Evaluation of Geophagia as a Pathway for Internal Exposure to Ionizing Radiation

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Abstract. Geophagia, the deliberate ingestion of soil, is a complex eating habit found among animals and human beings around the world. Among other reasons soil ingestion is perceived as a source of essential mineral supplements, hence its prevalence among subsistence communities. Geophagia has also been associated with a range of health effects. In the present study the potential of geophagia as a pathway for chronic internal radiation exposure has been evaluated. The most common geophagic materials in Kenya are the soft volcanic ashes. They occur naturally in various hues and shades of grey and pink colours. The volcanic ashes are quarried and sold in various kiosks and supermarkets either in pieces or in packets of about 100g. The concentrations of radionuclides in some of the common geophagic materials are determined, and the rates of their intakes (by ingestion) were estimated using the information obtained from a survey among people, including young mothers and pregnant women, who practice geophagia in Kenya. The range of annual effective doses estimated from the concentrations of ^{228}Th and ^{226}Ra in these materials, and the possible ingestion rates (1 to 90g/day), are below 1mSv. However, the committed effective dose for a fifty-year chronic ingestion evaluated using the biokinetic model calculation programme (LUDEP version 2.04) are high: up to 276 mSv. The results are discussed in the light of the need for reliable human data on the effects of low-level radiation, also bearing in mind that these materials are essential consumer products and there may be need to control exposures arising from their consumption.

1. Introduction

Soil ingestion do occur inadvertently due to mouth breathing, consumption of food items contaminated with soil, mouthing of dirty hands or other contaminated non-food items, etc. However, geophagia – the term for intentional ingestion of soil and other earthen materials – is the subject of this study. A recent review [1] shows that geophagia has been documented over centuries and is still taking place today among various communities all over the world. The reasons why people engage in geophagia are varied, including nutritional or dietary, medicinal, cultural, etc. Many authors have attributed geophagia to a behavioural response to correct deficiencies in basic minerals like iron, copper, manganese, and zinc [2, 3]. But other studies [4, 5] on the bioavailability of the basic nutrients in geophagic materials have given indications that, for human and animals that engage in it, geophagia may be the cause, rather than the response to their mineral deficiency. There were also few reports [1, 6] that linked geophagia to radiation exposures, and highlighted the need for assessment of radiation doses due to geophagia.

Internal doses arising from ingestion of radionuclides can be estimated if the levels of the radionuclides in the body (body burden) as well as the metabolic process involved are well known [7]. Body burdens are usually measured *in vivo*, e.g. with whole-body gamma ray counters, or *in vitro* by assaying samples of organs, tissues, urine, faeces, etc. Estimates of body burdens by model calculation based on the activity concentrations of the radionuclides in samples of the material ingested, the ingestion rate, fractional uptake and dose conversion coefficients are also possible and are usually sufficient at the screening stage [8]. Two of the challenges faced when assessing radiation doses due to geophagia are the problems of determination of the soil intake rates [1]; and the fact that soil-associated radionuclides may not be readily absorbed in the gut compared to food-associated radionuclides [9, 10]. But there are also experimental evidences [11] that release of soil-associated radionuclides actually do occur during digestion in the gastrointestinal tract.

This is a presentation of a screening study. The elemental composition of the commonly ingested materials and the concentration of radionuclides in them are determined. Finally an estimate of the

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internal doses that could arise from chronic ingestion of these materials are performed manually using dose calculation formula and also using standard dose assessment programme (LUDEP version 2.04 [12].

2. Materials and Methods

2.1. Measurement of Activity Concentrations of naturally–occurring radionuclides in Georphagic materials

2.1.1. Sample Description

The most commonly ingested materials are earthy in appearance, similar to the volcanic rocks (Tuffs) used as building-stones. But, unlike the building stones, they are composed of finer grains, contain no pyroclasts, and are so soft they are easily crushed between fingers. They occur naturally in various hues and shades of grey and pink colours. They have been vaguely classified as soft Tuffs or soft volcanic ashes [6], although the detailed geochemistry of these materials is still being investigated. The volcanic ashes are quarried in commercial scales and sold in various kiosks and supermarkets either in pieces or in packets of about 100g. Twenty-five samples of about 500g each were obtained randomly for the purpose of screening measurements.

2.1.2. Sample Preparation

The sample preparation for gamma-ray spectrometry involved pulverization with ball mills, drying overnight at about 110^{o}C. About 500g of the pulverized samples are stored in sealed glass bottles for about one month to achieve equilibrium between ^{226}Ra and its gamma emitting decay products before being analyzed with a gamma ray spectrometer. Pellets were also made from the pulverized samples for XRF analysis.

3. Results and Discussions

3.3. Specific activities and elemental concentrations

The results of the quantitative elemental analyses with XRF show that the volcanic ashes contain high levels of iron, around 8% dry weight (Table 1). This may explain why the female populations (human and domestic animals) are known to develop exceptional cravings for these materials during pregnancies, when they more likely to be anemic. Further investigations are necessary to ascertain whether the Fe in the volcanic ashes are released to the body system as believed by those who ingest the materials, or whether the ingestion is causing iron deficiency as concluded in the works of [4] and [5].

