URANIUM UPTAKE BY SELECTED FOOD GROUPS AND THE ASSOCIATED HEALTH EFFECTS TO THE RESIDENTS OF BAHI DISTRICT IN TANZANIA

ZAINAB JURAJI MZIRAY

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD SCIENCE OF THE SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2014

ABSTRACT

Assessment of Uranium levels in selected food groups and products with the associated health effects to the residents of Bahi District was carried out. The objective was to come up with information on whether these food groups contain significant amounts of Uranium and if the community has been affected by uranium related diseases. This was done to bring the awareness to the vulnerable communities and Tanzanian Government in general on the environmental and health hazards posed by the presence of Uranium deposits in the study area. Selected food groups and products used to assess uranium levels were maize, finger millet, rice, cassava leaves, salt, soda ash, fish, flamingo meat and water. These food groups were collected from three different villages of Bahi district. The levels of uranium in the named food groups and products (in $\mu g\ kg^{-1}$) were determined by using ICP–OES instrument. Maize and rice had uranium concentration below detectable limit (<10), millet was found to range 11.88 – 25.13; cassava leaves ranged 12.37 – 13.83. Fish had uranium content of 17.98 in the skin where as muscles had uranium level below detactable limit. Flamingo bird had uranium level of 31.78 in the liver , where as other tested parts had below detectable limit. Soda ash was found to have uranium content of 1910, whereas salt had uranium content below detectable limit. The results for water from different sources in three villages have shown that, in Ilindi village, Playa lake water had uranium concentration of 1233, while drinking water from one well had uranium content of 95.4, water from a well used for irrigation had uranium content below detectable limit. In Mpamantwa village, the water from one well had uranium content of 16.7 whereas other sources had uranium level below detectable limit. In Bahi village, the water from one well had uranium

level below detectable limit while river water had uranium concentration of 67.6 and another well had uranium content of 16.6. Secondary data from hospitals have shown that Bahi communities have not been affected by uranium exposure through foods consumed. However, further research need to be conducted on domestic animals since they use Illindi Playa lake water for drinking which was found to have high uranium concentration.

DECLARATION

I, Zainab Juraji Mziray do hereby declare to the Senate of Sokoine University of Agriculture that the work presented here is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

26/09/2014

Zainab Juraji Mziray — **Date**

(MSc Food Science Candidate)

The above declaration is confirmed

26/9/2014

Prof. Chove B.E. — **Date**

Supervisor

26/09/2014

Mr. Chaula D. — **Date**

Supervisor

COPYRIGHT

ACKNOWLEDGEMENTS

First and foremost, I thank God for gracing me with good health and patience during the whole period of this work.

As there are so many individuals who have contributed to the successful completion of this study, it is impossible to mention all by their names; I will therefore express my thanks to some of them.

My sincere gratitude is due to my supervisors Prof. Chove B.E and Mr. Chaula D (Sokoine University of Agriculture) for their guidance, suggestions, constructive criticisms and devotion to the work throughout the study. Their readiness to assist has been a key to the success of this study. Furthermore, the appreciation should go to the academic staff members of the Department of Food Science and Technology SUA for their various contributions made to this study. Thanks to Dr. Marwa E. of Department of Soil (SUA) for his great support and contribution to this study.

Thanks to my employer Tanzania Bureau of Standards (TBS) for the financial support as well as the study leave. Thanks also to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for their financial support in the whole period of this study.

I express my sincere thanks to Mr. Bomani of Southern and Eastern African Mineral Centre (SEAMIC) for his assistance in obtaining the standard (certified reference material) for Uranium during laboratory analysis of samples in this study. It was impossible to analyse the samples without standard and there was nowhere to be found in the country except at SEAMIC. I really appreciate his help. Thanks go to Government Chief Chemist Laboratory Agency staff members for their initiatives to assist me during the laboratory analysis.

I express my sincere and special thanks to my beloved Husband Mr Gaudence P. Maro for his moral support, willingness and patience for the whole period of my study. It was not a simple task for him to stay with family especially our young daughter by himself for such a long period. Thanks also to my young sweet daughter (Haika) for her patience during all had times of missing her mother. I appreciate the help from my parents in–law for taking care of my child during my absence. I would not be fair if I will not appreciate the presence of Lina Rimoy who was like the guardian and a friend to my daughter for the whole period of study, she was too young when I left her but Lina was taking care of her as if she was her own daughter, thanks a lot Lina.

Finally, I articulate my profound appreciation and lots of thanks to my father, mother, young brother and sister for their continuous love, support and encouragement for the whole period of this study.

DEDICATION

This work is dedicated to my beloved parents Mr. Juraji Daudi Mziray and Mrs. Latipha Idd Mfinanga who laid the foundation of my education. From the first day you take me to school you knew that your daughter will reach somewhere. For this I think I have impressed you because at least I did not let you down. I thank you very much Dad and Mom.

TABLE OF CONTENTS

LIST OF TABLES

FIGURE

LIST OF PLATES

UNEP	United Nations Environment Programme
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USAEPI	United States Army Environmental Policy Institute
USDE	United States Department of Energy
USEPA	United States Environment Protection Agency
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Uranium (U) is the heaviest naturally occurring element in the periodic table (Burkart *et al.*, 2002). According to Anke *et al.* (2007) Uranium was discovered by a German chemist Martin Heinrich Klaproth. It is a silvery, shiny metal that is both ductile and malleable. According to Kotec (2005), Uranium occurs naturally in low concentrations (a few parts per million) in soil, rock, surface water, and groundwater. It is a relatively reactive element which combines with non–metals such as oxygen, sulphur, chlorine, fluorine, phosphorus, and bromine (Anon, 2012). It also reacts with cold water when present in a finely divided state. In air it easily oxidizes and becomes coated with a layer of oxide. This explains why in nature uranium mainly occurs in oxidized form. It occurs in numerous minerals and is also found in lignite, monazite sands, phosphate rock and phosphate fertilizers. In ores, it occurs as uranite (UO_2^{2+}), pitchblende ($U_3O_8^{2+}$) or as secondary minerals (complex oxides, silicates, phosphates, vanadates) (Burkart *et al.*, 2002).

For many years, Uranium has been used to colour ceramic glazes, producing colours that ranged from orange, red to lemon yellow. It was also used for tinting in early photography. The radioactive properties of Uranium were not recognized until 1896, and its potential use as an energy source was not realized until the middle of the 20^{th} century. In nuclear reactors, Uranium serves as both a source of neutrons (via the fission process) and a target material for producing Plutonium. (Plutonium–239 is produced when Uranium–238 absorbs a neutron). Today, its primary use is as fuel in

nuclear power reactors to generate electricity. Uranium is also used in small nuclear reactors to produce isotopes for medical and industrial purposes around the World. (Kotec, 2005).

Naturally, Uranium exists as three isotopes ^{234}U, ^{235}U and ^{238}U with a relative abundance of 0.0055, 0.720 and 99.29 per cent respectively (U.S Department of Energy, 1998). All isotopes of Uranium are radioactive, with most having extremely long half–lives (Kotec, 2005). Although uranium is indeed radioactive, the discovery of radioactivity occurred during a study of uranium's properties (Burkart *et al.*, 2002). It has a very long half–life of about 4.46×10^9 years (ATSDR 1999), which means that it emits its radiations at a rather leisurely pace. It emits mostly alpha particles, which do not travel very far through the air and will not even penetrate the human skin (Burkart *et al.*, 2002). It follows that, therefore, the dangers associated with exposure are mainly through ingestion, inhalation or drinking contaminated water (USDE, 1998).

