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Evaluation of gross alpha and beta activity concentration in five vital organs of some goats

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1 SUMMARY

The objective of this study was to evaluate the gross alpha and gross beta activity concentrations in five vital organs (kidney, heart, lungs, liver and tongue) and dung from some twenty-five goats obtained from Turaku market in Minna, Niger state of Nigeria. The mean activity concentrations of gross alpha and beta ranges from 0.03 ± 0.01 to 1.06 ± 0.42 Bq/kg and 2.47 ± 0.35 to 40.59 ± 0.39 Bq/kg respectively across the five organs. These organs are highly consumed by humans and the radioactive concentrations in these organs ingested directly into the human systems could compromise the neural development of the foetus, which may result in mental retardation or other significant damage to the DNA arrangements resulting in a wide array of biological effects. The particles (alpha or beta) could react with molecules other than DNA molecules; lipids, proteins, water, etc. to produce free radicals that could adversely react with the DNA molecules in humans. The activity concentrations of the gross alpha and beta measured could cumulate (but does not always) and result in carcinogenesis or other adverse cellular events in some months or years after exposure due to DNA damage. For the dung, the average concentration of gross alpha activity was 0.2620 ± 0.0527 Bq/kg and gross beta activity was 3.210 ± 1.636 Bq/kg in all the twenty-five goats which could be transmitted into the food chain since the dung are widely used as manure in the country.

2 INTRODUCTION

Much is known about the biological, toxicological and toxicokinetic aspects of radionuclides, as well as the general mechanisms of action of radiation (Bernier et al., 2001). Radioactive materials contain radioactive atoms that emit radiation as they transform into other radioactive or stable atoms (Van Dyk, 2009). The terms "radiation," and "ionizing radiation" are defined in toxicological profile as a specific form of radiation that possesses sufficient energy to remove electrons from the atoms in the tissues that they penetrate (Spain, 2004). This process called ionization is the reason for ionizing radiation. When this energy is received in appropriate quantities and over a sufficient period time, it can result in tissue damage. The clinical manifestations of radiation can be negligible (no effect), acute (occurring within several hours after very large doses), or delayed or latent (occurring several years after the exposure), depending on the dose and the rate at which it was received and the type of damage produced (IAEA, 2002; 2007). All organisms (i.e., bacteria, plants or animals, including humans) are exposed each day to some amount of radiation from our environment. A report by NCRP (1987) shows that, in the United States, 81% of the dose received from radiation comes from natural sources: 55% from radon; 8% from cosmic radiation; 8% from rocks and soil; and 10% from internal exposures to radiation from the radioactive materials in food and water consumed in the daily diet, such as ^{40}K. The remaining 19% of the daily dose may originate from man-made sources; it is composed of medical x ray exposure (11%), nuclear medicinal exposure (4%), consumer products (3%), and other sources (<1%). This last category includes occupational sources, nuclear fallout, the nuclear fuel cycle radioactive waste, hospital radioactive waste, radioactively contaminated sites and other miscellaneous sources. Although much remains to be learned about the specific mechanisms by which radiation exerts its effects, how these effects can be minimized in living tissues, and what the effects of very low doses of radiation over long periods of time will be, we know enough to safely use radioactive materials and radiation in commerce, industry, science, and medicine. Alpha particle is composed of two protons and two neutrons, and thus is a helium nucleus. When a parent radionuclide emits an alpha particle, its atomic mass number (number of protons plus neutrons) decreases by four and its atomic number (number of protons) decreases by two, resulting in the formation of a different element (Passo and Kessler 1992 and USEPA, 2012a). In nature, alpha particles come from the radioactive transformation of heavy elements (e.g., uranium, radium, thorium and radon) where long transformation chains produce several successive alpha and beta particles until the resulting nuclide has a stable configuration (NRPB, 1992). A specific alpha emitting radionuclide emits monoenergetic alpha particles of discrete energies and relative intensities, making it possible to identify each alpha emitting radionuclide by its alpha energy spectrum. The alpha particle's electrical charge of +2 and mass number of 4, both of which are larger than most other types of radiation, hence cause the particle to interact strongly with matter (NRPB, 1992 and USEPA, 2012a). This relatively slow-moving, highly charged, high LET particle spends a relatively long time near each atom it passes; this enables it to pull electrons easily off those atoms. With a mass about 7,200 times that of each electron, each interaction has only a small effects on its velocity, but the strong interaction with each atom it encounters causes it to lose energy very quickly. The range of an alpha particle in biological tissue is25–80 µm, hence the particle deposit all of it energy in a small volume. Once its energy is expended, the alpha particle will combine with two electrons to become a helium atom, which does not chemically react with biological material (UNSCEAR, 1988).

