, the application of pesticides on livestock or their living facilities, and the use of herbicides. Rock phosphates, for example, contain elevated amounts of radium, thorium, and plutonium, which can contribute to higher radon levels in soil, surface air, and groundwater (decay product of uranium) (Wyman and Stevenson, 2007).

An Analysis conducted in Algeria in 2011 to measure soil radioactivity levels in relation to the use of phosphate fertilizers found a substantial rise in radionuclides in fertilized soils similar to virgin soils (Bramki *et al.*, 2018).

Internal radiation exposure results from radioactive decay of radionuclides inserted into animal tissues through inhalation/ingestion. Ionizing radiation, in whatever form it is administered, has the ability to cause damage by inducing neoplasia and genetic defects at the somatic and germ cell stages, respectively (Upadhyay, 2017).

This is caused by cellular DNA modification or destruction, as well as interfering with metabolic pathways. Single-stranded breaks (SSB), double-stranded breaks (DSB), sugar/base changes, and DNA-protein cross-links are all examples of DNA disruption that can be caused by radiation. Genomic instability, indirect DNA ionization by reactive oxygen species, and direct DNA ionization with subsequent chemical modification of the bases to molecules that are no longer recognized as coding signals are the multiple methods commonly involved in DNA destruction (Chatterjee & Walker, 2017).

Damaged DNA is usually not detected by sensory proteins, resulting in the recruiting of DNA repair enzymes. There is also a parallel generation of signals that prevent the cell cycle from progressing before the weakened DNA is restored. Attempts to repair the damaged DNA can fail depending on the condition, dose rate, and dose of the radionuclide, resulting in cell death or transformation to a malignant state (Cohn & D'Andrea, 2008).

The biological harm caused by radionuclide exposure in an animal is determined by the radionuclide's distribution and retention in the body, the dosage intensity and dose of irradiation, the tissue irradiated, and the animal's height, age, and physiological state. Animal tissue effects of radionuclide toxicity conducted in several laboratory experiments have shown that radionuclides cause damage to different organs and tissues of animals (Stewart *et al.*, 2012).

2.9 Sources and effects of human Environmental Radiation

Humans are on daily basis exposed to ionizing radiations that occur naturally in the environment. Environmental radiation is produced from a variety of sources, including over 60 naturally occurring radioactive materials present in soil, water, and air (Missimer *et al.*, 2019). Soil serves as a source of constant radiation human exposure, as a means of migration for radionuclide delivery to biological systems, and as a source of radiological contaminants in the environment. Radon, a naturally occurring chemical, is the primary source of natural radiation that is emitted from rock and soil (Al-Hamarneh & Awadallah, 2009). Every day, people breathe in and consume radionuclides from the air, food, and water. Radioactivity in the environment comprises of three known radioactive series of uranium, thorium and actinium (Hussain & Hussain, 2011).

The uranium series originates from U-238, the thorium series originates from Th-232 while the actinium series originates from U-235. The ratio of U-235 to U-238 is less than 1%, hence the contribution of U-235 to the environmental dose is very small. The most

important of this is K-40 since it is a gamma- ray emitter in addition to beta decays and therefore contributes immensely to gamma radiation exposure (Xinwei, 2005). The members of the radioactive decay of Th-232 (14%), U-235 (55.8%) and K-40 (13.8%) are the main contributors to the dose from natural source of radiation (Alencar & Freitas, 2005).

Natural radiation from cosmic rays is also a danger, particularly at high altitudes. Human terrestrial and cosmic radiation sources account for about 80% of a person's annual dose of background radiation. Because of geological variations, background radiation levels vary globally (Podolská & Rychtaříková, 2017). In certain cases, exposure can be more than 200 times greater than the global level. Humans are often exposed to radiation from man-made sources such as nuclear power generation and medicinal applications of radiation for diagnosis or treatment. Medical instruments, including X-ray machines, are the most popular man-made sources of ionizing radiation today. Ionizing radiation toxicity can be divided into three categories. The first, expected dose cases, arise from the systematic installation and operation of radiation sources for particular reasons, such as medicinal usage of radiation for patient care or care, or industrial or testing use of radiation (Fushiki, 2013).

Existing exposures are situations in which radiation risk still occurs and a determination on regulation must be made – for example, exposure to radon in households or offices or exposure to normal background radiation from the setting. The last type, emergency

exposure situations, result from unexpected events requiring prompt response such as nuclear accidents or malicious acts (Levitt & Lai, 2010).

Medical radiation utilization accounts for 98 percent of the population dose input from all artificial sources and 20 percent of overall population exposure. Per year, over 3600 million medical radiology tests are conducted globally, 37 million nuclear medicine experiments are performed, and 7.5 million radiotherapy cases are administered (Hendee & Ritenour, 2003).

Radiation produces both useful and harmful effects depending on the amount of dosage received. Radiation is a valuable tool in medicine, research and industry. It is used in medicine to detect illnesses, and in high concentrations, to cure diseases like cancer. Also, high doses of radiation are used to kill harmful bacteria in food and to extend the shelf life of fresh produce (Sherer *et al.,* 2013). Radiation produces heat that is used to generate electricity in nuclear power reactors. Radioactive nuclides are used in a number of security and advertising products, such as smoke detectors and exit signs, and for many other research and industrial purposes. The harmful effects on radiation (ionizing) are either stochastic or non-stochastic (Mettler, 2012). When ionizing radiations interact with body cells chemical reactions occur. Exposure risks to natural radiation can be assessed with a linear, no-threshold dose-response relationship (Tubiana *et al*., 2009). Since there is no dose below which there is absolutely no risk associated with and, moreover, experimental data on this are unavailable.

Stochastic (delayed) effects of radiation occur years later in exposed individuals. It includes cancer induced cases and genetic effects while non-stochastic are immediate effects. These effects are proportional to exposure and dosage and may result in large number of deaths as was experienced in Chernobyl disaster where 2 out of 30 operators died immediately and several others later (UNSCEAR, 2000b). In limiting stochastic effects, various tissues are given consideration in radiation measurements in accordance to recommendations by International Commission on Radiation Protection (Valentine, 2007). Skin and bone surface have a weighting factor of 0.01 while gonads have a factor of 0.20 because gonads are very sensitive to radiation resulting to genetic mutation, thus there is need for great care to reduce exposure to these organs.

Ionizing radiation is a confirmed human carcinogen; skin cancers originated among early X-ray personnel who developed leukemia after dealing around radioactive isotopes, demonstrating its carcinogenic potential (Shuryak *et al.*, 2015). The dependency of cancer risk on background radiation rate varies according to the type of ionizing radiation used. High doses of ionizing radiation (HDR) cause a wide range of negative effects, ranging from acute mortality to late carcinogenesis (Chege, 2015). Many studies have found evidence of harm associated with excessive UV exposure (WHO, 2003). Solar UV radiation is one of the most potent possible physical carcinogens, capable of disrupting skin integrity. UV radiation penetrates the epidermis and causes a host of biochemical effects in the skin's nervous parts of the system. Chronic UV toxicity is a significant environmental factor that contributes to skin aging (Rodriguez *et al.*, 2009).

UV radiations are produced by a wide range of biological and chemical processes, the majority of which are harmful to animal and plant systems (Chadysiene & Girgzdys, 2009). Lung cancer, skin cancer, thyroid cancer, multiple myeloma, breast cancer, stomach cancer, and leukemia are some of the cancers linked to radiation exposure. Leukemia is the most common radiation-induced cancer that develops in the bone marrow. The effects of radiation on human health vary depending on the level of radiation the person was exposed to, the duration of exposure, the type of radiation, the person's age and health, and the area of the body that was exposed. High energy charged particles migrate through living cells, depositing energy that induces structural damage to DNA and alters several cellular processes (Ohnishi *et al.,* 2009).

2.10 Accumulation of radionuclides in animals

Fukuda *et al*., (2013), evaluated emissions of gamma rays from nuclides artificially occurring in a number of organs in cattle around the zone of evacuation in Fukushima nuclear plant accident. It was found that radionuclides of shorter half- lives deposits on specific organs (for instance, 129 mTe and 110 mAg) in the kidney and liver, respectively. Higher concentrations of caesium were also observed in foetal organs rather than in maternal organs. Concentration of radionuclide deposits in internal organs is therefore greatly influenced by the geographic set up and conditions of feeding. Stricker *et al*., (1994), examined the effect of fodder growing on clays that were phosphatic on activity of radionuclides in livestock products. The research found that activity of Ra-226, Po-210, and Pb-210 in bones reached three times higher in magnitude than activity

in the muscle. This suggests a higher affinity for such radionuclides to the skeletal system.

2.11 Radiation exposure parameters calculated from activity concentrations

Diverse radiation dose parameters can be measured using the activity concentration of soil samples. Radium equivalents, absorbed dose rates, annual effective dose rates, and internally and externally hazard indexes are among them, (Ohnishi *et al.*, 2009)

2.11.1 Radium equivalent activity (Raeq)

Radium equivalent (Raeq) is a weighted total of Ra-226, Th-232, and K-40 activities; it is founded on the premise that 370 $Bq.kg^{-1}$ of Ra-226, 259 $Bqkg^{-1}$ of 232Th, and 4810 $Bqkg^{-1}$ of K-40 yield the same gamma radiation exposure amount. Materials with Raeqs higher than 370 $Bqkg^{-1}$ cannot be used to prevent radiation risks (Valentine, 2007).

2.11.2 Absorbed Dose Rates

Radiation released by a radioactive substance is absorbed by the element that it comes into contact with. The dose transfer factors for translating the action concentrations of Ra-226, Th-232, and K-40 into dose ($nGyh^{-1}$per $Bqkg^{-1}$) are 0.427, 0.662, and 0.043, respectively, according to UNSCEAR (2000b).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

The study site is located in West Pokot County. The County lies within Longitudes 340 47' and 350 49' East and Latitude 10 and 20 North. The County covers an area of approximately 9,169.4 km^2 stretching a distance of 132 km from North to South. West Pokot County is situated in the North Rift along Kenya's Western boundary with Uganda. It borders Turkana County to the North and North East, Trans Nzoia County to the South, Elgeyo- Marakwet County and Baringo County to the South East and East, respectively (County Government of West Pokot, 2013).