Uranium and its compounds are carcinogenic and highly toxic, which causes acute kidney failure and death in high concentrations as well as brain, liver and heart diseases (Sasmaz and Yaman, 2008). As with other heavy metal, it has been identified as a nephrotoxin. Its nephrotoxic effects are more likely due to its chemical properties rather than its radioactivity, though ingested Uranium may have a radiological effect on other tissues of deposition such as bone (Zamora *et al.*, 1998).

1.2 Problem Statement and Justification

Uranium deposits of commercial level have recently been confirmed in Bahi district, Central Tanzania (Anon, 2009). The deposits occur over weathered uranium–rich granites within 20 m from the surface in areas used for agriculture and human settlement. These areas are surrounded by wetlands. These wetlands act as sinks for uranium accumulation (Owen and Otto, 1995). However, for many years residents of these areas have been utilizing these wetlands for rice, millet, maize, and vegetable growing. In addition, these wetlands are used for fishing, grazing domestic animals, salt and soda ash harvesting. Equally of concern is that the ground water, which might contain dissolved uranium salts from underlying weathered granites, is used for drinking and irrigation.

It is well known that Uranium and its compounds are carcinogenic and highly toxic (Sasmaz and Yaman, 2008; USDE, 1988). It affects brain by altering behaviour and metabolism of neurotransmitters, causes kidney failure as well as liver and heart diseases (Bensoussan *et al.*, 2009; Sasmaz and Yaman, 2008).Uranium also interferes with re–absorption of proteins (Nancy, 2004). Since the metal is taken up and accumulated by plants tissues (Anke *et al.*, 2007), there is a likelihood that it is transferred from the ground to humans and other living species through the food chain. What is not understood is whether water, vegetables, fish, soda ash, salt and different food crops, which are normally produced and used in these areas contain significant amounts of Uranium. This situation calls for research on assessment of Uranium uptake by selected food groups and the associated potential health effects to the Bahi community.

The rationale of the study is to bring awareness to the vulnerable communities and Tanzanian Government in general on the environmental and health hazards posed by Uranium in the areas where subterranean Uranium deposits have been discovered. This information is important to be imparted to the public for their own safety so that proper preventive measures can be taken.

1.3 Objectives

1.3.1 Overall objective

To assess Uranium levels in selected food groups and products and the associated health effects to the residents of Bahi District.

1.3.2 Specific objectives

i. To determine Uranium levels and contamination patterns in cassava leaves, maize, finger millet and rice;

ii. To determine Uranium levels and contamination patterns in water, salt, soda ash, flamingo and cat fish, and

iii. To conduct a study to determine diseases that affect the local community and which could be linked to Uranium exposure.

1.3.3 Hypotheses

i. Food products in the study area do not contain Uranium and thus food chains are not the source of Uranium transmission to humans.

ii. There are no health problems that are affecting local communities that could be associated by Uranium contained food chains or exposure. This is the reason people are still living in those areas and the Government has not intervened.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Natural and Depleted Uranium

Natural Uranium is a naturally occurring chemical substance that is mildly radioactive (ATSDR, 2013). It consists of mixture of three radioactive isotopes which are identified by mass numbers ^{234}U, ^{235}U and ^{238}U with relative abundance of 0.0055, 0.72 and 99.29 per cent respectively (USDE, 1998; Craft *et al.*, 2004). Depleted uranium is an adjusted mixture of natural uranium isotope that is less radioactive (ATSDR, 2013). Uranium is used primarily in nuclear power plants; most reactors require Uranium in which the ^{235}U content is enriched from 0.72% to about 3% (Reichenbanch, 2002). The interest in ^{235} U is due to its ability to sustain nuclear chain reaction (Craft *et al.*, 2004). However, in naturally occurring uranium ^{235}U only accounts for 0.72% isotopic composition. Therefore, techniques have been developed in which uranium ore is chemically enriched, increasing the concentration of ^{235}U to 2–4% (ATSDR, 1999). Enriched uranium is a mixture of isotopes that has more ^{234}U and ^{235}U than natural uranium. Enriched uranium is more radioactive than natural uranium (ATSDR, 2013).

The Uranium remaining after removal of the enriched fraction is referred to as depleted Uranium (Craft *et al.*, 2004). Depleted Uranium typically contains about 99.8% ^{238}U, 0.2% ^{235}U and 0.0006% ^{234}U by mass (Reichenbanch, 2002). It follows that therefore, depleted uranium is a mixture of the same three uranium isotopes except that it has very little ^{234}U and ^{235}U (ATSDR, 2013). For the same mass, depleted Uranium has about 60% less of the radioactivity of natural Uranium.

Depleted Uranium may also result from the reprocessing of spent nuclear reactor fuel (Reichenbanch, 2002). Under these conditions another Uranium isotope, ^{236}U may be present together with very small amounts of the transuranic elements such as Plutonium, Americium and Neptunium and the fission product Technetium–99. The increase in the radiation dose from the trace amounts of these additional elements is less than 1%. This is insignificant with respect to both chemical and radiological toxicity (Reichenbanch, 2002).

2.2 Uranium Transmission from Soil to Food Chain

Uranium is found at an average concentration of 3 mg/kg in the earth's crust and concentration of 3.0 µg/ l in sea water (Burkart *et al.*, 2002). It can be found in soil, rocks, surface and underground water, air, plants and animals. Due to this, it occurs also in trace amounts in many foods and in drinking water (Burkart *et al.*, 2002). In accordance with Uranium occurrence in the soil, it gets into the flora and is comprehensively stored in young plants (Ankle *et al.*, 2007). According to Duff and Amrhein (1996), uranium could be transported by water in a soluble form as uranyl ion (UO_2^{2+}), which is complex formation with carbonates and phosphates. The uranyl is the Uranium species' most readily taken up and translocated by plants (Ebbs *et al.*, 1998). Uranium accumulates in the plant roots (Shahandeh and Hossner, 2002; Shtangeeva, 2010) at variable concentration and which are plant group dependant. According to Shahandeh and Hossner (2002), dicotyledonous plants species tend to accumulate more Uranium than monocotyledonous species.

2.3 Factors Affecting Uranium Transfer to Food Chain

According to Ankle *et al.* (2007), Uranium transfer to the food chain is significantly affected by the geological origin of the soils and the groundwater basin as well as the living area of the flora and the drinking water reservoir. Uranium is apparently taken up by plants in accordance with its concentration in the soil. Investigations confirmed that granite and its weathering soils, described as Uranium rich produced the Uranium richest vegetation. However, the Uranium content/kg dry matter in plants is diluted by assimilates with increasing age. Gervais *et al.* (2003) reported that plant roots are associated with microorganisms that can have either direct or indirect effects on the mobility, availability and uptake of elements by plants. Among the soil microflora, arbuscular mycorrhizal (AM) fungi are involved in the most widely distributed root symbioses forming association with most terrestrial flowering plants. In this symbiosis the fungus receives from the host plant carbohydrates necessary for its growth. In return, improved mineral nutrition and increased tolerance/resistance against toxic elements, root pathogens and water deficit stress are some of the benefits for plants. Mvos (2008) also found that Uranium uptake was always higher on the alkaline soil than on the acid soil.

2.4 Exposure and Exposure Pathways

Individuals can be exposed to depleted Uranium in the same way they are routinely exposed to natural Uranium, which is by inhalation, ingestion and dermal contact (including injury by embedded fragments). Inhalation is the most likely route of intake during or following the use of depleted Uranium munitions in conflict areas or when depleted Uranium in the environment is re–suspended in the atmosphere by

wind or other forms of disturbance. Accidental inhalation may also occur as a consequence of a fire in a depleted Uranium storage facility, an aircraft crash or the decontamination of vehicles from within or near conflict areas.