A beta particle is a high-velocity electron ejected from a transforming nucleus. This occurs when a nuclide has a nucleus that is very unstable because it has too many or too few neutrons to stabilize the number of protons. The particle may be either a negatively charged electron, called a negatron (β-), or a positively charged electron, called a positron (β+) (NRPB, 1992, USEPA, 2012b). Beta minus or negatron (β-) transformation is a process by which a radionuclide with too many neutrons achieves stability. It does not stabilize by emitting an extra neutron; instead, a neutron changes into a proton and the nucleus emits a negatron (β-) and an antineutrino (NRPB, 1992). This nuclear transformation results in the formation of a different element with one more proton, one fewer neutron and the same mass number as the original nucleus. Overexposure to negatron-emitting radionuclides outside the body can cause more injury to the skin and superficial body tissues than alpha particles or gamma radiation (IAEA, 2003). They are even more harmful as an internal radiation hazard when excessive amounts are taken into the body. Beta positive, or positron, transformation occurs when there are not enough neutrons (or too many protons) in the nucleus. In this case, a proton changes into a neutron and the nucleus emits a positron (Beir, 2000) The major amount of natural radionuclides enters the human body via ingestion and contributes much to the exposure of man. Approximately 20% of Radium isotopes and 10-15% of decay products of ^{238}U and ^{232}Th considered for this work reaches the blood stream (UNSCEAR, 1982, 1993, 2008) distributed to the whole body. Since the percentage distribution of annual intakes of uranium and thorium series radionuclides in food ranges between 4% to about 96% (UNSCEAR, 2000), accumulation of these radionuclides through the ingestion of the vital organs as food have significant health effects such as bone cancer, leukaemia and increase in blood pressure. Since humans rely on animals such as goats, cows, chicken as source of nutrients for healthy growth. These animals feed on plants of which absorb radionuclides via their roots from the soil (during the absorption of soil water/nutrient) or via their leaves (during photosynthesis) thereby allowing radionuclides to enter the human food chain. The accumulation of such radionuclides in the organs of these animals might pose radiological health risks to man and as such there be need to investigate the concentration of gross alpha and gross beta activity in the case of male goats consumed much in the northern part of Nigeria. This study is aimed to determine the gross alpha and beta activity concentrations of natural radionuclides of five vital organs; kidney, heart, lungs, liver, tongue and dung of some twenty-five experimented goats obtained from one of the major market in Turaku area of Minna, Niger State, Nigeria. The study would ascertain the radiological risk associated with the consumption of these vital organs based on the ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb and ^{210}Po of the Uranium series and ^{232}Th, ^{228}Ra and ^{228}Th of the Thorium series as the major alpha and beta emitting radionuclides (Lasheen et al. (2008) linked to internal irradiation (Wahl and Bonner, 1958; McGill, 2014 and Knoll 2010).

2 MATERIAL AND METHODOLOGY

2.1 The Sampling Location: The twenty-five experimented goats set for this research were obtained from Turaku an area located in Minna of Niger State, Nigeria around the rail way station. The activities there are rearing and selling of goats, cows, sheep and rams. Minna is a city with an estimated population of 304,113 in 2007 national population census commission in west central Nigeria. It is the capital of Niger State; one of Nigeria's 36 Federal State and is the headquarters of Chanchaga Local Government. Minna is situated in the central part of Nigeria basement complex, surrounded by rugged terrain of granite rocks (Alabi, 2011). Cotton, guinea corn and ginger are the main agricultural products. The economy of Minna supports cattle rearing; shear nut processing and gold mining. The soil in the exact location (Turaku) where these animals are reared and sold is a loamy soil due to excessive amount of the animal waste.