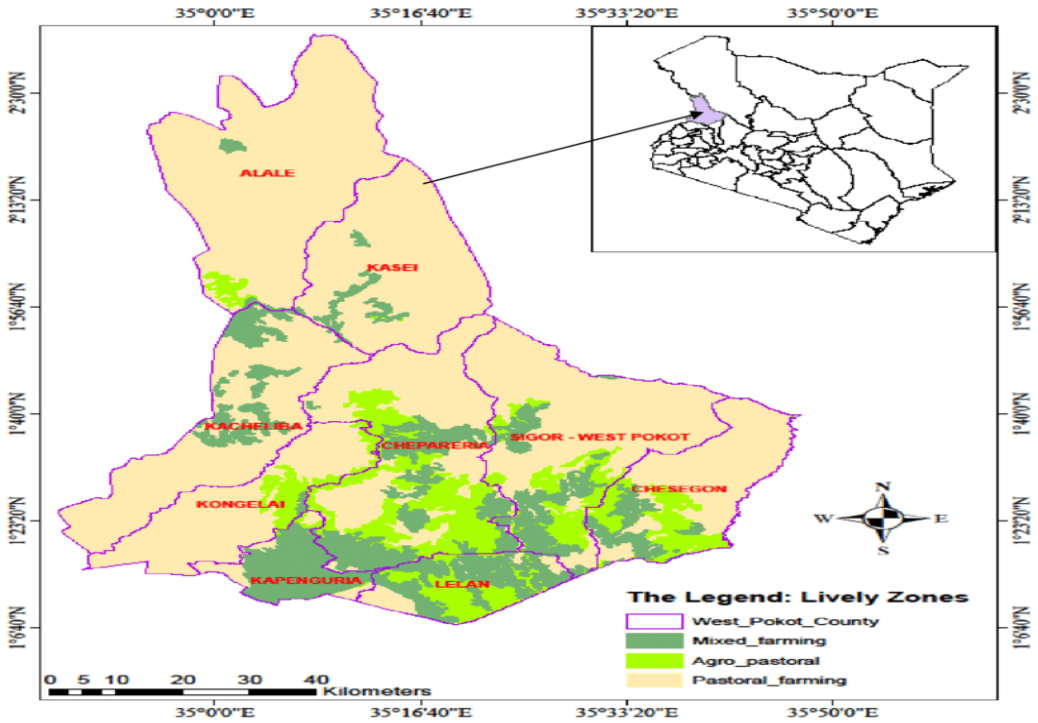

Figure 3.1: Map of West Pokot County (source: WFPA/AM Kenya, June 2005)

The tan coloured region represents West Pokot County.

Figure 3.2 A map showing the administrative divisions of West Pokot and livelihood zones (source: WFPA/AM Kenya, June 2005)

The county is characterized by a variety of topographic features. On the Northern and North Eastern parts are the dry plains, with an altitude of less than 900 m above sea level. On the South Eastern part are Cherang'any Hills with an altitude of 3,370 m above sea level. Landscapes associated with this range of altitude include spectacular escarpments of more than 700 m. The high-altitude areas have high agricultural potential while medium altitude areas lie between 1,500 m and 2,100 m above sea level and receive low rainfall in addition to being predominantly pastoral land. The low altitude areas include Alale, Kacheliba, Kong'elai, Masol and parts of Sigor. These areas are prone to soil erosion due to flash floods (County Government of West Pokot, 2013).

The county has a bimodal type of rainfall. The long rains fall between April and August while the short rains fall between October and February. There is, however, great variation in the total amount and distribution of rainfall received in the county. The lowlands receive 600 mm per annum while the highlands receive 1,600 mm per annum (County Government of West Pokot, 2013).

The county also experiences great variations in temperature with the lowlands experiencing temperatures of up to 30^{o}C and the highlands experiencing moderate temperatures of 15^{o}C. These high temperatures in the lowlands cause high evapo-transpiration which is un-favourable for crop production. The high-altitude areas with moderate temperatures experience high rainfall and low evapo-transpiration hence suitable for crop production (County Government of West Pokot, 2013).

The soil types vary from shallow and friable in the lowlands to deep, well-drained, reddish brown sandy loams in the upper regions of West Pokot (Sposito, 2013), while soil fertility varies from low to moderate (FAO, 2006). The vegetation is mainly steppe-like, dominated by grasslands and interspersed native and exotic tree species (Svanlund, 2014).

Two groups can be identified: Hill Pokots practicing both agriculture and pastoralism located in the rainy highlands of the West and Central South areas, Kapenguria and Alale and Plain Pokots found in the dry and infertile plains, being the majority. Historically though, the "people's livelihoods are pastoralism and cattle are at the heart of their culture" (Kopel *et al*., 2008).

The population of the county is estimated at 621,241 persons as per 2019 projections. This population consists of 307,013 males, 314,213 females and 15 intersex persons giving a sex ratio of 100:101. The county inter-censual growth rate is 5.2 percent which is higher as compared with the national average of 3.0 percent. If current trends prevail, the county population is expected to grow to 653,546 and 687,530 in 2022 and 2024, respectively. It is also worth noting that the youth (aged 15-34 years), whose population estimate is 196,830 forms 31 percent of the county population (State department of devolution, 2019).

The samples (rocks, rock licks, soil, and leaves) were collected from Mtembur and Atulya in Pokot North sub-county. The caves where rock lick samples were collected

were the ones mostly frequented by domestic livestock as directed by the local elders. Most of such caves are found near water sources although a few could be found away from the rivers. Soil and rock lick samples from Atulya were from an isolated area where livestock had been barred from accessing. The local elders claim the rock lick is harmful to their livestock.

Rock samples from both Mtembur and Atulya were collected from sedimentary basements along the roads. It was easy to obtain rocks from the underlying sediments due to ongoing road constructions in the sub-county.

Leaves of the *Balatanias aegyptica*, (desert date, mchunju) tree were collected from both Mtembur and Atulya. This is a common tree in the region that is edible by livestock and the local inhabitants. The animals eat the leaves, the bark and the thorns, especially the goats. The locals boil the leaves and use as vegetables together with the local ugali.

Animal skins and bones were collected from a butchery at Makutano trading centre. Samples were taken to the National Radiation and Protection Board laboratory, Nairobi, for analysis. The leaves were treated and analyzed using the R.E Ratemeter 903 which gives its values in counts per minute (cpm), while the soil, rock, rock lick and animal parts samples were analyzed using the LB 200 Becquerel monitor which gives its values in $Bqkg^{-1}$.

3.2 Sampling

3.2.1 Soil Sampling

Purposive sampling method was used to identify points for soil sampling where deformed domesticated animals are commonly found. Three sites were selected. A transect sampling pattern was used for field sampling. Soil samples were collected to a depth of 50 cm using soil augers that were kept clean and rust free. Three samples were collected at each site giving a total of nine samples. Collected samples were stored in labeled polythene bags. Stones and grass were removed from the soil, sun dried and ground with a grinder to powder then sieved through 100 μm mesh wire. A 500 grams of each of the soil samples were stored in sealed plastic containers and left for one month to dry. The samples were placed in uniform plastic containers, their masses determined and sealed for 30 days so that an equilibrium could be achieved where the rate of decay of the progeny becomes equal to that of the parent, (U-238 and Th-232), within the volume and the progeny also remained in the sample. Nine soil samples were analyzed (Xhixha *et al*., 2013).

3.2.2 Leaf sampling

The samples were sun dried before radioactivity measurement for 3-4 days at a temperature of 30^{o}C to ensure all moisture was lost. The samples were then cut into very small pieces using a blender and mixed with activated charcoal then sealed for about one

month to reduce leaching and to attain radioactive equilibrium between radon and thorium decay products (Xhixha *et al*., 2013).

3.2.3 Rock sampling

Purported rock samples from the two sites were chipped off from the cave surfaces using a pick axe. The samples were placed in polybags for transportation. The rocks were crushed to powder and passed through a 2 mm mesh sieve. The powdered rock was stored in plastic containers and taken to laboratory for radionuclide determination (Gbadebo, 2011; Cetin *et al*., 2012).

The powdered rock was transferred to a 1 litre Merinelli beaker and firmly sealed for secular equilibrium with the radioactive progeny prior to gamma determination for 4 weeks (Kaharan *et al.*, 2000).

3.2.4 Animal parts sampling

Animal parts sampled were skins and bones. The samples were obtained from a butchery in Makutano trading centre within West Pokot. Collected samples were placed in plastic containers with formalin and tightly sealed for transport to the laboratory. They were dried at room temperature for 2 weeks before being oven dried at 105^{o}C for 3 hours. The dried samples were heated under controlled temperatures and ground to powder and placed in sealed plastic containers to attain equilibrium between the radioactive progenies.

3.3 Radio safety

3.3.1 Radio safety in the field

While collecting the samples, protective clothing was used. These included gloves, and an X-ray jacket (lead-dust coat).

3.3.2 Radio safety in the laboratory

Laboratory personnel put on protective attire including sturdy and disposable lead gloves, gas masks, leaded dust coats, protective foot wear, etc. The samples were shielded to minimize radio-emissions to the personnel. The contaminated area was defined using a survey meter. Radioactive samples were kept in a secured container and visitors were supervised in the laboratory.

3.3.3 Sample Preparations for Radioactivity Measurements

The samples collected from the two regions were transported to the National Radiation Protection Board laboratory (Nairobi) for radioactivity analysis. The samples were oven-dried at 105^{o}C for 48 hours to constant weight, before preparation. Storage of the samples for a minimum period of one month was allowed to enable equilibrium of Ra-226 with its decay products in the uranium series and Ra-228 with its daughters in the thorium series.