Ingestion could occur in large sections of the population if their drinking water or food became contaminated with depleted or natural Uranium. However ingestion of depleted Uranium is not considered the major exposure pathway (WHO, 2001; UNEP, 2001). Uptake of Uranium with drinking water and food is one of the major ways of incorporation of natural Uranium (UNSCEAR, 2000). Direct ingestion of contaminated soil must be taken into consideration, in particular for children, some adult human beings and animals such as cattle and sheep that will be as a pathway to humans.

Dermal contact is considered a relatively unimportant type of exposure since little of the Uranium will pass across the skin into the blood. However, Uranium could enter the systemic circulation through open wounds or from embedded depleted Uranium fragments (Burkart *et al.*, 2002).

Given an exposure, the rate of uranium entry into the body depends upon chemical form and solubility, physical form and mode of entry into the body. Generally, more soluble forms with greater [surface area/ mass] ratios present the greater risk. Equivalently, areas of the body encouraging solution or presenting large interfacial surface areas present the most rapid routes of entry. Soluble forms present a risk for general systemic toxicity, while insoluble forms present more localised risk since they are more likely to be retained at the site of entry (Leach *et al.*, 1970).

2.5 Uranium in the Human Body

After ingestion, most Uranium is excreted within a few days and the remainder will enter the blood (Nancy, 2004). The small fraction (0.2 to 5%) that is absorbed into the blood stream is deposited preferentially in bone (about 22%) and kidneys (about 12%), with the rest being distributed throughout the body (12%) and excreted (Kotec, 2005). Most of what goes to the kidneys leaves within a few days (in urine), while that deposited in bone can remain for many years. Many experiments have shown the kidney as the most sensitive and the first affected organ after uranium exposure (Taylor and Taylor, 1997). Uranium accumulated in the proximal tubules, where it could induce severe damage. After inhalation, generally only a small fraction penetrates to the lung's alveolar region, where it can remain for years and from which it can also enter the bloodstream (Kotec, 2005). The study which was done by Pellmar *et al.* (1999), to follow uranium distribution over 18 months, found that uranium was deposited in the skeleton, kidney, liver, spleen, brain, lymph nodes, and testicles; with the kidney and skeleton being the principal reservoirs.

Regardless of the site of entry, once inside the body, distribution is primarily through blood. Uranium has been shown to complex with carbonates, proteins, minerals, and phospholipids (Cooke and Holt, 1974; Schullery and Miller, 1977), and small quantities can distribute through lymph (Leach *et al.*, 1970, 1973). Chevari and Likhner (1968) indicate approximately 47% of blood forms uranium complexes with bicarbonates in plasma, 32% binds to plasma proteins and 20% binds to red blood cells. However, most studies show no measurable effect of uranium on haematological parameters.

Furthermore, the biochemical reaction to heavy metals can alter cellular mechanisms, principally oxidative metabolism, leading to genetic mutations which in turn, can restrain cell growth and cause cancer. Heavy metals, that are also radioactive, amplify these effects. Several reports have shown that uranium, both toxic and radioactive, induces oxidative stress causing adverse biological effects which include DNA damage, cancer and other neurological defects (Miller *et al.*, 2002; Abou–Donia *et al.*, 2002; Barber *et al.*, 2007). Reichenbanch (2002), reported that, approximately 90 μg (micrograms) of Uranium exist in the human body from normal intakes of water, food and air; approximately 66% is found in the skeleton, 16% in the liver, 8% in the kidneys and 10% in other tissues.

2.6 Health Effects of Uranium

Uranium ore is relatively harmless, as long as it remains outside of the body. Once ingested Uranium is highly toxic and attacks the inner organs such as kidneys (Fact sheets on Uranium mining 4, 2010), lungs and heart (Nancy, 2004). Studies show that Uranium causes birth defects in foetuses and infants and that the risk of leukaemia is increased. Uranium mutates human DNA and chromosomes and deforms them (Fact sheet on Uranium mining 4, 2010). According to Burkart *et al.* (2002), uranium has been repeatedly claimed to be the cause of cancer, leukaemia and other health effects. Health effects from external exposure are limited to skin contact and Uranium object would have to stay in direct skin contact for more than 250h. If this will happen then a person will be susceptible to skin cancer.

2.7 Potential Source for Human Exposure to Uranium

2.7.1 Uranium content in drinking water

According to Anke *et al.* (2007), the lowest Uranium concentrations in East Germany's drinking water, only varied between 0.05 and 0.11μg/L. The maximum values are regionally very different, varying between 0.94 and 8.6 μg/L. The Uranium concentration in local tap waters can considerably affect the Uranium intake via home–made tea and coffee as well as locally produced beverages.

2.7.2 Uranium content in cereals

Studies show that the Uranium content in cereals and other foods with high sugar, starch and fat are generally low. The concentration of Uranium in rice was found to be 1.7μg/kg dry matter basis, while those of maize flour, wheat flour and banana were found to be 1.5, 1.7 and 1.1 μg/kg dry matters respectively (Ankle *et al.*, 2007). Uranium levels in wheat were also determined by Mukesh *et al.* (2009) in India, and it was found to range between 1.82 and 2.9 μg/kg.

2.7.3 Uranium contents in fruits and roots

The investigation was done on the uptake, distribution and concentration of Uranium in several kinds of root–crops, bulbous and tuberous plants grown on barren soil in natural conditions. The results showed that potatoes had highest Uranium concentration followed by red beet, sugar beet, carrot, radish and lastly onion (Sarik *et al.*, 2012). All plant species in that study showed higher concentration of Uranium in the peel of the surface root layer, and it differed among the plant species. Plant species differed in the level of concentration of Uranium in the remainder of the root

as well as in leaves. The concentration of Uranium in leaves for all plant species was higher than the concentration of Uranium in the remainder of the root (Sarik *et al.*, 2012).

Furthermore, Anke *et al.* (2007) found that fruits, pulses and potatoes contain 2 – 5.9 µg/kg DM, which was low level compared to that of vegetable spices and herbs. However, ATSDR (2011) reported that root crops such as potatoes, parsnips, turnips, and sweet potatoes contribute the highest amounts of Uranium to the diet.

2.7.4 Uranium content in vegetables

Fairly high Uranium concentrations among vegetable foodstuffs were found in cauliflower, carrots, cucumber, white champignon and red peppers (7.5 – 19 µg U/kg DM) leaf – rich vegetables, herbs, sauerkraut, dill, parsley, lettus and marjoram accumulate between 8 and 40 µg/kg DM. High Uranium content was also found in asparagus (Anke *et al.*, 2007). Choudhury *et al.* (1992) found that leafy vegetables contained the range of Uranium between 0.16 and 0.55 mg/kg while fruits vegetable such as tomatoes was found to contain 0.37 to 0.52 mg/kg.

2.7.5 Uranium content in animal foods

Animal foodstuffs accumulate lower Uranium contents, with 0.7µg U/kg DM in butter and 1.1 – 1.9 µg U/k µg DM in condensed and normal cow's milk, 1.5 – 3.1 µg U/k µg DM in pork, beef, chicken and mutton, 3 – 1 0µg U/k µg DM in fish and 16 µg U/k µg DM in hen's eggs (Anke *et al.*, 2007). Compared to vegetable foods, animal foodstuffs contribute less Uranium to human nutrition although hen's eggs, kidneys and livers can accumulate relatively more Uranium.