2.2 Evisceration of the Goats: This area of research is very important because these goats are usually left to wonder about in order to eat and survive from the surrounding environment or on any available food or grasses which might be contaminated with radioactive substances or grasses growing on highly radioactive vicinity. The conditions favouring goat meat are; (i) early maturing of the females, (ii) highly prolific, (iii) good fecundity and mothering ability (iv) extended breeding season (v) foraging preferences (i.e. grazing in a wider spectrum of plants) (vi) adaptation to hot environments, (vii) tolerating extremes desert conditions and high temperature-humidity conditions of the tropics and (viii) ability to conserve water, limited subcutaneous fat cover and the particular nature of their coats. The life twenty-five goats purchased randomly from the market were slaughtered by severing the jugular vein, the carcass flayed, and organs removed using surgical gloves to avoid contamination. The organs were then processed into forms suitable for home use and then cut into smaller pieces, washed with distilled water and dried on trays under the sun for two weeks. They were then taken to the laboratory where they were oven dried at a temperature of 105 ^{0}C for 48 hours.

2.3 Targeted Organs: Lungs, kidney, liver, heart and tongue are excellent sources of protein that contains all the essential amino-acid sufficient for the growth, development and repairs of body tissues. The protein of these organs are of high biological value as it is highly digestible and easily absorbable (Olorunsanya, 2014). Protein cannot be stored in the body in a large amount, which is why some people consume part of these organs every day. The quality and quantity of protein in animal feed are of utmost importance to the growth and development of the meat animal (Olorunsanya, 2014). Minerals and vitamins content of the diet have a role in optimum growth of the animals. Some other factors include; genetics, environmental physiology, and human manipulation.

2.4 Sample preparation and measurement: The samples were carefully prepared according to International Atomic Energy Agency (2003) specifications for gross alpha and beta analyses, after which the samples were each contained in their planchets and were stored in desiccators waiting counting. The samples were analyzed for gross alpha and beta activity using an IN-20 model gas-flow proportional counter available at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. Each sample was counted three times and the mean used in computing the activity. The operational modes used for the counting were the α-only mode for the alpha counting and the β (+α) mode for the beta counting. The count rate of each sample was automatically processed by the computer using the equation below;

$$A_{(\alpha,\beta)} = B_{(\alpha,\beta)} \times 60/T \qquad 1.0$$

where $A_{(\alpha,\beta)}$ is the count rate (cpm) of alpha and beta particles, $B_{(\alpha,\beta)}$ is the raw count of alpha or beta particle, T is the counting time (2700 sec.).

The activity of each of the samples was calculated as;

$$C_{(\alpha,\beta)} = \left(A_{(\alpha,\beta)} - G_{(\alpha,\beta)}\right) \times \frac{U_{(\alpha,\beta)}}{H_{(\alpha,\beta)} \times S_{(\alpha,\beta)} \times V} \qquad 2.0$$

where $C_{(\alpha,\beta)}$ is the alpha and beta activity (Bq/kg), $G_{(\alpha,\beta)}$ is the background count of alpha and beta particle, $U_{(\alpha,\beta)}$ is the unit coefficient of alpha and beta particle (1.67 x 10^{-2}) conversion factor from cpm to cps (1cps=1Bq), $H_{(\alpha,\beta)}$ is the channel efficiency for alpha or beta counting, $S_{(\alpha,\beta)}$ is the sample efficiency for alpha or beta counting and V is the sample mass.

However, the sample efficiency for the goat samples was computed using;

$$\varepsilon_{gs} = \frac{M_r}{M_i} \times 100 \qquad 3.0$$

where M_r is the recovered mass after pellet was formed and M_i is the initial mass of the sample in powder form.

The error associated with the sample activity was computed using;

$$E_r = \frac{\left[B + \frac{(100000)^2}{T_{bgd}} \times G_{(\alpha,\beta)}\right]}{100000} \times \frac{U_{(\alpha,\beta)}}{H_{(\alpha,\beta)} \times S_{(\alpha,\beta)} \times V} \qquad 4.0$$

where B is the sample raw count, T_{bgd} is the background count time.

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3. RESULTS AND DISCUSSION

3.1 The gross alpha and gross beta activity concentration for all the organs: The gross alpha and gross beta activity concentration for all the organs (kidney, liver, heart, tongue and lung) of the twenty-five goat samples were determined and the mean, median, maximum, minimum values are shown in Table 1. As seen in Table 1, the mean activity concentration (toxicological levels) in the organs ranges for gross alpha (α) and beta (β) were 0.03 ± 0.01 Bq/kg (for the heart) to 1.06 ± 0.42 Bq/kg (for the kidney) and 2.47 ± 0.35 Bq/kg (for the tongue) to 40.59± 0.39 Bq/kg (for the lung) respectively. The maximum values recorded were 1.93 Bq/kg (kidney) for gross alpha and 41.43 Bq/kg (lung) for gross beta while the minimum were 0.01 Bq/kg (heart) for gross alpha and 1.58 Bq/kg (tongue) for gross beta.

