AFRICA ENVIRONMENTAL REVIEW Journal
ISSN: 1727-8341

AER Journal Volume 4, Issue 2, pp. 214-226, Aug, 2021

RESEARCH ARTICLE
Available Online at *http://www.aer-journal.info*

Assessing the Presence of Natural Radioactive Isotopes in the Soils and Leaves and their Effects on Domestic Livestock of Atulya and Mtembur of Pokot North Sub-County, West Pokot County

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Abstract

Natural radioactivity from celestial sources and radioactive matter in the earth's crust is a source of constant radiation exposure to animals. 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. The levels due to the terrestrial background radiation are related to the types of rock from which the soils originate. This research investigated the absorbed dose and annual effective dose rate from radiations emitted by radionuclides from soil, leaves and cattle's animal parts in West Pokot region, Kenya. Purposive sampling method was used to identify points for soil sampling where deformed domesticated animals are from. Soil samples collected samples were analysed using LB 200 Bequerel Monitor. Bones and skin parts were obtained from a slaughter house from the two regions and radioactivity analysis was done at the National Radiation Protection Board laboratory (Nairobi). Leaves samples which weighed less than 500g were analysed using a Ratemeter. Soil samples from Atulya had a higher mean activity concentration (300.00 ± 1.080) Bql^{-1} while the soil samples from Mtembur had the lower mean activity concentration (228.50 ±.645) Bql$^{-1,}$ these values were well above world average values. The mean activity for leaves were 57cpm and 56 cpm for Atulya and Mtembur respectively. Both animal parts had lower mean activity concentrations: 162.00 ± .913 Bql^{-1} for the skin 167.00 ± .816Bql^{-1} for the bones from West Pokot County. The results further showed elevated radioactive exposure in soils 0.561 mSv/y and leaves samples 0.573 mSv/y from Mtembur. Samples from Atulya also indicated high radioactive levels of 0.737 mSv/y in soil samples and 0.5835 mSv/y from leaves samples as compared to recommended minimum levels UNSCEAR. Domesticated cattle bones and skin collected from slaughter house indicated radioactivity of 0.4029 mSv/y. There was a significant difference ($p \leq 0.05$) in the levels of radiation in soil between Mtembur and Atulya according to T- test results (P=0.000, df=3, t=-41.288). There was a negative correlation in radiation activity levels between the soil and leaves and skin and leaves and bones found Mtembur and Atulya in West Pokot County. Evidently, animals in West Pokot County are exposed to harmful radiations leading to deformities like fragile limbs, misplaced organs and multiple organs. This leads to poor economic returns to the pastoral community. The study therefore recommends that a system should also be put in place to monitor radionuclides in major food commodities in order to reduce human exposure to radiation through consumption of animal products.

Keywords: Radioisotopes, Gamma, Bequerel, Leaves, Soil, Bones, Deformed Animals

INTRODUCTION

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 human 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, 2000). 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).

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 collection of animals 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 animal collection comes from the neighboring West Pokot County. The increase in incidences of disorders could be attributed to environmental exposure. Some 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 be exposed to about 100 times the normal background levels (approximately 2.4 $mSvy^{-1}$) (Usman, 2015; Leonard, 2014). This could pose danger to human health and can even result in death due to cancer. Radiation exposure must be maintained as low as possible since even the lowest doses may cause cancer over a prolonged period of exposure

Soil is a complex material composed of mineral (inorganic) as well as an organic matter that originated from plant decomposition. It is a compact matter providing necessary micro- and macro-nutrition elements for plants to function and grow. Domesticated animals consume leaves from different plants as they are important for their diet. Most of the radionuclide plants are absorbed from soil by plants.