2.8 Tolerable Intake of Uranium through Water and Food

The World Health Organisation (WHO) recommends that Uranium concentration in drinking water should not exceed 2 μg/l (SWDHA, 2001). However, in the USA the recommended level is 20 μg/l. These levels are set to represent a concentration that does not result in any significant risk to health over a lifetime of drinking the water. The WHO value for Uranium concentration in drinking water is based on a "Tolerable Daily Intake" (TDI) of 0.6 μg/kg bodyweight. The TDI is an estimate of the amount that can be consumed daily over a lifetime without appreciable health risk. This is a TDI of 36 μg/kg for an average adult weighing 60kg. For a typical daily water consumption of 2 litres per day, the WHO limit of 2 μg/l leaves a considerable safety margin (South and West Devon Health Authority, 2001).

Insoluble uranium compounds are markedly less toxic to the kidneys, and a tolerable intake of 5 μg per kg of body weight per day is applicable. Inhalation of soluble or insoluble depleted uranium compounds by the public should not exceed 1 $\mu g/m^3$ in the respirable fraction. This limit is derived from renal toxicity for soluble Uranium compounds, and from radiation exposure for insoluble uranium compounds. Excessive worker exposure to depleted Uranium via ingestion is unlikely in workplaces where occupational health measures are in place. Occupational exposure to soluble and insoluble uranium compounds, as an 8–hour time weighted average should not exceed 0.05 mg/m^3. This limit is also based both on chemical effects and radiation exposure (Reichenbanch, 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Area of Study

This study was conducted in Bahi District, which is one of the six districts that make Dodoma region. The District lies between Latitude 4°and 8° South and Longitude 34°and 38° East. Bahi District is largely covered by granite rocks surrounded by wetlands. These rocks are the ones that are likely to release Uranium together with sand during weathering to the wetlands used for food production and human settlements.

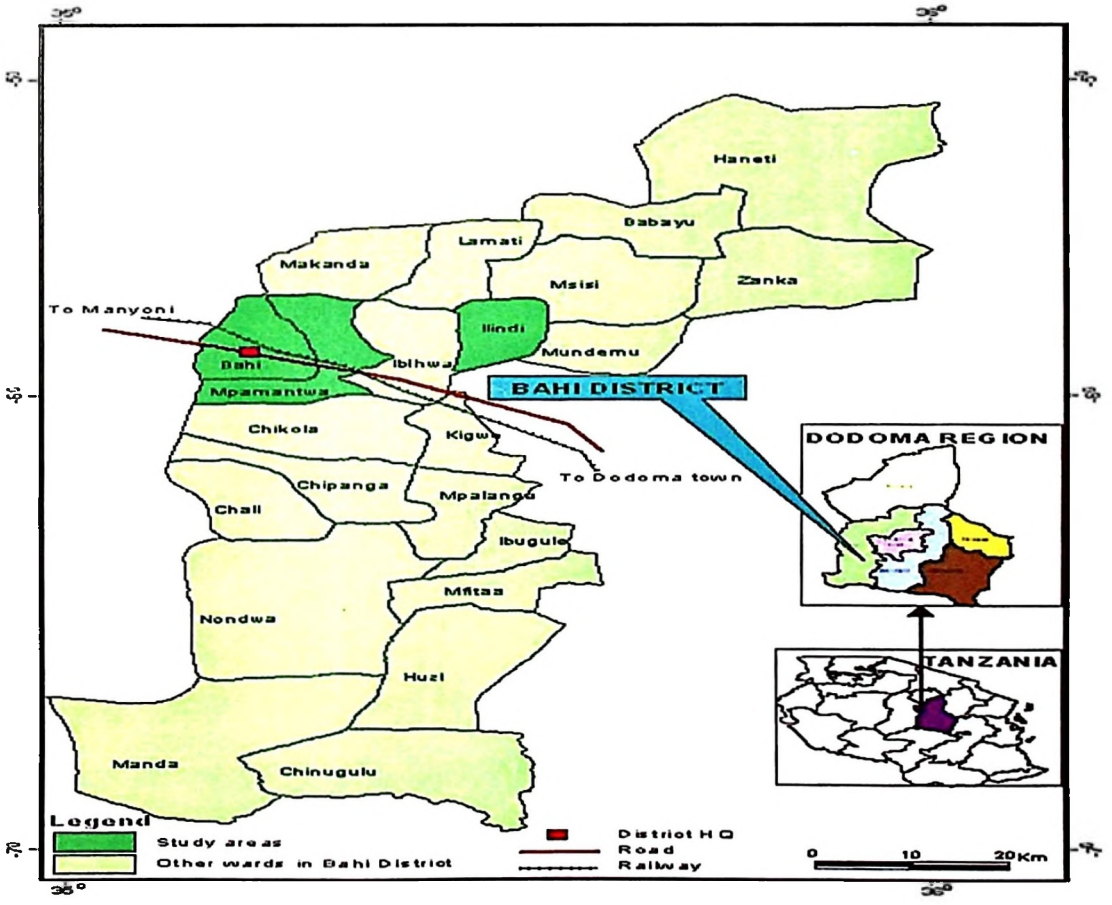

Figure 1: Bahi District Map showing the studied areas

The district has an estimated population of 221 645 persons (NBS, 2012) mostly farmers who keep livestock of different types such as cows and goats. They also farm different types of food crops such maize, rice, millet, sorghum, cassava, potato and ground nuts. Other economic activities that contribute to livelihoods in the area include fishing in swamps and rivers (particularly during the rainy season), salt and soda ash production and trading in farm products, livestock, fish and salt. The Wetlands of Bahi are famous for the production of *Clarias* and Tilapia fish.

3.1.1 Climate

Bahi is a semi–arid District (Swai *et al.*, 2012). It has a dry savannah type of climate, which is characterized by unimodal and erratic rainfall that falls between late November and mid–April. The annual average rainfall is about 500 to 700 mm and mean monthly of temperature is about 22.6°C (Swai *et al.*, 2012). The district experiences flash floods during rainy seasons. In addition, it has high evaporation rate and severe soil erosions, which are caused by strong winds and relative low humidity. It also experiences long dry seasons from mid–April to late November each year.

3.2 Data Collection

3.2.1 Sample collection

Samples were collected from three villages of Bahi District which were; Ilindi, Mpamatwa and Bahi. From Ilindi village; nine samples of each of maize, finger millet and cassava leaves were randomly collected from three randomly selected plots, where three samples were collected from each plot. Nine samples of water were also collected from three randomly selected sources of water in which samples

were collected in triplicate from each source. A total of six samples of salt (Plate 1) were collected from two sources in triplicate. Three samples of soda ash were collected from one source which was the only one at Ilindi village. Three flamingo birds were caught for analysis where their livers, gizzard, skin and flesh were analysed separately. Cat fish (Plate 2) were also collected from the swamp and their skin and fillet were analysed for uranium content separately.

Plate 1: Traditional salt production in Ilindi village

Plate 2: Fishing in Ilindi villlage (Cat fish).

Source: Mbogoro and Mwakipesile (2010).

From Mpamantwa village; nine samples of each of maize, finger millet and cassava leaves were randomly collected from three randomly selected plots, where samples were randomly collected in triplicate from each plot. Nine sample of water (Plate 3) were also collected from three randomly selected sources and three samples were collected.

Plate 3: Water source from Mpamantwa village

From Bahi village; a total of 15 samples of rice were collected from five randomly selected paddy fields (Plate 4) in which three samples were drawn from every field at random. A total of nine samples of water were also collected from three randomly selected sources at Bahi village from three sources in triplicate.

Plate 4: Paddy harvesting in Bahi village

3.2.2 Water sampling procedures

Water from the river was collected from different positions such as upstream, at the middle and downstream. In swamp, water samples were taken from the edge and at the middle of swamp. Water samples from taps were left to run for about two minutes in order to empty standing water before collection.