The samples were crushed using a pestle and mortar to reduce the particle sizes and ensure homogeneity. This was followed by sieving to ensure particle sizes less than the mesh. For each sample, mechanical grinding was carried out using a Fritsch Pulverisette type 120 for about 20 minutes each to further reduce the particle size. Sample weights of 500 g were portioned in a beaker for gamma radiation analysis.

To avoid detector contamination and sample cross-contamination, every beaker used was cleaned with a solution of EDTA and dried before putting in a new sample. To enable calculation of activity concentration using the intercomparison method, the background spectrum, standard reference material spectrum and the samples spectra were collected.

The background spectrum was collected by counting an empty beaker for 20 hours. Spectra acquisition for the samples and the standard reference material was carried out by counting a known mass of material for a minimum period of 5.6 hrs. However, a spectrum for the standard material was collected daily for use in the activity calculations, with sample spectra collected on any particular day.

3.4 Instruments used

The instrument used in the laboratory was LB 200 Bequerel Monitor. It is a scintillation instrument for the assessment of gamma activity in both solid and liquid samples giving the measurements in Bql^{-1} or $Bqkg^{-1}$. The maximum time it can take to give accurate measurements is 1 hour. Statistical accuracy is displayed for each measuring result hence the user can decide how long the measurement should be. The accurate result can be read off a few seconds after the start of the measurement.

For leaf samples and animal parts samples that were less than 500 g, an R.E Ratemeter 903 was used for analysis giving its measurement in counts per second, CPS. It has a pancake GM probe and a foot monitor with specified efficiency.

Plate 3.1: An R.E Ratemeter 903 with a GM foot monitor

Plate 3.2: Plate 2: An LB 200 Becquerel monitor

Plate 3.3:Photographs from the sampling sites. (SOURCE: Author, 2018).

Clockwise 1)-inside a rock lick cave in Mtembur, 2)-with Pokot North veterinary officer and local chiefs, 3)-collecting soil samples in Atulya, 4)-collecting soil samples in Mtembur, 5)-collecting soil samples under *Balanites aegyptica* in Mtembur and 6)-after collecting the samples at Atulya with a local chief

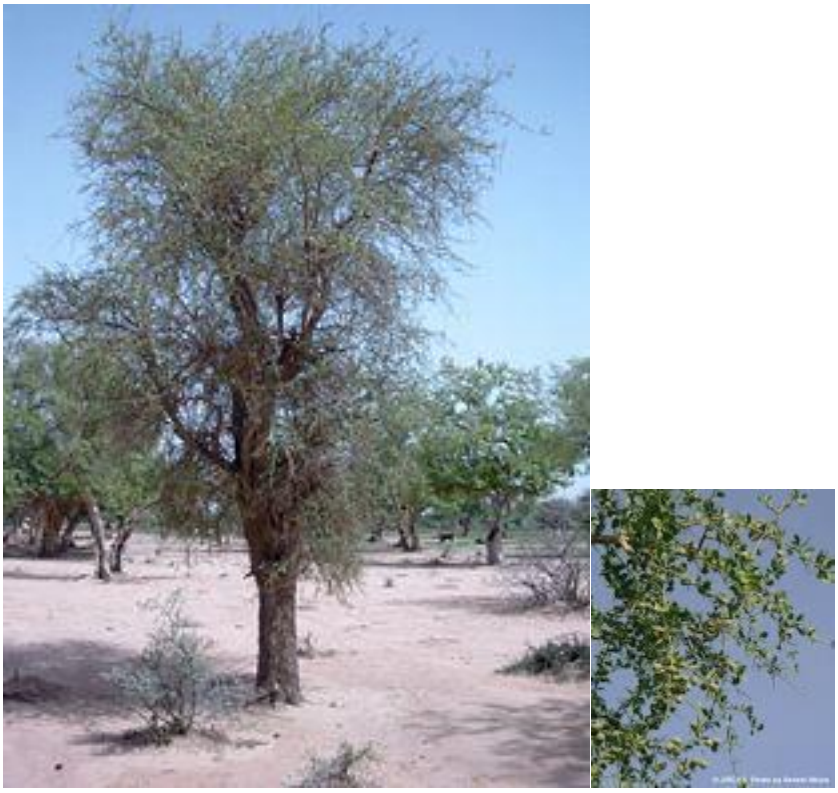

Plate 3.4: A picture of *Balanites aegyptica* (desert date) tree. (SOURCE: Author, 2018).

3.5 Statistical analysis

The collected data were analysed descriptively using SPPS statistical analysis and results were presented in tables and figures. Pearson correlation was used to analyse correlation of activity radiations between variables. t-test and ANOVA were used to analyse if there was any significant difference between two variables.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Collection site characteristics

The sites are characterized by dry plains with low altitude of 900 m above sea level which are prone to soil erosion due to flash floods. The soils are shallow and friable with low fertility. Vegetation is mainly steppe-like with grasslands and interspersed native tree species (Maina *et al*., 2004).

4.2 Results from Mtembur

Table 4.1: Activity concentration in Bql^{-1} of soil (B_1), rock licks (B_2) and crushed rock (B_4) samples from Mtembur

Soil (B_1)	Rock lick (B_2)	Crushed rock (B_4)
227	350	301
228	348	300
229	346	299
230	345	302

From Table 4.1, rock lick samples had a higher activity concentration (345-350) Bql^{-1} compared to crushed rock (299-302) Bql^{-1} while the soil samples (B_1) had the lowest activity concentration (227-230) Bql^{-1}.

4.3 The mean activity concentration for soil, rock licks and crushed rocks from Mtembur

The samples activity concentration from soil, rock licks and crushed stones collected from Mtembur were analyzed and the results presented in figure 4.1.

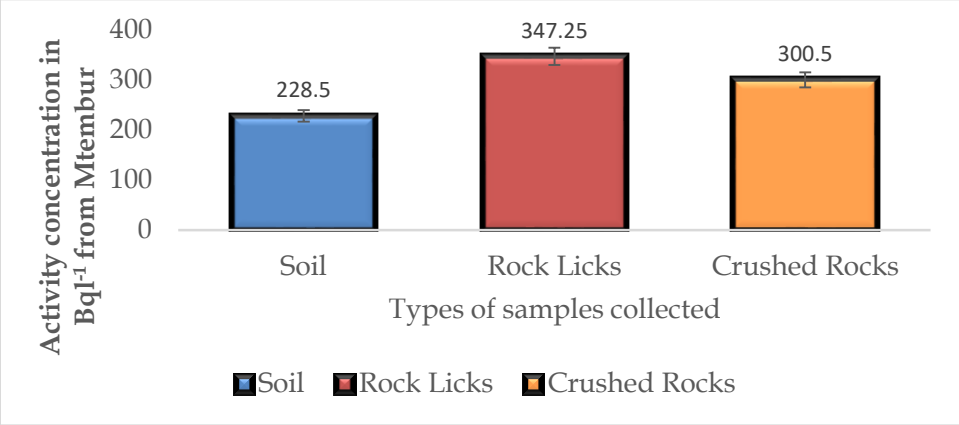

Figure 4.1: Activity concentration in Bql^{-1} of soil (B_1), rock licks (B_2) and crushed rock (B_4) samples from Mtembur

From Figure 4.1, rock lick samples from Mtembur had a higher mean activity concentration (347.25± 1.109) Bql^{-1}compared to crushed rock (300.50 ± .645) Bql^{-1} while the soil samples (B_1) had the lowest mean activity concentration (228.50 ±.645) Bql^{-1}.

4.3 Results from Atulya

Table 4.2: Activity concentration in (Bql^{-1}) of soil (A_1), rock licks (A_2) and crushed rock (A_3) samples from Atulya

Soil (A_1)	Rock lick (A_2)	Crushed rock (A_3)
298	334	302
303	337	304
300	337	298
299	335	300

From Table 4.2, rock lick samples had a higher activity concentration (334-337) Bql^{-1} compared to crushed rock (298-304) Bql^{-1} while the soil samples had the lowest activity concentration (298-303) Bql^{-1}.

4.4 The mean activity concentration for soil, rock licks and crushed rocks from Atulya

The samples activity concentration from soil, rock licks and crushed stones collected from Atulya were analyzed and the results presented in Figure 4.2.

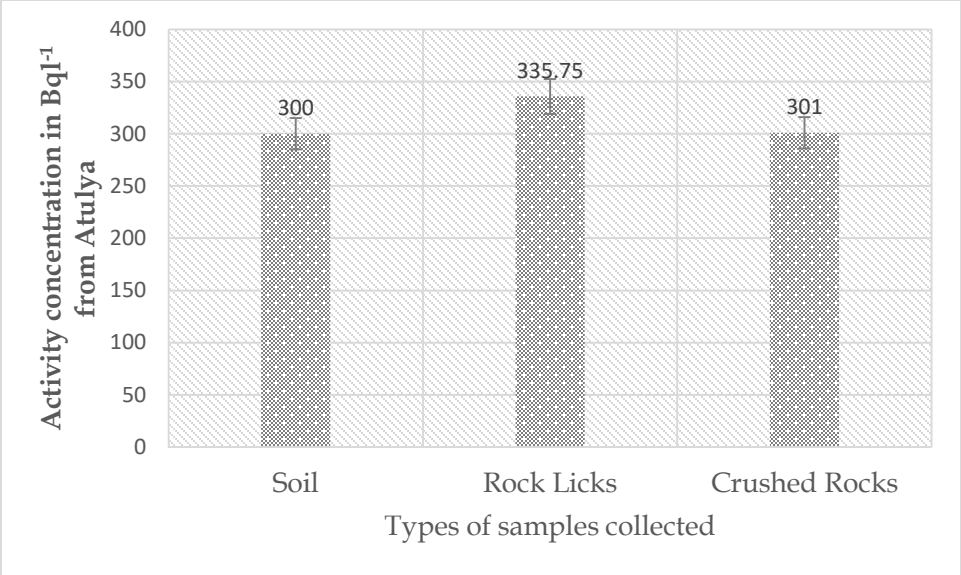

Figure 4.2: Activity concentration in (Bql^{-1}) of soil (A_1), rock licks (A_2) and crushed rock (A_3) samples from Atulya

From Figure 4.2, rock lick samples had a higher mean activity concentration (335.75 ± 0.750) Bql^{-1} compared to crushed rock (301.00 ±1.291) Bql^{-1} while the soil samples had the lowest activity concentration (300.00 ± 1.080) Bql^{-1}.