Table 1: Gross alpha activity concentration in the organs

Sample	Mean values (Bq/kg)		Max. Value		Min. value		Median	
	Gross α-activity	Gross β-activity	Gross α-activity	Gross β-activity	Gross α-activity	Gross β-activity	Gross α-activity	Gross β-activity
Kidney	1.06 ± 0.42	6.20 ± 0.94	1.93	8.88	0.63	4.98	0.88	5.98
Liver	0.09 ± 0.04	3.87 ± 0.68	0.17	5.69	0.05	2.69	0.09	3.69
Heart	0.03 ± 0.01	3.72 ± 0.56	0.05	4.75	0.01	2.09	0.03	3.79
Lung	0.28 ± 0.16	40.59 ± 0.39	0.66	41.53	0.15	39.34	0.18	40.59
Tongue	0.17 ± 0.01	2.47 ± 0.35	0.19	3.11	0.13	1.58	0.17	2.49

From the alpha activity in Table 1, the concentration in kidney was high because the kidney deals with liquid substances which might have much concentration of alpha emitting radioactive nuclides which is of high linear energy transfer (high LET) and can cause significant damage to the DNA of humans when eaten continuously resulting to a wide array of biological effects. They could react with molecules other than DNA (lipids, proteins, water, etc.) to produce free radicals, which would go on to adversely react with the DNA molecule. DNA damage is cumulative and could (but does not always) result in carcinogenesis or other adverse cellular events months or years after exposure. In terms of gross beta activity as observed in Table 1, the concentration was high in lung and since nothing else other than air gets to the lungs, then the elevated values of the natural radioactivity might have attached to aerosol particles and are inhaled via respiration to the lungs. Alpha particles increases the risk of cancer, in particular alpha radiation is known to cause lung cancer in humans when alpha emitters are inhaled (Globocan, 2002). The greatest exposure to alpha radiation for average citizens comes from the inhalation of radon and its decay products, several of which also emit potent alpha radiation. Lasheen et al., (2008) recognizes ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb and ^{210}Po for the Uranium series and ^{232}Th, ^{228}Ra and ^{228}Th for the Thorium series as the major alpha and beta emitting radionuclides which are of importance to internal irradiation (Lasheen et al., 2008; Agbalagba, 2012 and Tettey-Larbi, 2013). Beta radiation can cause both acute and chronic health effects but acute exposures are uncommon. Chronic effects result from low-level exposure over a long period. They develop relatively slowly (5 to 30 years). When taken internally beta emitters can cause tissue damage and increase the risk of cancer. The risk of cancer increases with increasing dose. Some beta emitters such as carbon-14 distribute widely throughout the body. Others accumulate in specific organs and cause chronic exposures, which might be the case of the lungs recording a high gross beta concentration of 40.3335 ± 1.831 kg. The dung recorded an average value of the gross alpha activity concentration of 0.2620 ± 0.0797 Bq/kg and gross beta activity concentration of 3.210 ± 1.636 Bq/kg. From this work it revealed that the goat-dung used as manure in the farm have a relatively high alpha and beta activity concentration. This might contribute to the activity concentration in soil, which eventually gets into the food chain.

3.2 Annual consumption rates in consuming these organs: The annual consumption rates in consuming these organs in relation to the accumulation of the gross alpha and beta activity have been evaluated for different age groups and results are presented in Figures 1 and 2.