3.2.3 Sample preparation

Maize, finger millet, cassava leaves and rice samples were oven dried at 70°C for 48 hours then grounded by the use of laboratory milling machine known as Christy made by Christy and Norris Ltd, Process Engineers Chelmsford England. Rice samples were dehulled before grinding. Fish and flamingo samples were sundried

then oven dried for overnight at 100°C then ground by the use of domestic blender (HE HOUSE, Model number HE–3380–BL, Made in China). Salt and soda ash were in powder form so they were just sundried and sieved. Water samples were preserved at freezing temperature while waiting for laboratory analysis.

3.2.4 Laboratory analysis of Uranium

This was done at The Government Chemist Laboratories Agency (GCLA) in Dar es Salaam by the use of Inductively Coupled Plasma–Optical Emission Spectrometry (ICP–OES) model iCAP 6000 series manufactured by Thermofishers in England using the method recommended by ISO 2171: 2007 (Plate 5).

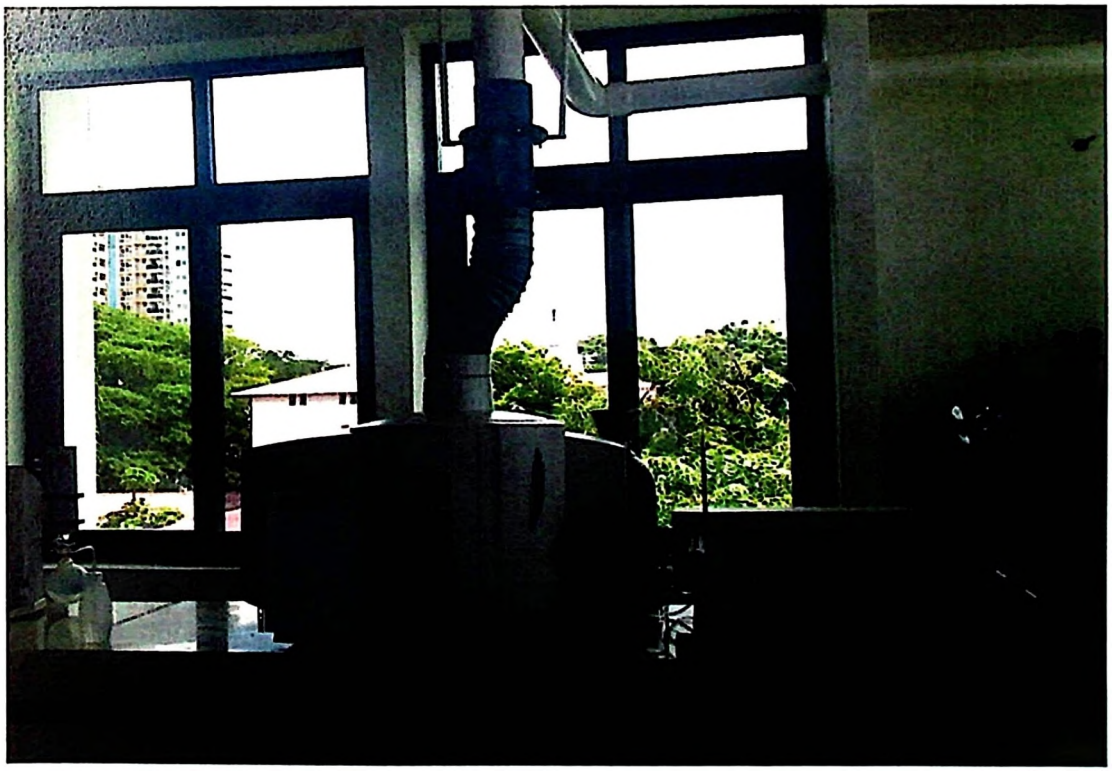

Plate 5: ICP–OES used in analysis at GCLA

Solid samples were first prepared for HNO_3 Block digestion, where 0.5 g of maize, finger millet, cassava leaves, rice, salt, soda ash, flamingo and fish samples were weighed in an empty test tube by the use of analytical balance machine. Then tubes were placed in fume chamber and 5ml of hydrogen peroxide (H_2O_2) were added to each test tube followed by 10ml of nitric acid (HNO_3) 60% then again 5ml of hydrogen peroxide were added and made the ration of H_2O_2 and HNO_3 to be 1:1. About 5 granules of aluminium trioxide (anti–bumping) were added to every test tube to avoid over flowing during boiling. When the temperature of hot plate reached 180°C the mixture was placed and boiled for one hour and left to cool to touch. Digested samples were then filtered by filter paper into 100 ml volumetric flask and diluted with distilled water to the mark then mixed well.

Blank and reference standard (Spexcertiprep from United States of America) were used to control quality of the analysis. Sample blank was prepared by adding 5 ml of H_2O_2 to an empty test tube followed by 10 ml of HNO_3 60% then 5 ml of H_2O_2 and then digested in the same way as other samples. About 10 ml of digested samples were transferred to the vials and arranged to the auto sampler ready for reading in the Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP–OES).

Water samples 10 ml were mixed with 2 ml of 1% HNO_3 and read directly with digested solid samples (ISO 2171: 2007). The detection limit for this instrument was 10 ppb. In the ICP–OES method, a solution of the sample was introduced into argon plasma, whose temperature in various parts of the torch was between 6000K and 10 000K. ICP–OES utilised that high temperature plasma source which atomised the sample and excite the atoms. This caused an emission of protons, with each element

in the sample emitted different and specific wavelengths. This technique measured the intensity of these individual wavelengths and the quantity of each element present in the sample was then calculated from the observed intensity. Then Uranium concentration in each sample was recorded and at the end all results were printed.

3.2.5 Gathering information of diseases with possible association with Uranium contamination

Information of diseases that are affecting the local communities and which could be linked to Uranium exposure was gathered by visiting Dodoma Regional hospital for patients from Bahi district since there was no district hospital. Mpwapwa District hospital was used as the control and Mirembe referral Hospital was included since it is specific for people with brain diseases. Records of patients in the past 20 years were taken from the areas reported with acute kidney failure, brain, liver and/or heart diseases, as well as lungs diseases. Mpwapwa District was selected as a control since at the time of this study there was no any information suggesting presence of Uranium and also the District is self–sufficient in terms of food. A summary of these diseases was then established.

3.2.6 Statistical analysis

Statistical data evaluation on Uranium concentration was done by statistical software GenStat 14th edition. Then analysis of variances (ANOVA) was employed on analysis of the difference in means whereas New Duncan's Multiple Range Test was applied for mean separation such that high and low risk foods were identified. The obtained secondary data were summarised by the use of Microsoft excel.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Uranium Uptake by Maize, Finger Millet, Rice and Cassava Leaves

In Table 1 results of Uranium uptake by maize, finger millet and cassava leaves are displayed.