Studies done by Daniel & Daniel (2015), on spectrometric analysis of gamma rays of radionuclides that occur naturally in soil samples collected in Migori County on the Lake Victoria shores, 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. Maina, (2002) reported elevated concentrations of Ra-226 and Th-232 in soils samples from the densely populated areas like Nairobi, Kiambu, Bungoma and Trans Nzoia districts. 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 and53±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 $mSvy^{-1}$. Fukuda *et al*., (2013), evaluated emissions of gamma ray 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, 129mTe and 110mAg) in the kidney and liver, respectively. Higher concentrations of Caesium were also observed in fetal organs rather than in maternal organs.

Measurement of natural radioactivity is crucial in implementing precautionary measures whenever the source is found to exceed the recommended limit. The present study aims at investigating naturally occurring radioactive elements and exposure levels to ionizing radiation at some selected parts in West Pokot region, Kenya. Soil and vegetation contamination by radioactive substances pose a major concern due to their toxicity and threat to both human and animal life. As the country 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. This provides a need to generate data to inform and guide the process of workplace safety as well as the residential places. This research aims 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. Also, environmental monitoring and assessment is vital in regulatory and advisory policy making for the safety of public due to radiation exposure. It is against this background that this research sets out to analyze the radiation exposure to the livestock, the grass they graze on and the soil where the vegetation grows.

METHODOLOGY

Study Area

The study site is located in West Pokot County. The County lies within longitudes 34^0 47’ and 35^o 49’ East and latitude 1^o and 2^o North. 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).