4.4 Results for animal parts (skin and bones)

Table 4.3: Activity concentration of animal parts (skin and bones) in Bql^{-1}

Skin	Bones
161	167
163	169
164	165
160	167

From Table 4.3, when compared to Tables 4.1 and 4.2, both animal parts had lower activity concentrations: 160-164 Bql^{-1} for the skin and 165-169 Bql^{-1} for the bones.

4.5 The mean activity concentration for cattle's skin and bones collected from West Pokot County

The samples activity concentration from cattle's parts (skin and bones) collected from butcheries from West Pokot County were analyzed and the results presented in Figure 4.3.

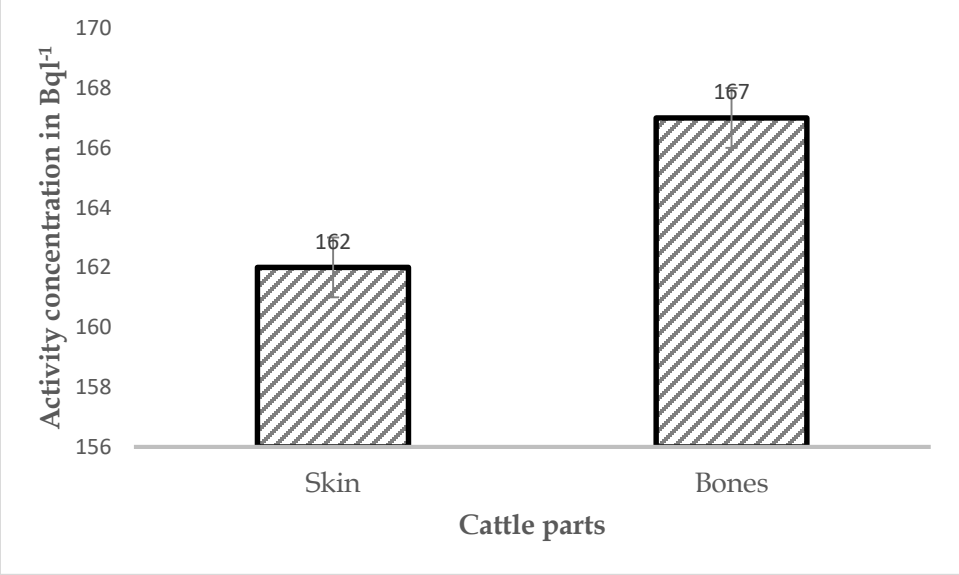

Figure 4.3: Activity concentration of animal parts (skin and bones) in Bql^{-1}

From Figure 4.3, both animal parts had lower mean activity concentrations: 162.00 ± .913 Bql^{-1} for the skin and 167.00 ± .816Bql^{-1} for the bones.

4.5 The R.E Ratemeter results of activity concentration for leaves, soil, rock licks, crushed rock and soil

Table 4.1 shows concentration of leaves, crushed rock, rock lick and soil samples in counts per minute (cpm) in both areas (Mtembur and Atulya). The table values were compared to the cpm reading of the standard Americium reading which was 65 cpm.

Table 4.4: Sample results using the R.E Ratemeter, (cpm)

Sample	Mtembur	Atulya
Leaves	56	57
Rock	70	70
Rock lick	72	75
Soil	69	71

The standard Americium sample had a cpm of 65.

The results of leaves, crushed rock, rock lick and soil samples in counts per minute (cpm) in both areas (Mtembur and Atulya) indicated high concentrations which were above standard Americium sample of 65 cpm.

4.6 Correlation Studies between activity concentration in soil, rocks, crushed rocks, leaves and animal parts found in Mtembur in West Pokot County

The presence of radiation activity concentration in leaves could be occurring naturally in the plant or sourced from soil. The study established the correlation between the radiation activity concentrations in soil verses activity levels in leaves and also in soil verses cattle's parts (skin and bone). There was a negative correlation between radiation activity levels within soil and leaves from Mtembur in West Pokot County (0.368, $p>0.05$). This means that the radiation activity levels found in soil appears to not influence the uptake of radiation leaves. There were also negative correlation between radiation activity levels within rock licks and skin (0.1, $p>0.05$) and between rock licks and bones (0.632, $p>0.05$) found in Mtembur. Further, radiation activity concentration appears not to influence the uptake of radiation in the cattle parts sampled. Results analyzed are presented in table 4.2 as shown below. Other correlation tables for rocks, rock licks and animal parts are found in the appendices.

Table 4.5: Correlation studies between activity concentration in soil and leaves found in Mtembur West Pokot County

		Soil	Leaves
Soil	Pearson Correlation	1	0.632
	Sig. (2-tailed)		0.368
	Sum of Squares and Cross-products	8.000	4.000
	Covariance	2.667	1.333
	N	4	4
Leaves	Pearson Correlation	.632	1
	Sig. (2-tailed)	.368	
	Sum of Squares and Cross-products	4.000	5.000
	Covariance	1.333	1.667
	N	4	4

Table 4.5: Correlation studies between activity concentration in soil and leaves found in Mtembur West Pokot County

The study also looked at the correlation of radiation activity concentration between the leaves and animals' parts (skin and bones). There was negative relationship of radiation activity concentration between the leaves and skin (0.145, $p>0.05$) and between leaves and bones (0.522, $p>0.05$) found in Mtembur. The radiation activity concentration in the leaves appears not to influence the uptake of radiation in the cattle parts sampled.

The study further looked at the correlation in radiation activity concentration between crushed rocks and cattle parts (skins and bones). There were negative correlations

between radiation activity levels within crushed rocks and skin as the correlation coefficient was (0.01, $p>0.05$), while crushed rocks and bones (0.684, $p>0.05$). It was also found radiation activity concentration in the crushed rocks did not influence the uptake of radiation in the cattle parts sampled.

4.7 Correlation Studies between activity concentration in soil, rocks, crushed rocks, leaves and animal parts found in Atulya in West Pokot County

The presence of radiation activity concentration in leaves could be occurring naturally in the plant or sourced from soil. The study established the correlation between the radiation activity concentrations in soil verses activity levels in leaves and also in soil verses cattle's parts (skin and bone). There was a negative correlation between radiation activity levels within soil and leaves found in Atulya (0.548, $p>0.05$). This means that the radiation activity levels found in soil appears not to influence the uptake of radiation leaves. There were negative correlations between radiation activity levels within rock licks and skin (0.148, $p>0.05$) and between rock licks and bones (0.1, $p>0.05$) found in Atulya. Radiation activity levels seemed not to influence the uptake of radiation in the cattle parts sampled.

This study also considered the correlation of radiation activity levels between the leaves and animals' parts (skin and bones) sampled from Atulya. There was positive correlation of radiation activity concentration between the leaves and skin (0.038, $p>0.05$) implying that radiation activity concentration in the leaves influenced the uptake of radiation in the cattle skin sampled. However, negative correlation between radiation activity levels

within leaves and bone was noted with the correlation coefficient (0.522, $p>0.05$). Therefore, radiation activity concentration in the leaves would not influence the uptake of radiation in the cattle bones sampled from Atulya in West Pokot County.

The study further evaluated the correlation in radiation activity levels between crushed rocks and cattle parts (skins and bones). There were negative correlations between radiation activity levels within crushed rocks and skin as the correlation coefficient was (0.859, $p>0.05$) and radiation activity concentration in the crushed rocks did not appear to influence the uptake of radiation in the cattle skin sampled. However, there was a positive correlation between radiation activity levels within crushed rocks and bones with a correlation coefficient of (0.050, $p>0.05$) which means radiation activity concentration in the crushed rocks influenced the uptake of radiation in the cattle bones sampled.

4.8 Comparisons in radiation activity concentration between Mtembur and Atulya region in West Pokot County for soil, crushed rocks and rock licks

Paired t-test was carried out to determine if there existed significant differences in the activity concentration of radiation in soil, rocks and rock licks in the two sampled sites (Mtembur and Atulya) in West Pokot County. The outcomes are presented in table 4.3.

Table 4.6: Paired Samples T- test results comparing activity concentration in soil, rock licks and crushed rocks from two sites in West Pokot County

Samples	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Soil	-72.500	3.512	1.756	-78.088	-66.912	-41.288	3	.000
Rock licks	11.500	3.109	1.555	6.553	16.447	7.398	3	.005
Crushed rocks	-.500	2.646	1.323	-4.710	3.710	-.378	3	.731

According to T- test results above, the p-values of soil, rock licks and crushed rocks were 0.00, 0.005, and 0.731, respectively. The results of soil (P=0.000, df=3, t=-41.288) and rock licks from Atulya and Mtembur were below 0.05 (P=0.005, df=3, t=7.398) significance level implying there was a significance at 95 % in activity concentration from the two regions.

However, the results of crushed rocks from Atulya and Mtembur was above 0.05 (P=0.731, df=3, t=-0.378) significance level indicating there was no significance at 95 % in activity concentration from the two regions.

4.9 Comparisons in radiation activity concentration between cattle's skin and bones from West Pokot County

Paired t-test was carried out to determine if there existed significant differences in the activity concentration of radiation in cattle's skin and bones from West Pokot County. The outcomes are presented in table 4.4.