Table 1: Uranium levels in maize, finger–millet and cassava leaves

Villages	Products	Coordinate	U levels ($\mu g\ kg^{-1}$)
Ilindi	Maize	05° 94'85"S and 35° 54'13"E	<10
Ilindi	Maize	05° 95'10"S and 35° 54'08"E	<10
Ilindi	Maize	05° 95'16" S and 35° 54'00"E	<10
Mpamantwa	Maize	05 ° 98'06"S and 35 ° 39'11" E	<10
Mpamantwa	Maize	06 ° 00'11" S and 35 ° 38'53" E	<10
Mpamantwa	Maize	06 ° 00'05" S and 35 ° 3859" E	<10
Ilindi	Millet	05 °94'78"S and 35 °54'13" E	25.13j ± 0.57
Ilindi	Millet	05 °95'21" S and 35 °54'12" E	<10
Ilindi	Millet	05 °94'56" S and 35 °5436" E	14.97i ± 0.57
Mpamantwa	Millet	05 °96'36"S and 35°38'59" E	13.38fgh ± 0.57
Mpamantwa	Millet	05 °95'93"S and 35 ° 38'65" E	11.88e ± 0.57
Mpamantwa	Millet	05 ° 95'72" S and 35 ° 38'56" E	13.67gh ± 0.57
Ilindi	Cassava leaves	05 ° 94'59" S and 35 ° 54'36" E	<10
Ilindi	Cassava leaves	05 ° 94'58" S and 35 ° 54'41" E	<10
Ilindi	Cassava leaves	05 ° 95'19" S and 35 ° 54'06"E	13.35fgh ± 0.57
Mpamantwa	Cassava leaves	05 ° 95'76" S and 35 ° 38'49" E	13.83h ± 0.57
Mpamantwa	Cassava leaves	05 ° 95'93" S and 35 ° 38'47" E	12.37ef ± 0.57
Mpamantwa	Cassava leaves	05 ° 96'11" S and 35 ° 38'57" E	12.71efg ± 0.57
Bahi	Rice	05 ° 98'62" S and 35 ° 30'12" E	<10
Bahi	Rice	05 ° 98'82" S and 35 ° 29'58" E	<10
Bahi	Rice	05 ° 99'94" S and 35 ° 32'27" E	<10
Bahi	Rice	06 ° 00'76" S and 35 ° 32'32" E	<10
Bahi	Rice	06 ° 00'78" S and 35 ° 32'39" E	<10
	Villages		0.33
LSD	Products		0.67
	Interaction		0.95
s.e			0.57
CV (%)			6.5

The means along the same column bearing similar letter(s) are not significantly different at 5% level of probability based on the New Duncan's Multiple Range Test (NDMRT)

4.1.1 Uranium levels in maize

Uranium uptake by Maize grains was below detectable limit of the ICP–OES used in this study. This meant that the content of Uranium in maize grain was below 10 μg kg^{-1}. This implies that uranium is less taken by maize grain from soil. These results were in line with the results presented by Vandenhove *et al.* (2007) when assessing soils and plant parameters affecting uranium availability and uptake. His results for maize showed that, most Uranium is concentrated in the first few mm from the root tip onwards and then decreases importantly. At the level of shoot, according to his study still there was no sign of uranium, this means that uranium translocation is limited in maize grain. Sheppard (1980) reported that once uranium is absorbed by the plant root is stored as a yellow deposit in the cell nuclei of the meristem. This results in destruction of the chromatin, and cessation of cell nuclear activity, preventing uranium translocation to other parts. Further studies showed that uranium concentration in plants varies in different tissues. In most of plants investigated, the highest uranium concentration was in roots and the lowest in fruits or grains (Lamas, 2005; Laroche *et al.*, 2005; Chen *et al.*, 2005).

4.1.2 Uranium levels in rice

From the results obtained it was observed that uranium uptake by rice was also below detectable limit of the machine used. The reasons for these low levels could be the same as those discussed for maize. However, rice has more supporting reasons for this observation, apart from the shared reasons. This is due to its growing procedures that rice is first prepared in a nursery before being transplanted in field with marsh condition. This condition may limit uranium uptake by rice. It has been

reported by Sheppard (1980) that, soils with high concentrations of uranium impart high uranium concentrations in plants except in marshy areas where the uranium content in plants has been found to be lower than the uranium content in soils. That means in marshy areas uranium uptake by plant is limited. Lakshmanan and Venkateswarlu, (1988) also found that the percentage of uranium uptake by the rice decreased with increasing concentrations of uranium in soil. Sometimes, differences between uranium concentration of roots and other tissues are very large, for instance, in the study done by Laroche *et al.* (2005) found that uranium concentration on roots in *Phaseolus vulgaris* in a hydroponics culture was about 2400 times more than that in leaves at seedlings stage, and at least 156 times more than in stems so, more than 99% of uranium was accumulated in the roots. Singh (1997) report implies that the highest concentration of uranium in different tissues (root, straw and grain) of wheat and rice was found in leaves. All these results showed that uranium did not accumulate much on paddy grain (rice).

4.1.3 Uranium levels in finger millet

For the case of finger millet the results for uranium concentration were found to range from 11.88±0.57 to 25.13±0.57 μgkg^{-1} for both Ilindi and Mpamantwa villages. It was also observed that there was no variation of Uranium levels between the two villages at 5% level of significance but there was significant variation of Uranium concentration among different plots for both villages. This may be due to geological nature of the plots from which specific samples were collected (Ankel *et al.*, 2007). When comparing finger millet with other grains such as maize which were all collected from the same area, finger millet was observed to contain high

levels of Uranium than maize whose value was below the detectable limit. The ability of finger millet to accumulate uranium in grains may be contributed by its root system. Finger millet has permanent adventitious roots developed from the second internodes and above. These roots are branched laterally (about 1 m^2) interlacing the soil vertically and mainly supply nutrients to the plant. In additional the roots can grow more than 2 m in pursuit of water and soil nutrients (ICRISAT, 2007).

However, this range (11.88 ± 0.57 to 25.13 ± 0.57) µg/kg is still far below the toxic level to human. Singh (1997) reported that uranium is tolerated in small quantities and results in toxicity when more than 400 μgkg^{-1} concentration of uranium is accumulated in plants.

4.1.4 Uranium levels in cassava leaves

For cassava leaves it was observed from the results that the values were just around the detectable limit as the range was <10 and 13.87 for both villages Ilindi and Mpamantwa. The findings do not apper to be supported by other researchers. However studies on cassava leaves conducted by SIDA (2012) show the concentration of other heavy metals such as lead (1700 μgkg^{-1}), arsenic (210 μgkg^{-1}), and cobalt (65200 μgkg^{-1}), but the concentration of uranium has not been established yet. The author also reported that strong contamination of the surface of cassava leaves with heavy metals can be significantly reduced simply by washing them.

4.2 Uranium levels in water

Uranium concentration in water is shown in Table 2. Water samples collected from different sources within the three villages showed variation in uranium content. The levels ranged from below detectable to 1233 μgl^{-1}. Ground water from the well near primary school at Ilindi village used for drinking and other domestic uses, had uranium content of 95 μgl^{-1}. This value is very high as compared to the standard limit of drinking water set by USEPA 2011 of 30 μgl^{-1} (ATSDR 2013).

High uranium values in drinking and domestic water affects uranium intake by the surrounding community as water is used for production of other drinks and food. This was supported by Ankle *et al.* (2007) who reported that the uranium content in local tap waters can considerably affect the uranium intake via homemade tea, coffee and locally produced beverages.

Table 2: Uranium levels in water from Ilindi, Mpamantwa and Bahi villages

Villages	Source discription	Coordinates	Elevation (m)	Uranium levels ($\mu g\ l^{-1}$)
Ilindi	Well near primary school	05°56' 45.0" S & 035°32' 26.3" E	987	95.4
Ilindi	Well for irrigation	05°57' 07.8" S & 035°32' 41.3" E	1010	<10
Ilindi	Swamp	05°57' 49.9" S & 035°31' 34.2" E	966	1233
Mpamantwa	Well near village office	05°57' 19.3" S & 035°23' 10.9" E	939	16.7
Mpamantwa	Well near the main road	05°59' 12.23"S & 035°23' 04.0" E	910	<10
Mpamantwa	Well for irrigation	05°58' 20 "S & 035°23' 38.4 E	953	<10
Bahi	Well near main road	05°58' 18." S & 035°18' 23.8" E	830	<10
Bahi	River used for irrigation	05°58' 19.1" S & 035°18' 21.6 E	837	67.6
Bahi	Well after the bridge	05°58' 19.8"S & 035°18' 21.4" E	840	16.6

Uranium level of 67.6 μgl^{-1} was established for river water used for irrigation in Bahi village. Children were found playing/ swimming inside that water and it also used for paddy farming. This is dangerous as the contaminated water was in direct contact with their skin which is one of the pathways of uranium into the body. Although dermal contact is considered a relatively unimportant type of exposure since little of the Uranium will pass across the skin into the blood, Uranium could enter the systemic circulation through open wounds or from embedded Uranium fragments (Burkart *et al.*, 2002). This water could also affect plant uptake of uranium as it has been reported that contaminated irrigation water affect uptake of the plant (Ankle *et al.*, 2007).