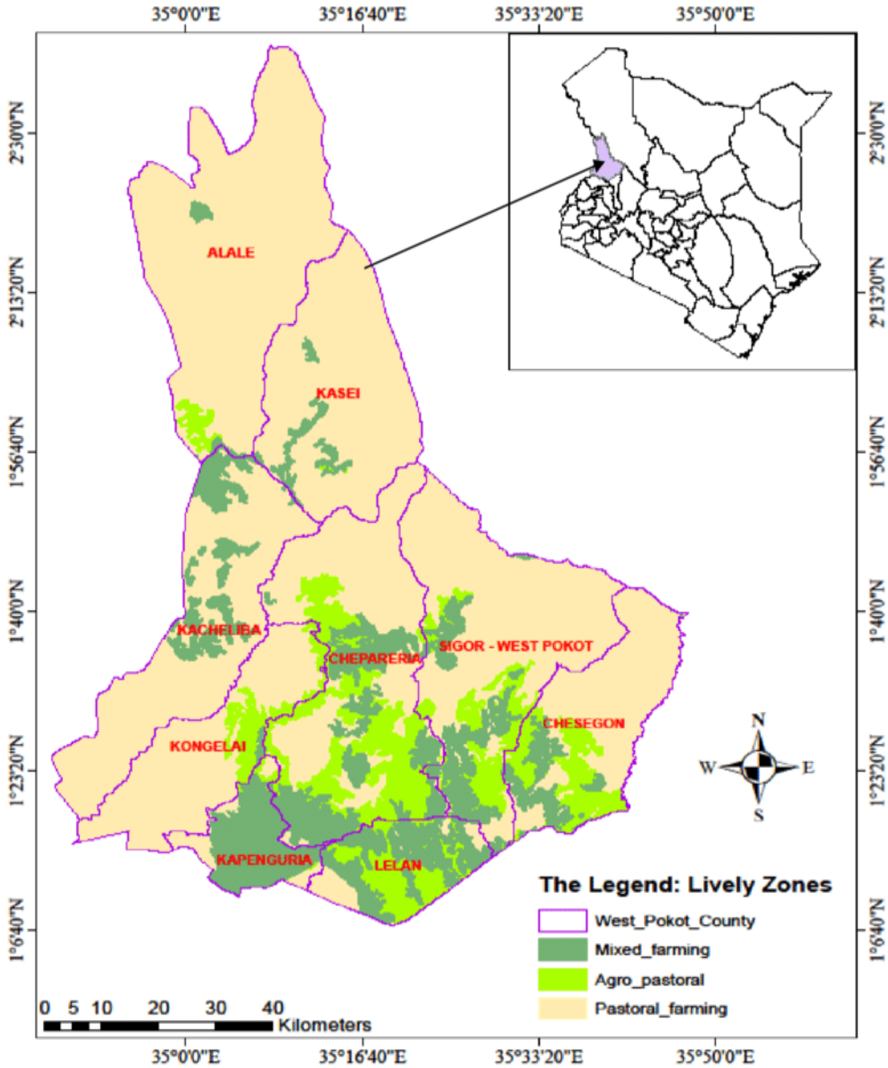

Figure 1: Map of Kenya showing Position of West Pokot County.

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.

The county also experiences great variations in temperature with the lowlands experiencing temperatures of up to 30^0C and the highlands experiencing moderate temperatures of 15^0C. 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.

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 631,231 persons as per 2013 projections. This population consists of 313,746 males and 317,484 females giving sex ratio of 100:101. The county inter-censual growth rate is 5.2%, 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 700,414 and 771,180 in 2015 and 2017, respectively. It is also worth noting that the youth (aged 15-34 years), whose population estimate is 196,830 forms 31% of the County population.

The samples were collected from Mtembur and Atulya in Pokot North sub-county. Soil samples were collected from Atulya were from an isolated area where livestock have been barred from accessing. The local elders claim the rock lick is harmful to their livestock.

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 and animal parts samples were analyzed using the LB 200 Becquerel monitor which gives its values in Bqkg-1.

Sampling

Soil Sampling

Purposive sampling method was used to identify points for soil sampling where deformed domesticated animals are commonly found. Three regions were selected. A transect sampling pattern was used for field sampling. Soil samples were collected using soil augers that were kept clean and rust free. 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. 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 mass determined and sealed for 30 days so that an equilibrium can 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 will also remain in the sample. Nine soil samples were analyzed.

Leaf Sampling

Purposive sampling method was used to identify points for leaf samples where deformed domesticated animals are commonly found. The samples were dried before radioactivity measurement for 3-4 days at a temperature of 30°C to ensure all moisture is 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.

Animal Parts Sampling

Animal parts sampled were hides and bones. The samples were obtained from a slaughter house in Makutano town 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 105^0C for 3 hours. The dried sample was heated under controlled temperatures to powder and placed in sealed plastic containers to attain equilibrium between the radioactive progenies.

Radio Safety in the Field

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

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.

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 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 a 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 hrs. 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.

Instrument 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.

Statistical Analysis

Data is presented using tables and figures. SPSS analysis was used to compare the variation in radiation concentration in the samples.

RESULTS

Collection Site Characteristics

The site is 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.

The Mean Activity Concentration for Soil and Leaves from Mtembur and Atulya

The samples activity concentration from soil and leaves collected from Mtembur and Atulya were analyzed and the results presented in Figure 1.

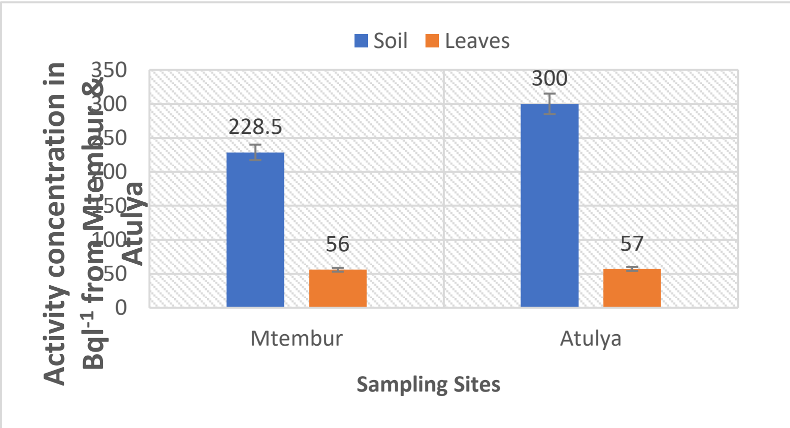

Figure 1: Activity Concentration in Bql^{-1} of Soil (B_1), Rock Licks (B_2) and Crushed Rock (B_4) Samples from Mtembur and Atulya.

