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Soil-to-cassava transfer of naturally occurring radionuclides from communities along Ghana's oil and gas rich Tano Basin

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A R T I C L E I N F O

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A B S T R A C T

Soil-to-plant transfer factor (TF) is widely used to assess the impact of soil radioactivity on agricultural crops. The root crop cassava (*Manihot esculenta*) provides 30%–50% of the calories consumed in Sub-Saharan Africa and is widely used in South America. γ-ray analysis was used to measure activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in cassava root and soil. The TF values for ^{238}U, ^{232}Th, and ^{40}K were in the range 0.06–0.12, 0.01–0.10 and 0.04–0.28 respectively. The median transfer factors were 0.10 (^{238}U), 0.04 (^{232}Th) and 0.08 (^{40}K). For ^{238}U and ^{232}Th, the highest TF values were 0.12 and 0.10 respectively.

1. Introduction

Naturally occurring radioactive materials (NORMs) are found everywhere in the earth's crust and are present in very low concentrations (Doyi et al., 2013; UNSCEAR, 2000). Humans are continually being exposed to NORMs mainly through activities such as burning of fossil fuels, metal refining, manufacture and use of fertilizer (UNSCEAR, 2000) and natural processes like exhalation of radon gas to the atmosphere or by dissolving in groundwater (IAEA, 1999) or through the food chain (NRC, 1999).

Uptake of radionuclides by plants occurs both via the root system and from atmospheric deposition through activity trapping onto external plant surfaces (Vandenhove et al., 2009). The bioavailability of radionuclides in soils and hence their transfer to plants are rather complex, depending on several factors. These factors include the chemistry of the specific radionuclide, soil type and climatic conditions, soil pH, solid/liquid distribution coefficient, organic matter, plant genotype, and agronomic management (Chakraborty et al., 2013; Kabata-Pendias and Pendias, 1984; WHO & FAO, 2011; Malik et al., 2010). Some radionuclides mimic essential elements of plants such as potassium and calcium (James et al., 2011). Cassava, a root crop, exhibits greater root absorption of radioactivity than through the trapping onto external plant surfaces though there is some level of atmospheric capture (Asaduzzaman et al., 2014).

Cassava (*Manihot esculenta*) is native to South America and represents 30%–50% of all calories consumed in Sub-Saharan Africa (Long et al., 2017) and is the third most important source of calories in the tropics (FAO, 2008). There is a considerable range of soil types on which cassava is grown worldwide. In Ghana, cassava production is estimated to exceed 15,000,000 Mt by 2015. Estimates put the yield of the crop at 48.7MT per hectare under rain-fed conditions. The edible root varies significantly in size from 15 to 100 cm as well as in weight from 0.5 to 2.0 kg (Amponsah, 2016). In addition to being the most consumed staple crop in the study area and several other communities, cassava is also used as raw material for the production of industrial starch, ethanol (biofuel) and animal feed (Adjei-Nsiah & Sakyi-Dawson, 2012).

The transfer factor (TF) expresses the plant's intake of radionuclides from the soil, and is commonly used in environmental transfer models estimating dose impact on humans (Chakraborty et al., 2013).

Studies of the soil-to-cassava TF of radionuclides are limited. These few studies were done in Australia, Brazil, India, Indonesia, Marshal Islands and Vietnam (IAEA-TECDOC-1616, 2009; Velasco et al., 2009) and Malaysia (Asaduzzaman et al., 2014). There has been no study on the characterization of TFs for the Ghanaian ecosystem for any crop. This study TFs of naturally occurring radionuclides from soil-to-cassava as an important tool for future modelling of the accumulation of ^{238}U, ^{232}Th and ^{40}K by the root crop.

2. Methodology

2.1. Study area

The coastal communities bordering the Tano Basin in Ghana were selected for this study due to the offshore oil and gas activities. Ghana is