In the Ilindi swamp water, where residents do fishing and take their animal to drink water, uranium levels were highest. The concentration of uranium in this water was found to be 1233 $\mu g\ l^{-1}$. This high uranium value is believed to bring effects on uranium intake by the residents as it affects the organisms living in that water (such as fish) and those who use that water for drinking like domestic animals. In Mpamantwa village, ground water used for irrigation and domestic was observed to have a Uranium concentration level of 16.7 μgl^{-1} while ground water in Bahi village also used for drinking was found to have a Uranium concentration of 16.6 μgl^{-1}. These two values are not very dangerous as they are still below the limit level of 30 μgl^{-1} set by USEPA 2011 (ATSDR 2013).

The large variation in the uranium concentration in different sources of water is due to uneven distribution of uranium in the lithosphere (Sethyl *et al.*, 2011). This is

because uranium content in ground and surface water is equally affected by the geological origin and anthropogenic uranium emissions (Fisenne, 1994). Wade and Coetzee (2008) reported that the transport and dispersion of uranium in surface water and groundwater are affected by adsorption and desorption of uranium on aquatic sediments. As with soil, factors that control mobility of uranium in water include oxidation–reduction potential, pH, adsorbing characteristics of sediments and the suspended solids in the water. Oxidation–reduction conditions are very important in the geological transport and deposition of uranium. Under reducing conditions characteristic of swamps and wetlands like those found in Bahi district, the stable chemical form of uranium is the +4 state in which it will not readily soluble in water, and will thus become relatively immobile. Under oxidizing conditions, such as on the surface of the ground or in shallow water, uranium oxidizes to a state in which it can dissolve and become mobile in water. Metallic forms will oxidize faster as small particles than as large pieces (USAEPI, 2005).

4.3 Uranium Levels in Cat Fish (Clarias gariepinus) and Flamingo Phoenicopterus roseus)

4.3.1 Uranium level in cat fish

The results for flamingo bird meat and cat fish are as shown in the Table 3. The results of uranium concentration in different parts of cat fish and flamingo bird were significantly different at 5% level of significance. In cat fish where the skin and the muscles were analysed separately, the concentration of 17.78 μg/kg was obtained in the skin, while that of fish muscle was below detectable limit of the ICP–OES used.

Table 3: Uranium levels in flamingo *(Phoenicopterus roseus)* and cat–fish *(Clarias gariepinus)* collected from Ilindi village

Products	Uranium levels (µg kg^{-1})
Flamingo liver	31.78c ± 5.09
Flamingo gizzard	<10
Flamingo muscles	<10
Flamingo skin	<10
Cat–fish skin	17.98b ± 5.09
Cat–fish muscle	<10
LSD	11.55
s.e	5.09
CV (%)	29.3

All means are significantly different at 5% level of probability based on the New Duncan's Multiple Range Test (NDMRT).

These results are in line with other research results such as those found by Faucher *et al.* (2012) when assessing uranium–induced sensory alterations in the zebrafish (*Danio reri*). Those results showed that uranium displayed a strong affinity for sensory structures in direct contact with the surrounding medium (which was uranium contaminated), such as the olfactory and lateral line systems distributed on the skin. Faucher *et al.* (2012) also found a decreasing gradient of uranium concentration to be: olfactory rosettes > olfactory bulbs > skin > muscles > brain. At the end of that experiment, uranium was present in significant quantities in sensory tissues. Correa *et al.* (2008) also found that the organs that accumulated the highest uranium levels were the gills and skin. The high uranium accumulation levels detected in the skin indicate that a significant portion of this element could have remained adsorbed on the skin or have been absorbed into skin cells (Correa *et al.*, 2008). Skin is an important organ of uranium accumulation due to its adsorption on the skin or because more uranium was transferred from the gills to the blood and finally accumulated in the skin (Correa *et al.*, 2008).

The increase in gill, kidney and liver metal accumulation with the augment of waterborne cadmium levels was also observed in the African catfish, (*Clarias gariepinus*), after 21 days of exposure, but the highest accumulation levels were in the kidney, followed by the gills and liver (Asagba *et al.*, 2008). The major organ of accumulation for copper was the liver and for zinc was the gill (McGeer *et al.*, 2000). Therefore, high accumulation in the tissues changes with the metal tested.

Furthermore, Correa *et al.* (2008) reported that the increase of waterborne uranium concentration corresponded to a progressive increase of uranium levels in the gills, liver, skin and kidneys, with the highest accumulation in the gills and skin. Metabolic intermediates in the muscle were altered by uranium exposure, but no clear relationship was found. Catalase (CAT) and glutathione–*S*–transferase (GST) activities in the hepatic and muscular tissues of these species suggest that the enzymatic activities can be stimulated at the lowest uranium levels and inhibited at higher levels (mainly in 608.7 $\mu g\ l^{-1}$). In this study, fish were taken from the swamp found in Ilindi village whose uranium concentration was 1233 $\mu g\ l^{-1}$. This value was twice higher than that reported by Correa *et al.*, 2008. This might have caused the inhibition on enzymatic activities in fish muscles.

4.3.2 Uranium level in flamingo bird

The results for flamingo bird showed that among skin, gizzard, muscles and liver, the liver was found to accumulate 31.78 μg/kg concentration of uranium while other tested parts had values below detectable limit. Strumińska–Parulska *et al.* (2013) also found that the highest uranium content was in liver when assessing Polonium,

Uranium and Plutonium bioaccumulation in marine birds. The value for uranium was highest in the liver because this is the organ responsible for detoxification (Eagles–Smith *et al.*, 2008).

In most waters, sediments act as a sink for uranium and the uranium concentrations in sediments and suspended solids are of several orders of magnitude higher than in surrounding water (Brunskill and Wilkinson, 1987; Swanson, 1985). The highly frequent contact and ingestion of sediment during feeding expose Flamingos to metal intake much more than the other species collecting merely on plants and preys from environment (Zweers *et al.*, 1995).

4.4 Uranium levels in soda ash and table salt

4.4.1 Uranium levels in salt

Table 4 shows the concentration of uranium in soda ash and table salt. The concentration of uranium in salt was found to be below the detectable limit of the used instrument. Both boiled and unboiled salt had the same uranium concentration levels. That means there were no effects for uranium levels on boiling salt. These results were in line with those reported by Simion *et al.* (2006), who found the concentration of uranium in the iodinated commercially available sodium chloride salt sample to be $\leq$ 10 ppb.