From figure 1, soil samples from Atulya had a higher mean activity concentration (300.00 ± 1.080) Bql^{-1} while the soil samples from Mtembur had the lowest mean activity concentration (228.50 ±.645) Bql^{-1}. The mean activity for leaves were 57 cpm and 56 cpm for Atulya and Mtembur, respectively.

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 2.

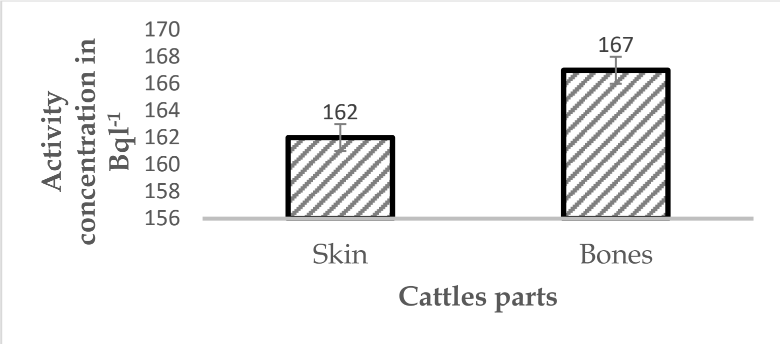

Figure 2: Activity Concentration of Animal Parts (Skin and Bones) in Bql^{-1}.

From figure 2, both animal parts had lower mean activity concentrations: 162.00 ± .913 Bql^{-1} for the skin 167.00 ± .816 Bql^{-1} for the bones from West Pokot County.

The R.E Ratemeter Results of Activity Concentration for Leaves, Soil, Rock Licks, Crushed Rock and Soil

Table 1 shows concentration of leaves 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.

Table 1: Sample Results using the R.E Ratemeter, (cpm)

Sample	Mtembur	Atulya
Leaves	56	57
Soil	69	71

- The standard Americium sample had a cpm of 65.

Results of leaves and soil samples in counts per minute (cpm) in both areas (Mtembur and Atulya) indicated high concentration which were above standard Americium sample of 65 cpm.

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 found Mtembur in West Pokot County (0.368, $p>0.05$). This means that the radiation activity levels found in soil appears to not to influence the uptake of radiation leaves.

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 Mtembur in West Pokot County. The radiation activity concentration in the leaves appears to not to influence the uptake of radiation in the cattle parts sampled.

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 Atulya in West Pokot County (0.548, p>0.05). This means that the radiation activity levels found in soil appears to not to influence the uptake of radiation leaves.

The study also looked at the correlation of radiation activity concentration 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) this means that radiation activity concentration in the leaves influenced the uptake of radiation in the cattle skin sampled. However, negative correlations between radiation activity levels within leaves and bone noted as the correlation coefficient was (0.522, p>0.05), therefore, radiation activity concentration in the leaves appears to not to influence the uptake of radiation in the cattle bones sampled found Atulya in West Pokot County.

Paired t-test was carried out to determine if there existed significant differences in the activity concentration of radiation in soil from the two sampled sites (Mtembur and Atulya) in West Pokot County. According to T- test results, the results of soil was (P=0.000, df=3, t=-41.288) from Atulya and Mtembur were below 0.05 significance level indicating there was a significance at 95 % in activity concentration from the two regions.

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 below.

According to T- test results, 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.

Activity Concentration and Absorbed Dose Rates

Table 2 below shows 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 (Meggit, 2008).