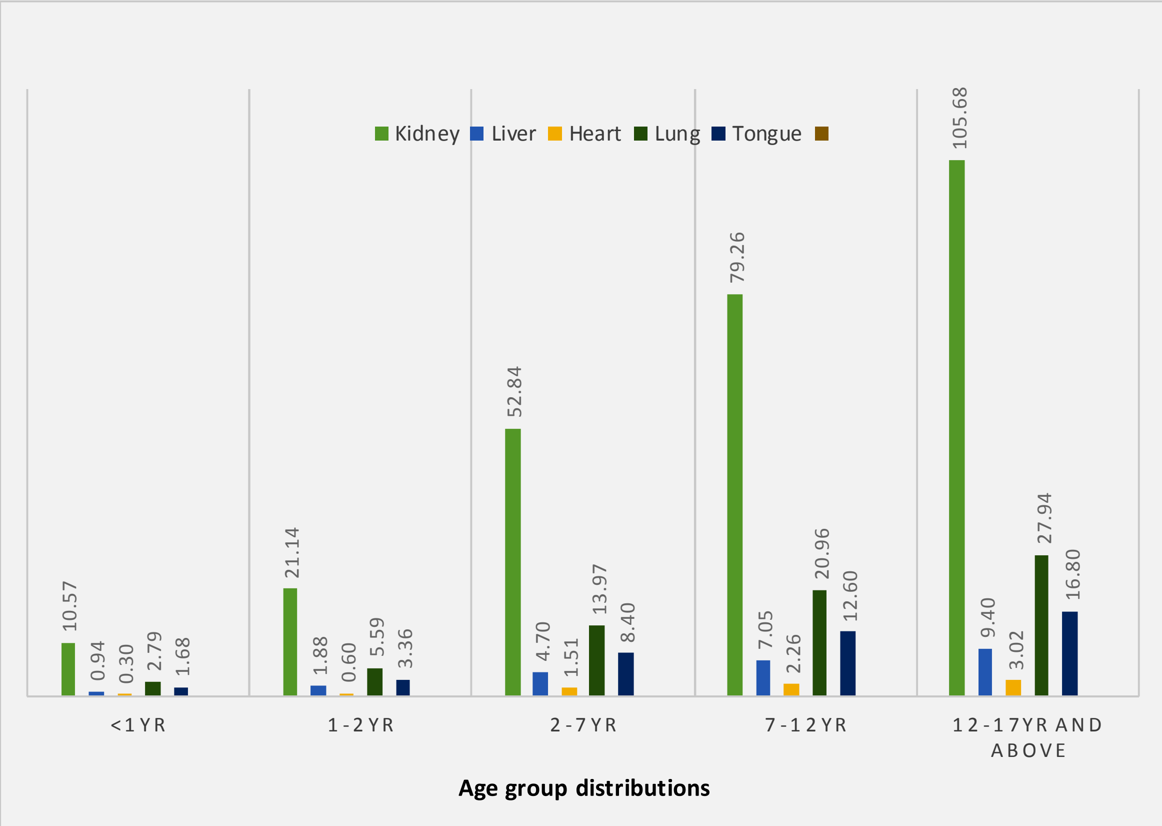

Figure 1: Gross alpha activity variation and annual consumption for different age groups

As shown in Figure 1, the variation of gross alpha activity concentrations in the organs of the randomly selected twenty-five goats and the annual consumption in Bq/yr shows high accumulation in the kidney followed by the lung for all the age groups. These values were calculated using the default annual consumption factors for exposed individuals in the critical group obtained from National Nuclear Regulator-RG002 document for the protection of persons, property and the environment against nuclear damage. The results of the activity accumulation for alpha particles in consuming the kidney over a year were 105.68 Bq/yr for 12 to 17 year and above, 79.26 Bq/yr for 7 to 12 years, 52.84 for 2 to 7 years, 21.13 Bq/yr for 1 to 2 years and 10.57 Bq/yr for less than one year olds. For consuming the lung, the alpha particle activity concentration over a year were 27.94 Bq/yr (12-17 years and above), 20.96 Bq/yr (7-12 years), 13.97 Bq/yr (2-7 years), 5.59 Bq/yr (1-2years) and 2.79 Bq/yr (<1 year). The alpha particles were high in the annual consumption of these organs (kidney, liver, heart, tongue and lung). Alpha particles increase the risk of cancer. In particular, alpha radiation is known to cause lung cancer in humans when alpha emitters are inhaled (Globocan, 2002). Lasheen et al., (2008) recognizes 238U, 234U, 230Th, 226Ra, 210Pb and 210Po for the Uranium series and 232Th, 228Ra and 228Th for the Thorium series as the major alpha and beta emitting radionuclides (Lasheen et al., 2008; Agbalagba, 2012 and Tettey-Larbi, 2013) which could react with molecules other than DNA molecules; lipids, proteins, water, etc. to produce free radicals which could adversely react with the DNA molecules in humans.