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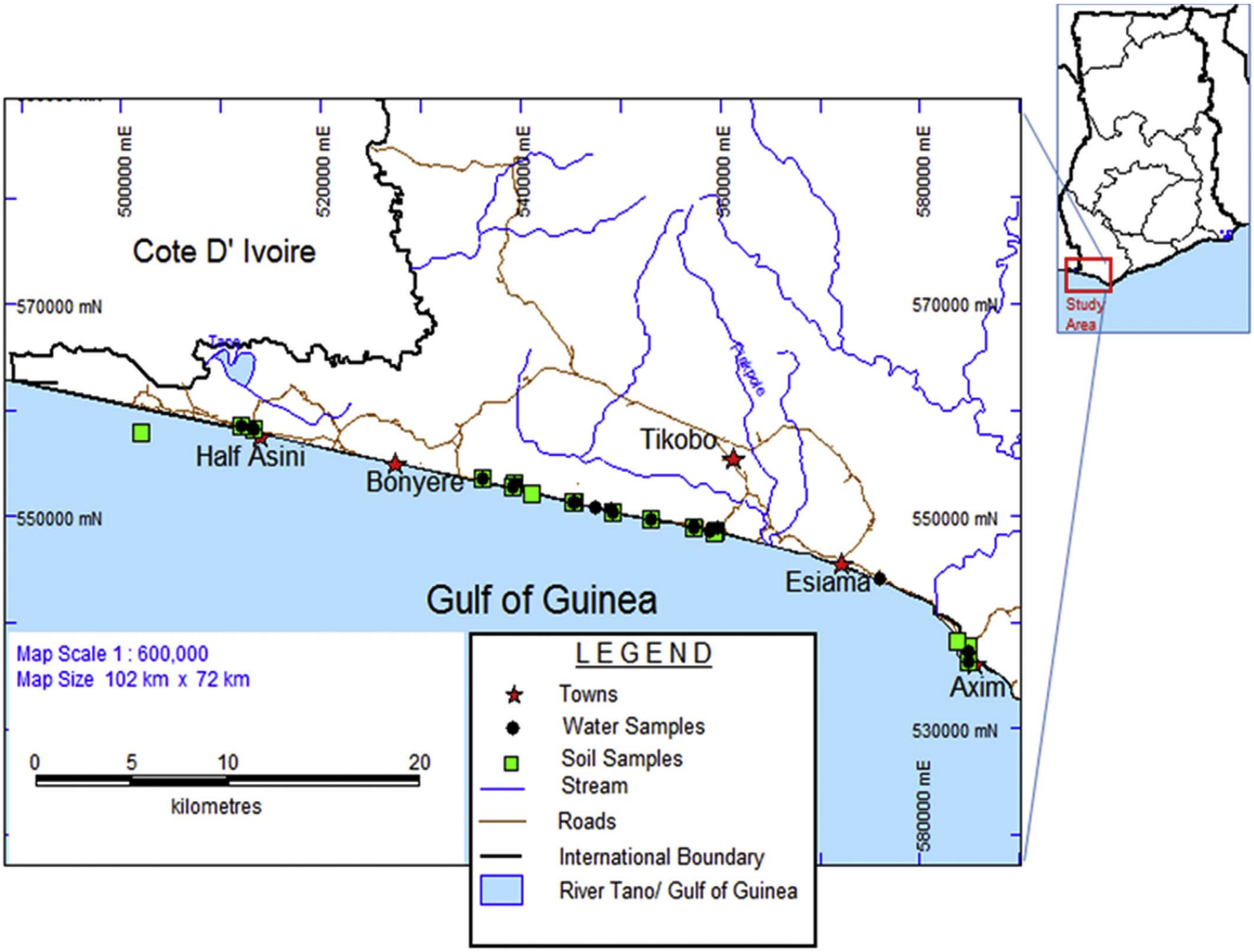

Fig. 1. Map of sampling locations. Soil and cassava are co-located.

located on the equator, the study areas experiences only two seasons, rainy (wet) and harmattan (dry) Subsistence farming is the main occupation of the people. The study locations have similar geologic formation composed of schists, phyllite and greywacks rocks (Atta-Peters and Garrey, 2014). This study is a component of wider research to establish background radioactivity for the communities from Axim to Newtown that are situated along the coast bordering the Tano basin. (see Fig. 1)

2.2. Sampling

2.2.1. Cassava

With the help of plastic trowel, each 2 kg composite of cassava root sample was harvested from three different plants within close proximity of each other from small backyard gardens at each study location, and carefully separated from the soil. The samples are placed in zip-lock bags, labeled and transported to the laboratory sample treatment area for subsequent analysis. The sampling was done during the harmattan season (February) from the crop cultivated under natural field conditions.

2.2.2. Soil

Co-located soil samples were collected using a plastic trowel that was wiped clean each time prior to sampling using wipes and deionised water. Before sampling commenced, the trowel was passed through soils immediately adjacent to the sample site to remove any possible effects associated with the previous sample site (Taylor et al., 2014; Taylor and Hudson-Edwards, 2008). Soil samples were taken at 0–20 cm depth (IAEA, 2010) from the open cavity left by the sampled cassava and placed into in non-coloured zip-lock plastic bags. The 20 cm depth is chosen to include the surface layer corresponding to the rooting zone. The samples were transported to the laboratory, dried, sieved and homogenized into a composite sample.

2.3. Sample treatment

2.3.1. Cassava

The sampled cassava was thoroughly cleaned and the edible portions chopped. The samples were freeze-dried using freeze drier model CHRIST Gamma 2–16 LSC. They were ground into fine powder using Laboratory Mortar Grinder (Pulverisette-2) at the A. Chatt Chemical Laboratory of the Ghana Atomic Energy Commission and sieved through 2 mm mesh. 200 g of the sieved cassava samples were weighed into a 1 L Marinelli beaker. The samples were counted using an HPGe detector for 36000s and the activity concentrations of ^{238}U, ^{232}Th and ^{40}K determined from the net counts of full energy events.

2.3.2. Soil

Samples were air-dried in trays for 2 weeks and then oven dried at a temperature of 105 °C for 3–4 min until the samples were well dried. Samples were milled into a fine powder using Laboratory Mortar Grinder (Pulverisette-2) at the A. Chatt Chemical Laboratory of the