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 2: Activity Concentration and Absorbed Dose Rates for Soil and Animals Parts Samples from Mtembur and Atulya

	Activity conc. (Bql^{-1})	**Exposure µSv/h**	**Effective dose rate mSv/y**	**Absorbed dose rate nGy/h**
Mtembur	228.5	0.046	0.561	45.7
Atulya	300	0.06	0.737	60
Animal parts samples	162	0.032	0.398	32.4

The effective dose rates for soil obtained from Mtembur ranged between 0.5578-0.5651 mSv/h while the absorbed dose rates ranged between 45.4-46.0 nGy/h. Atulya also showed elevated exposure of 0.7322-0.7445 mSv/h and 59.6-60.6 nGy/h. In both regions, they were higher than the recommended minimum UNSCEAR (2000) values of 0.5 mSv/h and 30 nGy/h, respectively. The effective dose rates obtained from animals' parts was 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 3: Conversion of cpm Values to Effective and Absorbed Dose Rates

Location	Sample	cpm	µSv/h	mSv/y	nGy/h
Mtembur	Leaves	56	0.0466	0.573	46.6
	Soil	69	0.0575	0.706	57.5
Atulya	Leaves	57	0.0475	0.5835	47.5
	Soil	71	0.059	0.7269	59.0
Standard	**Americium**	**65**	**0.0542**	**0.6655**	**54.2**

Table 3 shows conversions of leaves and soil 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). Results showed elevated levels of effecyive and absorbed dose rates in soil and leaves samples collected from Mtembur and Atulya from West Pokot County.

DISCUSSION

From the results, soil samples varied in radioactive concentrations. Atulya had higher activity concentrations (300.00 ± 1.080) Bql^{-1} than Mtembur (228.50 ±.645) Bql^{-1} these values were well above world average values of 33 Bql^{-1} for U-238. The difference in levels could be attributed 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.

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 (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}. This converts to about 2.6 $mSvy^{-1}$ to 3.6 $mSvy^{-1}$, respectively. William (2012), and Daniel & Daniel (2015), reported radioactive absorbed doses from Lake Nakuru to the shores of Lake Victoria. Their results show that concentrations increased towards the drier Lake Victoria region with values of 36.9 $Bqkg^{-1}$ to 64.5 $Bqkg^{-1}$, respectively.

Both animal parts had lower mean activity concentrations: 162.00 ± .913 Bql^{-1} for the skin 167.00 ± .816Bql^{-1} for the bones from West Pokot County. 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. Mathuthu & Olobatoke (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. Thorne (2003), 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.

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 need for protection (Lakhwani *et al*., 2019). Olobatoke & Mathuthu (2015), pointed out that 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 Mtembur, soil showed a count of 69 cpm and a count of 71 cpm in Atulya which were all above standard Americium sample of 65 cpm. The leaves showed 56 cpm and 57 cpm, from Mtembur and Atulya, respectively. This is as a result of massive erosion witnessed during sudden or flush rains 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.

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. In 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 radioactive count for the area is.

The calculated radioactive exposure, effective dose rate and absorbed dose rate in μSv/h, mSv/y and nGy/h, respectively. Soils from Atulya showed a higher calculated exposure and both effective and absorbed dose rates compared to soils from Mtembur. 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.

CONCLUSION AND RECOMMENDATION

Soils from Atulya showed a higher calculated exposure and both effective and absorbed dose rates compared to soils from Mtembur. The values above have mSv/y exceeding 0.5 mSv/y which is recommended as safe, UNSCEAR (2000). The absorbed dose rates are also higher than 30nGy/h. The study recommends a plan to implement regulatory control measure to reduce the exposure not only to livestock but also to the residents. Also, a system should also be put in place to monitor radionuclides in major food commodities in order to reduce human exposure to radiation through consumption of animal products. Further investigation is necessary to establish the types of concentration of nuclides present in the samples.

Acknowledgement

The authors acknowledge the assistance from the staff in the School of Science, Department of Chemistry and Biochemistry of University of Eldoret for their support. The authors also acknowledge the assistance of the Kenya National Radiations Protection Board for the analysis of the samples.

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