Table 4.7: Paired Samples t- test results comparing activity concentration in cattle skin and bones from West Pokot County

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Bones – Skin	5.000	2.708	1.354	.691	9.309	3.693	3	0.034

According to t - test results above, the p-value between skin and bones collected from West Pokot County was (P=0.034, df=3, t=3.693) and was below 0.05 significance level indicating there was a significance at 95 % in activity concentration between cattle skin and bones.

4.10 Comparisons of radiation activity levels found in soil, rocks licks and crushed rocks from Mtembur region West Pokot County

To determine whether there existed any significant differences in activity concentration among soil, rock licks and crushed rocks from Mtembur and Atulya West Pokot County, one-way analysis of variance was conducted. The results are presented in Table 4.5

Table 4.8: One Way ANOVA activity concentration for soil, rock licks and crushed rocks from Mtembur and Atulya

		Sum of Squares	Df	Mean Square	F	Sig.
Mtembur	Between Groups	28628.167	2	14314.083	5205.03	.000
	Within Groups	24.750	9	2.750		
	Total	28652.917	11			
Atulya	Between Groups	3315.500	2	1657.750	366.129	.000
	Within Groups	40.750	9	4.528		
	Total	3356.250	11			

The activity concentration of soil, rock licks and crushed rocks were both (p 0.05) significantly different in Mtembur (P=0.000, df=9, F=5205.03) and Atulya (P=0.001, df=9, F= 366.129).

4.11 Activity concentration and absorbed dose rates

Tables 4.6-4.12 show the activity concentration of the samples collected and the calculated absorbed dose rates. Exposure in µSv/h was calculated by dividing the activity concentration by a constant unit of 5000 (Glenn, 2000). To obtain the effective dose rate in mSv/y, the exposure was multiplied by a constant value of 12.2857. The obtained value of effective dose rate was multiplied by a further 1000 constant unit to obtain the absorbed dose rate (Faanu *et al.*, 2011)

The results from the ratemeter were also converted to show exposure and absorption doses. To convert cpm to µSv/h, the cpm value was divided by a constant unit of 1200 (Glenn, 2000).

Table 4.9: Activity concentration and absorbed dose rates for soil samples (B_1) from Mtembur

Activity conc. (Bql^{-1})	Exposure µSv/h	Effective dose rate mSv/y	Absorbed dose rate nGy/h
227	0.0454	0.5578	45.4
228	0.0456	0.5602	45.6
229	0.0458	0.5626	45.8
230	0.0460	0.5651	46.0

The effective dose rates ranged between 0.5578-0.5651 mSv/h while the absorbed dose rates ranged between 45.4-46.0 nGy/h. These values were above the suggested minimum by UNSCEAR (2000b) of 0.5 mSv/h and 30 nGy/h.

Table 4.10: Activity concentration and absorbed dose rates for rock lick samples (B_2) from Mtembur

Activity conc. (Bql^{-1})	Exposure µSv/h	Effective dose rate mSv/y	Absorbed dose rate nGy/h
350	0.07	0.8599	70.0
348	0.0696	0.8551	69.6
346	0.0692	0.8502	69.2
345	0.069	0.8477	69.0

The values obtained are 0.8477-0.8599 mSv/h (effective dose rates), and 69.0-70.0 nGy/h (absorbed dose rates) were higher than the suggested UNSCEAR (2000b) of 0.5 mSv/h and 30 nGy/h.

Table 4.11: Activity concentration and absorbed dose rates for animal parts samples

Activity conc. (Bql^{-1})	Exposure µSv/h	Effective dose rate mSv/y	Absorbed dose rate nGy/h
161	0.0322	0.3955	32.2
163	0.0326	0.4005	32.6
164	0.0328	0.4029	32.8
160	0.032	0.3931	32.0

Compared to UNSCEAR (2000b) suggested values of 0.5 mSv/h and 30 nGy/h, the effective dose rates obtained were lower at 0.3931-0.4029 mSv/h, while the absorbed dose rate was nearly close (32.0-32.8 nGy/h) to that suggested by UNSCEAR value.

Table 4.12: Activity concentration and absorbed dose rates for crushed rock samples (B_4) from Mtembur

Activity conc. (Bql^{-1})	Exposure µSv/h	Effective dose rate mSv/y	Absorbed dose rate nGy/h
301	0.0602	0.7395	60.2
300	0.06	0.7371	60.0
299	0.0598	0.7346	59.8
302	0.0604	0.7421	60.4

Exposure obtained within the range of 0.7346-0.7421 mSv/h was higher than the international exposure limit value of 0.5 mSv/h. Absorbed dose rate was also higher at 59.8-60.4 nGy/h against that suggested by UNSCEAR (2000b) of 30 nGy/h.

Table 4.13: Activity concentration and absorbed dose rates for rock lick samples (A_1) from Atulya

Activity conc. (Bql^{-1})	Exposure µSv/h	Effective dose rate mSv/y	Absorbed dose rate nGy/h
334	0.0668	0.8206	66.8
337	0.0674	0.8280	67.4
337	0.0674	0.8280	67.4
335	0.067	0.8231	67.0

The concentration obtained above within the range of 0.8206-0.8280 mSv/h was higher than the internationally suggested exposure level of 0.5 mSv/h. Also absorbed dose rates ranging from 66.8 to 67.4 nGy/h were higher than 30 nGy/h.

Table 4.14: Activity concentration and absorbed dose rates for soil samples (A_2) from Atulya

Activity conc. (Bql^{-1})	Exposure µSv/h	Effective dose rate mSv/y	Absorbed dose rate nGy/h
298	0.0596	0.7322	59.6
303	0.0606	0.7445	60.6
300	0.06	0.7371	60.0
299	0.0598	0.7346	59.8

The values from the table showed elevated exposure ranges of 0.7322-0.7445 mSv/h and 59.6-60.6 nGy/h for corresponding effective dose rate and absorbed dose rate. In comparison, they were higher than the suggested UNSCEAR (2000a) values of 0.5 mSv/h and 30 nGy/h, respectively.

Table 4.15: Activity concentration and absorbed dose rates for crushed rock samples (A_3) from Atulya

Activity conc. (Bql^{-1})	Exposure µSv/h	Effective dose rate mSv/y	Absorbed dose rate nGy/h
302	0.0604	0.7421	60.4
304	0.0608	0.7470	60.8
298	0.0596	0.7322	59.6
300	0.06	0.7371	60.0

Higher concentrations of exposure were witnessed, 0.7322-0.7470 mSv/h and 59.6-60.8 nGy/h compared to the required UNSCEAR (2000b) suggested corresponding values of 0.5 mSv/h and 30 nGy/h.

Table 4.16: Conversion of cpm values to effective and absorbed dose rates

Location	Sample	cpm	µSv/h	mSv/y	nGy/h
	Rock	70	0.058	0.7166	58.0
	Leaves	56	0.0466	0.573	46.6
Mtembur	Soil	69	0.0575	0.706	57.5
	Rock lick	72	0.06	0.7371	60.0
	Rock	70	0.058	0.7166	58.0
Atulya	Leaves	57	0.0475	0.5835	47.5
	Soil	71	0.059	0.7269	59.0
	Rock lick	75	0.0625	0.7678	62.5
Standard	Americium	65	0.0542	0.6655	54.2

Table 4.13 shows conversions of rock, leaves, soil and rock lick samples from the sampling areas. The conversion was done from cpm to exposure doses (µSv/h), effective dose rates (mSv/h) and absorbed dose rates (nGy/h).

From the results the samples showed higher activity levels for both sampling sites. Therefore H_{01} is rejected. It was also noted that the activity levels can cause deformities to the domestic animals hence H_{02} is rejected. Further the activity levels were above the

suggested WHO and NEMA values therefore H_{03} is also rejected. The correlations from analysis were negative hence H_{04} was rejected.

CHAPTER FIVE

DISCUSSION

5.1 Discussion

Figures 4.4 and 4.5 show that rock lick samples had higher activity levels in both Mtembur and Atulya compared to crushed rock samples. In Mtembur, activity level for rock lick samples ranged from 345-350 Bql^{-1} while in Atulya, it ranged from 334-337 Bql^{-1}. Crushed rock samples in the two regions ranged from 299-302 Bql^{-1} and 298-302 Bql^{-1} respectively. Similar findings by Anjos *et al*., (2005), reported that exposed rocks had higher activity concentration compared to unexposed samples. While studying sedimentary rock layers and granitic rocks commercially mined, it was showed that granite fragments registered lower radioactive counts compared to the underlying granitic basement rock. The sedimentary layers gave the same observation. The underlying basement granite and sedimentary layers gave radioactive counts of 308-313 Bql^{-1} and 302-307 Bql^{-1} respectively while the fragmented pieces of granite and sedimentary rocks showed correspondingly lower counts of 296-302 Bql^{-1} and 290-297 Bql^{-1}. These findings were in agreement with the findings of this research which also showed lower radioactive counts for crushed rock samples compared to the rock samples.

In Brasilia, a study research reported higher counts on commercially mined granitic rocks ranging from 370-377 Bql^{-1} compared to unexposed samples which ranged from 308-313 Bql^{-1}. This report agrees with the current results in the tables which showed exposed rock lick samples having higher count rates than the crushed rock samples. This could be

attributed to rock lick samples being the main materials holding the radioactive substances within the rock basement or layers (Vano *et al.,* 2006)

Lundquist *et al.,* (2005), studied radioactive counts in salty rock licks in selected salt ingestion caves along the Mediterranean region. The findings showed elevated count rates from unexposed salt lick caves (313-319 Bql^{-1}) compared to exposed salt lick rocks (303-309 Bql^{-1}). The findings of that study agree with the current research findings which showed higher radioactive counts for rock licks in unexposed areas (345-350 Bql^{-1}) compared to the radioactive counts from exposed rock lick areas (299-302 Bql^{-1}).