The other elements that are also found in appreciable concentrations (> 0.1%) include K, Ca, Ti, Mn and Zr. The remaining elements, including Th are in orders of parts per million (ppm). The health and nutritional implications of ingesting materials containing elements at these relative concentrations have not been studied. But there are documented evidences [4] about availability and uptake of certain elements being affected by the presence and concentrations of other competing elements in the body.

As expected on the naturally occurring radionuclides were observed from the gamma spectrometric measurements (Table 2). Although ^{40}K was also observed in all the samples, only ^{226}Ra and ^{228}Th are considered in the present calculation.

Table 1. Elemental composition of soft volcanic ash

Element	% by Weight	
	Range	Mean
K	(0.89 – 1.14) E+00	1.02 E+00
Ca	(5.30 – 6.97) E-01	5.83 E-01
Ti	(5.23 – 5.98) E-01	5.69 E-01
Mn	(1.26 – 1.39) E-01	1.32 E-01
Fe	(7.52 – 8.14) E+00	7.72 E+00
Cu	(2.97 – 5.76) E-03	3.91 E-03
Zn	(1.54 – 2.00) E-02	1.73 E-02
Ga	(4.23 – 6.05) E-03	5.13 E-03
As	(0.96 – 2.09) E-03	1.45 E-03
Rb	(2.70 – 3.04) E-03	2.90 E-03
Sr	(1.20 – 1.79) E-03	1.47 E-03
Th	(3.29 – 3.68) E-03	3.50 E-03
Y	(1.05 – 1.15) E-02	1.09 E-02
Zr	(1.46 – 1.76) E-01	1.60 E-01
Nb	(2.74 – 3.35) E-02	3.05 E-02

Table 2. Activity concentrations of radionuclides in sample of soft volcanic ash and the range of calculated effective doses

Radionuclide	Range of Activity concentrations (Bq/kg)	Range of Effective Dose (mSv/y)
226Ra	1 – 40	1.02 E-03 – 3.68 E-01
228^{Th}	105 - 455	1.34 E-02 – 5.23 E-01

3.2. Dose calculation

The effective close *E* (Sv per year) due to intake of a radionuclide with the ingested material is calculated using the expression [8]:

$$E = C\sum_i A_i \cdot DCF_i \qquad (1)$$

where

C (kg/yr) = annual ingestion rate of the geophagic material of interest;
A_i (Bq/kg) = activity concentration of radionuclide *i* in the ingested material; and
DCF_i (Sv/Bq) = Committed effective dose coefficients for radionuclide *i*.

Ideally the summation over *i* should include all the radionuclides present in the ingested material, but only the two most important radionuclides, ^{226}Ra and ^{228}Th, are considered in the present calculation, and the corresponding dose coefficients are 2.8 E-07 and 3.5 E-08 Sv/Bq, respectively [13].

The ingestion rates were also estimated from a survey conducted among people who ingest these materials [6]. The values vary from 1 g per day to 100 g per day with an arithmetic mean of 25 g per day, similar to the result (10 – 90 g per day) of an earlier study carried out by [14]. Using these figures as inputs in equation 1 the values of effective doses in Table 2 were obtained.

In order to put into perspective the radiological implication of chronic ingestion of these materials, the committed effective dose (for a 50 year post intake) was calculated using the computer code LUDEP version 2.04 [13]. The biokinetic model used is for ^{232}Th and equilibrium with its decay products is assumed. The values obtained for the maximum and mean ingestion rates are 276.2 and 25.6 mSv, respectively. These results show that geophagia could constitute an additional source of internal doses and it should be studied more keenly. Although there are doubts in the appropriateness of the data used in the calculation – they were obtained from experiments based on radionuclides associated with food not soil.

4. Conclusion

The results of the screening survey indicate that some of the geophagic materials in Kenya contain elevated concentrations of naturally occurring radionuclides. Since the materials are essential consumer products for a section of the population, further studies are required to determine whether the sale should be controlled and whether geophagia itself should be classified. One must also ear in mind that geophagia is an additional exposure pathway not included in the normal background exposures. In principle, the population receiving the doses encountered in the screening survey could provide human data on the health effects of low doses of radiation, but the large sample size required to prove the existence or absence of these effects is still difficult to attain. Finally, the dose calculations were based on data for food-associated radionuclides, and caution must be exercised in the interpretation of the results.

5. Acknowledgements.

We are grateful to Dr. Gary H. Kramer – Head, Human Monitoring Laboratory, Canadian National Calibration Reference Centre for In-vivo Monitoring – for useful discussions and for performing the Ludep calculation. The paper was presented during the IRPA11 in Madrid through the financial supports from the Abdus Salam International Centre for Theoretical Physics (ICTP) Programme for Training and Research in Italian Laboratories, the Society for Radiological Protection (SRP), and Ente Per Le Nuove Tecnologie, L'Energia E L'Ambiente ENEA IRP, Bologna, Italy.

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