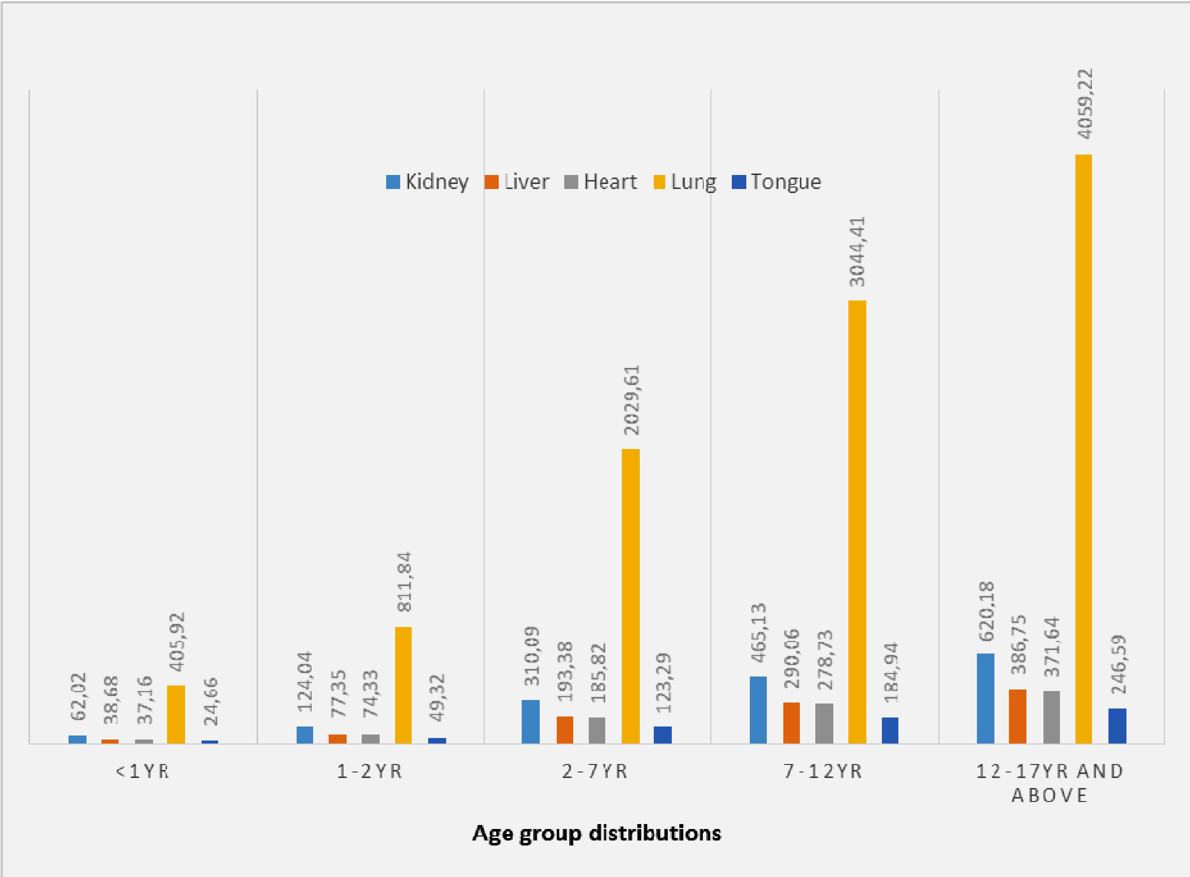

Figure 2: Gross beta activity variation and annual consumption for different age groups

From Figure 2, the beta activity concentration in consuming the lung is very high in all the considered age groups, especially in the age group of 12 to 17 years and above. It has a value of 4,059.22 Bq/yr followed by 3,044.41 Bq/yr for 7 -12 years, 2,029.61 Bq/yr for 2-7years, 8,11.84 Bq/yr for 1-2 years and 405.92 Bq/yr for < 1 year. For eating the kidney based on the average consumption values established from international literature, which includes values obtained from South African national food balance sheets, the kidney also recorded higher values for all the age groups. This shows that eating the lung and kidney can cause damage to the DNA of humans resulting in a wide array of biological effects. These particles (alpha and beta) could react with molecules other than DNA (lipids, proteins, water, etc.) to produce free radicals, which would go on to adversely react with the DNA molecule (USEPA, 2012 and UNSCEAR, 2008). However, DNA damage is cumulative and could (but does not always) result in carcinogenesis or other adverse cellular events years after exposure. The annual accumulation rate were high in consuming the lung and kidney for both alpha and beta activity concentration and were relatively low in consuming the other organs.