From Figure 4.1, rock lick samples had a higher activity concentration (345-350) Bql^{-1} compared to crushed rock (299-302) Bql^{-1} while the soil samples (B_1) had the lowest activity concentration (227-230) Bql^{-1}. The low activity concentration in soil samples could be attributed to effects of soil forming processes which could lead to loss of radiation nuclides in the process as soil is being formed (Svanlund, 2014). Weathering processes involve transfer of weathered rock particles down the slope hence there is subsequent loss of radioactive nuclide particles. The final soil deposited may have a lower concentration of radionuclide activity than the original rock. Even if soil is formed in-situ, agents of weathering for example, wind play a significant role in displacing rock particles containing the radioactive nuclides. Arafa (2004) found that activity concentration decreases as the granite rock is weathered to soil. In his study, granite samples collected from the eastern desert of Egypt showed a higher activity concentration

(323 Bql^{-1}) compared to soils from the same area (198 Bql^{-1}). This shows that weathering agents have an effect in the loss of radioactive material from the original basement rocks.

Weathering is the physical and chemical change over time of ground under influence of biosphere consisting of atmosphere, hydrosphere and cryosphere involving nuclear radiations. Quantities of weathered material removed do not need to be large to change the geotechnical properties of a ground mass (Mohanty *et al*., 2004). Exogenic processes (physical, chemical and biological), will alter the physical and chemical state of rocks near the earth's surface. Intensity of weathering decreases with depth since variations in temperature and moisture decreases with depth. Hence, weathering is mostly confined to the uppermost few metres of soil and rock. Some of the processes contributing to weathering are here under discussed.

Hydration is wetting, swelling and disintegration of soil aggregates and fine grained rocks. Pressure of air drawn into pores under dry conditions and trapped as water advances into soil and rock exert considerable stress, such as biotite expands 40% by volume contributing to weathering of granite. Montmorillonite, bentonite, illite and kaolinite expand by 150%, 1500%, 120% and 50%, respectively (Revelli, 2010).

Oxidation processes lead to loss of an electron from an element within the rock to the dissolved oxygen. Iron is the most commonly oxidized mineral from Fe^{2+} to Fe^{3+} as shown by the chemical reaction:

$$4FeO + O_2 \rightarrow 2Fe_2O_3 \quad \text{.........} 1$$

Others are magnesium, sulphur, aluminium and chromium.

Hydrolysis is the decomposition of minerals as H^+ ions which replace cations in minerals. Pure water is a poor H^+ donor but CO_2 dissolves in water to produce carbonic acid:

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^- \quad \ldots\ldots 2$$

Carbonic acid readily reacts with calcium carbonate in rocks often resulting in Karst scenery, shown by the chemical reaction:

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^- \quad \ldots\ldots 3$$

Hydrolysis is most important in weathering of silicate minerals. In feldspars, hydrolysis affects kaolinite to a large extent. Other weathering products such as silicic acid and ions are in solution hence the residue is clay, as can be shown by the chemical equation,

$$2KAlSi_3O_8 + 2H_2CO_3 + 9H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 4H_4SiO_4 + 2K^+ + 2HCO_3^- \quad \ldots\ldots 4$$

Chelation can also take place where mineral cations get incorporated into hydrocarbon molecules (Singh *et al*., 2009). Chelates are stable at pH under which the incorporated cation would normally precipitate hence leached in seeping soil water. H^+ released during chelation is available for hydrolysis.

From the results shown in Figures 4.1 and 4.2, soil samples varied in radioactive concentrations. Atulya had higher activity concentrations (298-303 Bql^{-1}) than Mtembur (227-230 Bql^{-l}). The difference in levels is due to the topography of the two areas which shows a sloppy nature that favours Atulya in terms of deposition of weathered soil and soil erosion. Being on the lower ground, agents of weathering often transport weathered materials from Mtembur (highland area) to Atulya (lowland area). Radioactive levels vary on earth from place-to-place ranging from narrow limits to abnormally high levels

(Allisy-Roberts & Burns, 2005). This observation mainly depends on the distribution of rocks the soil originated from. Weathering and deposition as soil contribute to sediment pollution. As a result, deposition is higher on the lower and drier areas. Anjos *et al.*, (2005), pointed out that natural rocks such as granite, limestone, dolomite and marble vary in their radionuclide concentrations. This impact is negative on phosphate rocks which are easily eroded and weathered to form soils.

Further, in comparison, samples collected from Atulya (Figure 4.2) had higher activity concentrations than samples taken from Mtembur (Figure 4.1). This is attributed to difference in altitude between the two sites. Atulya is at a lower altitude while Mtembur is at a higher altitude. Lower altitude areas are near the basement rocks hence a higher activity concentration than high altitude areas where the basement rock is far deep. For instance, Singh *et al*., (2009) have suggested that lower altitude areas experience higher activity concentration as a result of basement rock getting closer to the earth's surface compared to higher areas across the slopes from upper Silawaks in Punjab to the lowlands.

Maina *et al*., (2002), proved that moving towards drier areas from Rift Valley, Kenya, to the coastal region exposes the environment to higher radiations from as low as 200 Bqm^{-3} to 400 Bqm^{-3}. These convert to about 2.6 $mSvy^{-1}$ to 3.6 $mSvy^{-1}$, respectively. William (2012), and Daniel (2015), reported radioactive absorbed doses from Lake Nakuru to the shores of Lake Victoria. Their results showed that concentrations increased towards the drier Lake Victoria region with values of 36.9 $Bqkg^{-1}$ to 64.5 $Bqkg^{-1}$, respectively.

From Figure 4.3, when compared to Figures 4.1 and 4.2, both animal parts had lower activity concentrations: 160-164 Bql^{-1} for the skin and 165-169 Bql^{-1} for the bones. This is attributed to the transfer effect across the food-chain. In a study on radionuclide exposure in animals and public health implications in the outskirts of Ankara, Turkey, Olobatoke & Mathuthu (2015), recorded decreasing radioactive count rates in samples along the food chain. Soil, grass and skin samples collected from selected sites showed counts of 302 Bql^{-1}, 221 Bql^{-1} and 147 Bql^{-1}, respectively. From the basement rocks, weathering agents break down the rock to soil which provides support to vegetation eaten by the animals. Across the food chain, there is substantial loss of activity concentration. Valentine (2007) showed that animal parts have reduced activity concentration as radioisotopes which are lost across the food chain. In a study carried within Oxford, it was found that animal parts recorded the lowest radioactive concentrations compared to pastures and soil samples (101, 213 and 299 Bql^{-1}, respectively). These findings agree with the present results of this study which also showed decreasing radioactive concentrations along the food chain towards the final consumer.

Table 4.4 shows concentration on leaves, crushed rock, rock lick and soil samples in counts per minute (cpm) in both areas (Mtembur and Atulya). The table values were compared to the cpm reading of the standard Americium reading which is 65 cpm.

Rock lick samples for both regions showed the highest cpm (72 and 75) while the leaves showed the lowest cpm reading (56 and 57). In the samples, Mtembur recorded lower

cpm reading (56, 70, 72 and 69) compared to Atulya (57, 70, 75 and 71). As shown earlier, Atulya is in a lower altitude than Mtembur and this elevates radiation levels (Valentine, 2007).

On exposure to radiations, many animal tissues are affected. However, response to radiation effects gives the weighting factor which is used to determine the parts that can be used for monitoring radiation effects. Gonads have a higher weighting factor of 0.2 while the skin and bones have a weighting factor of 0.1. Gonads are therefore more sensitive to radiations hence the need for protection (Valentine, 2007). Stricker *et al*., (1994), pointed out that activity levels of bones were three orders of magnitude higher than levels found in the muscle, suggesting the affinity of these high-risk radionuclides for the skeletal system. However, radioactive concentrations reduce along the food chain as a result of transfer of radioisotopes through tissues. The same concept can explain the reduced counts per minute detected by the R.E. Ratemeter on the leaves of *Balanites aegyptica* tree.

In all the sampling areas, soil had the lowest concentration of radiation compared to crushed rocks and rock lick samples. In Mtembur, soil showed a count of 69 cpm and a count of 71 cpm in Atulya while crushed rocks and rock lick samples showed 70-72 cpm and 70-75 cpm, respectively. This is as a result of massive erosion witnessed during sudden or flush floods which may wash away loose soil to the lowlands. While studying natural radionuclide distribution in the granitic rocks and soils of abandoned quarry sites in Abeokuta, South Western Nigeria, Gbadebo (2011) found out that eroded soils had

lower activity concentration than non-eroded soils. In one of the sampling sites, eroded soils showed activity concentration of as low as 63 cpm while it was high in non-eroded soils reaching 71 cpm. These findings agree with the results of this research.

Table 4.4 also shows that Atulya generally recorded a higher radioactive count in all the samples compared to Mtembur. The leaves, crushed rocks, rock lick and soil samples in Atulya gave respective radioactive counts of 57, 70, 75 and 71, while in Mtembur, it showed corresponding radioactive counts of 56, 70, 72 and 69, because Atulya is lower in altitude than Mtembur. Garba *et al*., (2013), had shown that towards the lower altitudes, deposition of soil is higher and radiation tends to increase but reduces in the highlands. In a study carried out in Kelantan, India, it was reported that there was increased radioactivity in the lowlands in various samples ranging from 42-51 cpm compared to 35-41 cpm in the highlands. The increased vertical distance of the surface from the basement rock and increased erosion could be attributed to these differences. Akhtar *et al*., (2005), have also proved that in Pakistan, forested areas where erosion is minimal had increased radioactive levels recorded than bare lands where massive erosions had taken place. They found that Lahore, forested city estates registered a lower count of radiation than the areas near deposition zones like rivers. Anjos *et al*., (2005), have also shown that the closer the basement rock is to the surface, the higher the radioactive count.