3.3 Average effective dose per kg of the five vital organs and the dung: The United Nation Scientific Committee on Atomic Radiation (UNSCEAR, 2008) has estimated that the global average annual dose per person from all source of radiation in the environment is approximately 3.0 mSv/year, of this 80% (2.4 mSv) is due to naturally occurring radiation and 19.6% (almost 0.6 mSv) is due to the use of radiation for medical diagnosis. The mean activities were converted to dose in mSv using the following conversion factor as indicated in the published work of IAEA/WHO Secondary Standards Dosimetry Laboratory, (2007).

Table 2. Average alpha and beta effective dose par kg of organs and dung

Sample	Mean alpha effective dose (mSv) per kg	Mean beta effective dose (mSv) per kg
Kidney	0.00789 ± 0.00099	0.075±0.0219
Liver	0.00074 ± 0.00043	0.046±0.0224
Heart	0.00029 ± 0.00033	0.039 ±0.0202
Lung	0.00199 ± 0.00054	0.504 ±0.0229
Tongue	0.00205 ± 0.00058	0.026 ±0.0222
Dung	0.00326 ± 0.00066	0.040`±0.0205

Based on the conversion and consideration of per kg of the vital organs from the mean value of the gross alpha activity of 0.2072 ± 0.0462Bq/kg, an effective dose of 0.00259 ± 0.00003mSv and for the average value of gross beta activity of 11.0352 ± 1.7536Bq/kg per kg, an effective dose of 0.138 ± 0.0219 mSv was obtained (Table 2). However, the average effective dose due to the mean values of both gross alpha and beta obtained were far less than 0.3 mSv annual effective doses for food ingestion established by UNSCEAR (2000). Hence, consuming these organs (heart, kidney, lungs, tongue and liver) is relatively safe. This in relation to Globocan (2002) for cancer cases worldwide showed great agreement for cancer cases in the lung and kidney since the gross alpha activity and gross beta activity were high for the experimented twenty-five goats. Goat meat comprises 63 % of all red meat that is consumed worldwide (Casey, 1992). Currently, goats are the main source of animal protein in many North African and Middle Eastern nations, and are important in Southeast Asia, the Caribbean and other tropical regions. Goat meat has been established as a lean meat with favourable nutritional qualities (Casey, 1992), and it is an ideal choice for the health-conscious consumer. The nutrient values of prepared goat meat, chicken, and other red meats consumed in the United States by USDA Nutrient Database for Standard Reference, USDA (2001) showed that goat had the least value of fat in grams of 2.6 against pork with 8.2. The protein value in gram is 23 compared to chicken, beef and pork with values of 25 each and lamb with a value 24. The cholesterol in mg is 63.8 compared to 78.2 in lamb, 76 in chicken and 73.1 in beef and pork. The calories value is 122 in goat, 162 in chicken, 180 in pork, 175 in lamb and 162 in chicken. Lastly, the Iron value in mg is 3.2 for goat, 1.5 for chicken, 2.9 for beef, 2.7 for pork and 1.4 for lamb. These aforementioned nutritive values of goat indicate that consuming goat meat is of great dietary benefit. However, consuming the organs and poor management in goat keeping might pose serious health related risks to the human biological system.

4 CONCLUSION

The research for natural radioactivity by gross alpha and gross beta measurement in six samples obtained from twenty-five goats has been carried out using one channel-gas flow proportional counter (MPC-200-B-DP). The range of the average gross alpha from; ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb and ^{210}Po for the Uranium series and average gross beta from; ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{45}Ca, ^{89}Sr, ^{90}Sr, and ^{90}Y (NCRP 1985) were 0.03 ± 0.01 Bq/kg to 1.06 ± 0.42 Bq/kg and 2.47 ± 0.35 Bq/kg to 40.59 ± 0.39 Bq/kg respectively. These activities concentration were converted to mean effective doses. For the total alpha activities, an average dose of 0.00259 ± 0.0003 mSv was obtained while for total beta activities, we obtained 0.138 ± 0.0219 mSv. However, the beta effective dose per kilogram consumption of the lungs was obtained to be 0.504 ±0.0229 mSv, which appeared to be above the standard annual effective dose of 0.30 mSv for humans as recommended by the committee on the effects of atomic radiation report (UNSCEAR, 2000). Finally, the gross alpha and beta activity in the goat-dung were 0.26 ± 0.0527 Bq/kg and 3.21 ± 1.64 Bq/kg respectively. Hence, it is not relatively advisable to be used as manure in farmlands continuously.

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