In Table 4.6 the t-test results show increasing p-values of soil, rock licks and crushed rocks from 0.000, 0.005 and 0.731 correspondingly. In all the results analyzed both sites showed higher activity levels above 0.05 significance levels. Table 4.7 shows paired

differences of the bones and skins. The results show a mean of 5.000 with a standard deviation of 2.708. The p-values obtained also show significance at 95% activity levels from the bones and skins. Table 4.8 shows the ANOVA results from the two sampling sites. It shows p-values from 0.000 and 0.001 in Mtembur and Atulya respectively. These values suggest increased activity concentration in Atulya than in Mtembur. This could be attributed to the low altitude in Atulya making the basement rock closer to the surface hence increased activity levels.

Tables 4.9-4.15 present calculated radioactive exposure, effective dose rate and absorbed dose rate in μSv/h, mSv/y and nGy/h, respectively. Table 4.9 compared with Table 4.14 show corresponding radioactive exposure of soils from Mtembur and Atulya, respectively. Soils from Atulya showed a higher calculated exposure and both effective and absorbed dose rates compared to soils from Mtembur. This is in line with the explanation given for Tables 4.4 and 4.5 which is due to the fact that Atulya is in the low land, compared to Mtembur (Meggit, 2008). Domestic animals in Atulya were exposed to higher radiations ranging from 0.7322-0.7445 mSv/y while in Mtembur the exposure was lower and ranged from 0.5578-0.5651 mSv/y.

Table 4.16 shows conversion of values from the ratemeter as compared to the standard radioactive Americium. All samples from both areas showed higher counts per minute than the standard except the leaves of *Balanites aegyptica.* This could be as a result of loss of radioactive isotopes along the food chain as the trees absorb nutrients containing the radioactive isotopes from the soil. Harb (2004) showed that as radionuclides transist

along the food chain, activity concentration at each level reduces considerably. In a study in a rural set up near Hanover, Germany, it was found that activity concentration dropped consistently from the underlying granitic rock to the grasses used as fodder. Activity concentrations were given as 96 cpm (underlying granitic rock), 93 cpm (weathered rock), 82 cpm (weathered rock with sand sized particles), 71 cpm (soils) and 56 cpm (grass samples). This is consistent with the findings of this research.

All the values, except in B_3 samples had exposure exceeding 0.5 mSv/y which is the recommended dose exposure, UNSCEAR (2000b). The exposure levels are therefore hazardous especially as one moves towards the more drier areas of Pokot North. Rock lick samples pose the highest hazards. This could be the reason why some rock lick zones have been banned by the local elders. The shrubs which are consumed raw by livestock and cooked by the residents are also hazardous.

Table 4.16 shows the conversion of the values in cpm (compared to the standard Americium-243). For all the samples, Atulya showed elevated absorbed dose rates, effective dose rates and exposure rates than Mtembur. The samples collected from Atulya showed a cpm of 57, 70, 71 and 75 for leaves, crushed rock, soil and rock lick samples respectively. Mtembur showed a corresponding cpm of 56, 69, 70 and 72 for leaves, crushed rock, soil and rock lick samples.

When compared to Am-243 whose cpm is 65, it was found that the absorbed dose rates from the samples analyzed was far higher than the standard sample. UNSCEAR (2000b)

has showed that effective dose rate of 0.5 mSv/h and absorbed dose rate of 30 nGy/h are harmful to livestock and man. The absorbed dose rates and effective dose rates as shown for Mtembur and Atulya were higher for all the samples (Tables 4.9-4.16).

Assessing the levels of radiation in the samples collected from Mtembur and Atulya was to evaluate whether the levels of exposure were high enough to warrant radiological health effects among the livestock in West Pokot to enable implementation of regulatory control. From the results above, the investigation recorded an effective dose rate of more than 0.5 mSv/y except for animal parts. The results show that radiation levels were harmful to the livestock in the region. However, the lower values in animal parts samples could result from lose of concentrations over the food chain. The absorbed dose rate in nGy/h was also higher than 30 nGy/h, (UNSCEAR, 2000a). The absorbed dose rates calculated from the cpm conversion ranged from 46.6-60.0 nGy/h for Mtembur and 47.5-62.5 nGy/h for Atulya. When related to the conversions made from values calculated from the activity concentration in Bql^{-1}, it was noticed that the ranges were however, close.

Rock lick samples from Mtembur showed lower absorbed dose rates of 66.8-67.4 nGy/h while those from Atulya showed higher absorbed dose rates of 69.2-70.0 nGy/h. When compared with the calculated absorbed dose rates from cpm values, it was also noticed that the ranges were close. When the effective dose rates and absorbed dose rates from both areas were compared to the UNSCEAR minimum exposure limits, it was noticed

that the areas recorded higher rates more than 0.5 mSv/h and 30 nGy/h for effective dose rates and absorbed dose rates, respectively.

Soils from Atulya recorded higher absorbed dose rates of 59.6-60.6 nGy/h (Table 4.14) while the soils from Mtembur showed lower absorbed dose rates of 45.4-46.0 nGy/h (Table 4.9). On comparison with the calculated absorbed dose rates from cpm values, absorbed dose rates of 57.5 nGy/h and 59.0 nGy/h (Table 4.16) for Mtembur and Atulya, respectively were registered. This shows a very close relation for the two methods of measurements used. Further, the absorbed dose rates and effective dose rates were above the UNSCEAR limits of 30 nGy/h for absorbed dose rates and 0.5mSv/h for effective dose rates. The effective dose rates of soils from Atulya were between 0.7322-0.7445 mSv/h (Table 4.14) while the soils from Mtembur showed between 0.5578-0.5651 mSv/h (Table 4.9).

Crushed rock samples from Atulya showed an absorbed dose rate of 59.6-60.8 nGy/h (Table 4.15) while the crushed rock samples from Mtembur showed absorbed dose rates of 59.8-60.4 nGy/h (Table 4.12). When compared with the calculated absorbed dose rates from cpm values (Table 4.16), absorbed dose rates of 58.0 nGy/h for both Mtembur and Atulya were noted. These values compare closely with those obtained using the Bequerel monitor. The effective dose rates showed a corresponding range of 0.7346-0.7421 mSv/h (Table 4.9) and 0.7322-0.7470 mSv/h (Table 4.15) for Mtembur and Atulya respectively. These values were above the UNSCEAR limit of 0.5 mSv/h. Further, the absorbed dose rates were far above the limit of 30 nGy/h minimum suggested by UNSCEAR.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

1. The activity levels of the naturally occurring radionuclides ranged between 227-350 Bql^{-1}

2. Estimated effective dose rate in the samples ranges from 0.5578-0.8599 mSv/y and the annual absorbed dose rate ranged between 45.4-67.4 nGy/h.

3. The activity levels of samples from the two regions were above the WHO and NEMA suggested levels of 0.05 mSv/y and 30 nGy/h.

4. There was a positive correlation in activity levels for samples from the two regions.

6.2 Recommendations

6.2.1 Recommendation from the study

A plan to implement regulatory control measure to reduce the exposure not only to livestock but also to the residents.

6.2.2 Suggestions for Further Research

Further investigation is necessary to establish the concentration of U-238, Th-232 and K-40 present in the soil, rocks, rock licks, leaves and animal parts.

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APPENDICES

A: Descriptive Statistics

Appendix I: Report on descriptive statistics on soil, rock licks and crushed rocks from Mtembur

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Soil	4	227	230	228.50	.645	1.291
Rock licks	4	345	350	347.25	1.109	2.217
Crushed rocks	4	299	302	300.50	.645	1.291
Valid N (listwise)	4					

Appendix II: Report on soil, rock licks and crushed rocks from Atulya

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Soil	4	298	303	300.00	1.080	2.160
Rock licks	4	334	337	335.75	.750	1.500
Crushed rocks	4	298	304	301.00	1.291	2.582
Valid N (listwise)	4					

Appendix III: Report on skin and bones from cattle from West Pokot County

		N	Minimum	Maximum	Mean		Std. Deviation
		Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Skin		4	160	164	162.00	.913	1.826
Bones		4	165	169	167.00	.816	1.633
Valid (listwise)	N	4					

Appendix IV: Report on Pearson Correlation analysis between soil and leaves from Mtembur West Pokot County

Correlations

		Soil	Leaves
Soil	Pearson Correlation	1	.632
	Sig. (2-tailed)		.368
	Sum of Squares and Cross-products	8.000	4.000
	Covariance	2.667	1.333
	N	4	4
Leaves	Pearson Correlation	.632	1
	Sig. (2-tailed)	.368	
	Sum of Squares and Cross-products	4.000	5.000
	Covariance	1.333	1.667
	N	4	4

Appendix V: Report on Pearson Correlation analysis between rock licks and skin from Mtembur

		Rocklicks	Skin
Rock licks	Pearson Correlation	1	.000
	Sig. (2-tailed)		1.000
	Sum of Squares and Cross-products	14.750	.000
	Covariance	4.917	.000
	N	4	4
Skin	Pearson Correlation	.000	1
	Sig. (2-tailed)	1.000	
	Sum of Squares and Cross-products	.000	10.000
	Covariance	.000	3.333
	N	4	4

Appendix VI: Report on Pearson Correlation analysis between rock licks and bones from Mtembur

		Rocklicks	Bones
Rocklicks	Pearson Correlation	1	.368
	Sig. (2-tailed)		.632
	Sum of Squares and Cross-products	14.750	4.000
	Covariance	4.917	1.333
	N	4	4
Bones	Pearson Correlation	.368	1
	Sig. (2-tailed)	.632	
	Sum of Squares and Cross-products	4.000	8.000
	Covariance	1.333	2.667
	N	4	4

Appendix VII: Report on Pearson Correlation analysis between crushed rocks and skin from Mtembur

		Crushedrocks	Skin
Crushedrocks	Pearson Correlation	1	-.990*
	Sig. (2-tailed)		.010
	Sum of Squares and Cross-products	5.000	-7.000
	Covariance	1.667	-2.333
	N	4	4
Skin	Pearson Correlation	-.990*	1
	Sig. (2-tailed)	.010	
	Sum of Squares and Cross-products	-7.000	10.000
	Covariance	-2.333	3.333
	N	4	4

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix VIII: Report on Pearson Correlation analysis between crushed rocks and bones West Pokot County

		Crushedrocks	Bones
Crushedrocks	Pearson Correlation	1	.316
	Sig. (2-tailed)		.684
	Sum of Squares and Cross-products	5.000	2.000
	Covariance	1.667	.667
	N	4	4
Bones	Pearson Correlation	.316	1
	Sig. (2-tailed)	.684	
	Sum of Squares and Cross-products	2.000	8.000
	Covariance	.667	2.667
	N	4	4

Appendix IX: Report on Pearson Correlation analysis between leaves and skin from Mtembur

		Leaves	Skin
Leaves	Pearson Correlation	1	-.855
	Sig. (2-tailed)		.145
	Sum of Squares and Cross-products	8.750	-8.000
	Covariance	2.917	-2.667
	N	4	4
Skin	Pearson Correlation	-.855	1
	Sig. (2-tailed)	.145	
	Sum of Squares and Cross-products	-8.000	10.000
	Covariance	-2.667	3.333
	N	4	4

Appendix X: Report on Pearson Correlation analysis between leaves and bones West Pokot County

		Leaves	Bones
Leaves	Pearson Correlation	1	.478
	Sig. (2-tailed)		.522
	Sum of Squares and Cross-products	8.750	4.000
	Covariance	2.917	1.333
	N	4	4
Bones	Pearson Correlation	.478	1
	Sig. (2-tailed)	.522	
	Sum of Squares and Cross-products	4.000	8.000
	Covariance	1.333	2.667
	N	4	4

Appendix XI: Report on Pearson Correlation analysis between soil and leaves from Atulya

		Soil	Leaves
Soil	Pearson Correlation	1	.452
	Sig. (2-tailed)		.548
	Sum of Squares and Cross-products	14.000	5.000
	Covariance	4.667	1.667
	N	4	4
Leaves	Pearson Correlation	.452	1
	Sig. (2-tailed)	.548	
	Sum of Squares and Cross-products	5.000	8.750
	Covariance	1.667	2.917
	N	4	4

Appendix XII: Report on Pearson Correlation analysis between rock licks and skin from Atulya

		Rocklicks	Skin
Rocklicks	Pearson Correlation	1	.852
	Sig. (2-tailed)		.148
	Sum of Squares and Cross-products	6.750	7.000
	Covariance	2.250	2.333
	N	4	4
Skin	Pearson Correlation	.852	1
	Sig. (2-tailed)	.148	
	Sum of Squares and Cross-products	7.000	10.000
	Covariance	2.333	3.333
	N	4	4

Appendix XIII: Report on Pearson Correlation analysis between rock licks and bones from Atulya West Pokot County

		Rocklicks	Bones
Rocklicks	Pearson Correlation	1	.000
	Sig. (2-tailed)		1.000
	Sum of Squares and Cross-products	6.750	.000
	Covariance	2.250	.000
	N	4	4
Bones	Pearson Correlation	.000	1
	Sig. (2-tailed)	1.000	
	Sum of Squares and Cross-products	.000	8.000
	Covariance	.000	2.667
	N	4	4

Appendix XIV: Report on Pearson Correlation analysis between crushed bones and skin from Atulya West Pokot County

		Crushed rocks	Skin
Crushed rocks	Pearson Correlation	1	-.141
	Sig. (2-tailed)		.859
	Sum of Squares and Cross-products	20.000	-2.000
	Covariance	6.667	-.667
	N	4	4
Skin	Pearson Correlation	-.141	1
	Sig. (2-tailed)	.859	
	Sum of Squares and Cross-products	-2.000	10.000
	Covariance	-.667	3.333
	N	4	4

Appendix XV: Report on Pearson Correlation analysis between crushed rocks and bones from Atulya

		Crushed rocks	Bones
Crushed rocks	Pearson Correlation	1	.949
	Sig. (2-tailed)		.050
	Sum of Squares and Cross-products	20.000	12.000
	Covariance	6.667	4.000
	N	4	4
Bones	Pearson Correlation	.949	1
	Sig. (2-tailed)	.051	
	Sum of Squares and Cross-products	12.000	8.000
	Covariance	4.000	2.667
	N	4	4

Appendix XVI: Report on Pearson Correlation analysis between skin and leaves from Atulya

		Leaves	Skin
Leaves	Pearson Correlation	1	.962*
	Sig. (2-tailed)		.038
	Sum of Squares and Cross-products	8.750	9.000
	Covariance	2.917	3.000
	N	4	4
Skin	Pearson Correlation	.962*	1
	Sig. (2-tailed)	.038	
	Sum of Squares and Cross-products	9.000	10.000
	Covariance	3.000	3.333
	N	4	4

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix XVII: Report on Pearson Correlation analysis between bones and leaves from Atulya

		Leaves	**Bones**
Leaves	Pearson Correlation	1	-.239
	Sig. (2-tailed)		.761
	Sum of Squares and Cross-products	8.750	-2.000
	Covariance	2.917	-.667
	N	4	4
Bones	Pearson Correlation	-.239	1
	Sig. (2-tailed)	.761	
	Sum of Squares and Cross-products	-2.000	8.000
	Covariance	-.667	2.667
	N	4	4

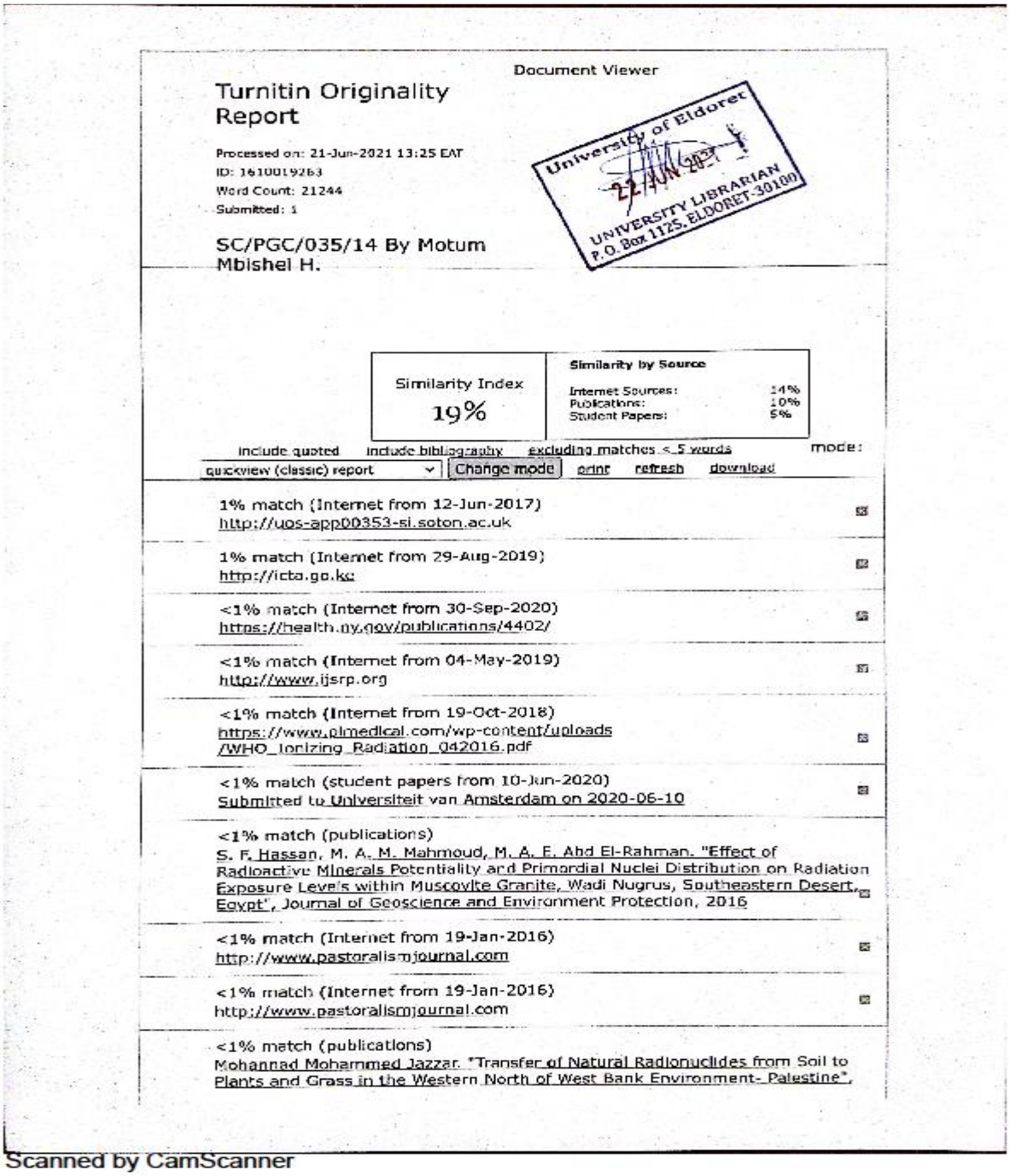
Appendix XVIII: Report on Paired t- test on Rock licks between Mtembur and Atulya from Atulya

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Rock licks	11.500	3.109	1.555	6.553	16.447	7.398	3	.005

Appendix XIX: Report on Paired t- test on Crushed Rocks between Mtembur and Atulya from Atulya West Pokot County

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Crushed rocks	-.500	2.646	1.323	-4.710	3.710	-.378	3	.731

Appendix XX: Similarity report



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