Table 4: Uranium levels in soda ash and table salt of Ilindi village

Products	Uranium levels ($\mu g\ kg^{-1}$)
Soda ash	1910
Boiled salt	<10
Un–Boiled salt	<10

4.4.2 Uranium levels in soda ash

The concentration of uranium in soda ash (Na_2CO_3) was found to be 1910 μg/kg. This value was the highest of all samples tested in this study. The reason for this could be the affinity of uranium to carbonate. It has been reported that Carbonate in the soil increases the mobility of uranium through the formation of anionic Uranium and CO_3 complexes (Allard *et al.*, 1982; Sheppard and Evenden, 1987). In carbonate leaching system, uranium is solubilized as tetra sodium uranyl tricarbonate ($Na_4UO_2(CO3)_3$), when uranium is present as hexavalent state (UO_3) in the ore matrix (Merritt, 1971). Too high carbonate concentration could cause some uranium to precipitate as sodium diuranate (Dry, 2010). During weathering, organic complexes of Uranium occur, which are easily soluble and are in the mobile phase. However, various relatively stable compounds of Uranium including oxides, carbonates, phosphates and arsenates occur under arid conditions (Kabata–Pendias and Pendias, 2001).

4.5 Diseases Affecting Bahi District Communities that are Related to Uranium Exposure

Results obtained from different hospitals that were visited are shown in Table 5. From the results obtained from hospitals it was observed that both Bahi and Mpwapwa Districts residents were affected by different diseases that may be uranium associated. These diseases include Brain, heart, liver, lungs and kidney diseases as reported by Burkart *et al.* (2002).

Table 5: Cases of uranium associated diseases collected from Dodoma, Mpwapwa and Mirembe hospitals documented from 1992 to 2012

Organ Affected	Age (years)	District	
		Bahi	Mpwapwa
Brain	≤5	17	2 557
	>5	571	27 204
Heart	≤5	0	281
	>5	53	7 977
Liver	≤5	0	1 553
	>5	5	8 126
Lungs	≤5	0	159 189
	>5	8	104 211
Kidney	≤5	0	0
	>5	5	0
	Total	**659**	**311 098**

Mpwapwa which was used as a control due to lack of information on presence of uranium and hence assumed to be no uranium showed high number of infected people as compared to Bahi District which was hypothesized to be the affected one. This implies that confirmation of the presence of uranium in Bahi district has yet to bear discernible effects on the health status of the residents.

Experimental studies in humans consistently show that absorption of uranium by the oral route is <5% (Tasat *et al.*, 2012). Evidence from several animal studies showed that the amount of uranium absorbed from the gastrointestinal tract was about 1% (La Touche *et al.*, 1987). Priest (2001) reported that Uranium, after absorption in the gastrointestinal tract or lungs before translocation into the blood, deposits rapidly in the skeleton and kidneys. The most sensitive target of uranium toxicity to mammals, and perhaps humans, is the kidney. However it has been reported that, acute high–level exposure to uranium compounds can clearly cause nephrotoxicity in humans

(Lu and Zhao, 1990; Pavlakis *et al.* 1996), the evidence for similar toxicity as the result of long–term, lower–level occupational exposures is equivocal. Gilman *et al.* (1998); Pellmar *et al.* (1999) and Lemercier *et al.* (2003) have demonstrated that Uranium can cross the blood–brain barrier to accumulate in the brain. This accumulation was not uniform throughout the brain and showed to be dose–dependent (Pellmar *et al.*, 1999).

Several epidemiology studies done by Kurttio *et al.* (2002) and Zamora *et al.* (1998, 2009) examined the possible association between chronic exposure to elevated levels of uranium in drinking water and alterations in kidney function. These effects might have represented a subclinical manifestation of uranium toxicity not necessarily leading to renal dysfunction. By contrast, chronic ingestion of this toxicant could be the starting point of an irreversible renal injury. Mao *et al.* (1995) found a significant association between cumulative uranium exposure (product of uranium concentration in drinking water) and urine albumin levels (expressed as mg/moll creatinine) in adults living in households with elevated uranium levels in drinking water. Zamora *et al.* (1998, 2009) found a significant association between β2–microglobulin, and alkaline phosphatase levels observed in residents living in an area of high uranium levels in the drinking water.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on this study, confirmation of the presence of uranium in Bahi district has not yet borne discernible effects on the health status of the residents. The levels of uranium in different selected food groups and products showed great variation. Most of these food groups were found to be with uranium concentration below detectable limit such as maize, rice and salt. Finger millet was found with high uranium concentration, but this concentration was still below the toxic level in plants for human consumption. Cassava leaves were not found to have high uranium concentration. Fish was found to have uranium concentration in the skin part whereas muscles had the concentration below detectable limit. However skin does not contribute a large part to the whole fish, meaning that fish has low effect on health as far as uranium is concerned. Flamingo bird that is sometimes considered as food in Bahi district was found to have uranium concentration in the liver part only, where as for other parts the concentration was below detectable limit.

Soda ash was found to have the highest uranium concentration as compared to other samples. However it is not a commonly used food additive, which means it does not pose a great effect to health.

Water samples from different sources had great variation in uranium concentration. Some of these sources had values below detectable limit while other sources like the well near primary school at Illindi village, that is used for drinking and domestic uses had uranium concentration that is above the recommended limit.

5.2 Recommendations

Since uranium concentration in some of the drinking water sources was above the recommended limits for human consumption, there is a need of taking measures on controlling the uranium level to the minimum concentration that will not result into health hazards or people should avoid using these water sources.

The water from Ilindi swamp had very high uranium concentration. This water is used for drinking by domestic animals that are used as source of food. Thus further research should be conducted to examine animals' contribution to uranium exposure in human.

Since this study was done on some of the food groups, there is a need to conduct further research on other food groups, especially root crops such as sweet potatoes and cassava that seem to accumulate high uranium concentration due to direct contact of the crops with soils.

REFERENCES

Abou–Donia, M., Dechkovskaia, A., Goldstein, L., Shah, D., Bullman, S., and Khan, W. (2002). Uranyl acetate–induced sensorimotor deficit and increased nitric oxide generation in the central nervous system in rats. *Journal of Pharmacol Biochemical Behavious* 72(4): 881– 90.

ATSDR (2011). Natural and depleted Uranium. Division of Toxicology and Environmental Medicine ToxFAQs.

ATSDR (2013). Toxicological Profile for Uranium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

ATSDR (1999). Toxicological profile for uranium: Atlanta, GA: Public Health Service. *Gulf War leaves legacy of cancer British Medical Journal* 319: 401.

Allard, B., Olofsson, U. and Torstenfelt, B. (1982). Sorption of actinides in well–defined oxidation states on geologic media. *Material for Research Society symposium proceedings* 11: 775–782

Ankle, M., Seeber, O., Muller, R., Schafer, U. and Zerull, J. (2007). Uranium transfer in the food chain from soil to plants, animal and man. *Chemie der Erde Geochemistry* 69: 75–90.

Anon, (2012). Uranium – Uranium's Radioactivity – Isotopes, Radon, Radioactive, and Life [http://science.jrank.org/pages/7113/Uranium radioactivity.html] Sited on 29/03/2012

Anon, (2009), [www.chemistryexplained.com/element/T–Z/Uranium.html]site visited on 29/3/2012.

Asagba, S. O., Eriyamremu, G. E. and Igberaese, M. E. (2008). Bioaccumulation of cadmium and its biochemical effect on selected tissues of the catfish (Clarias gariepinus). *Journal of Fish Physiology and Biochemistry* 34: 61–69.

Barber, D., Hancock, S., McNally, A., Hinckley, J., Binder, E., Zimmerman, K., Ehrich, M. and Jortner, B. (2007). Neurological effects of acute uranium exposure with and without stress. *Journal of Neurotoxicology* 28(6): 1110–1119.

Bensoussan, H., Grancolas, L., Dhieneux–Lestaevel, B., Delissen, O., Vacher, C–M., Dublineau, I., Voisn, P., Taouis, M. and Lestaevel, P. (2009). Heavy metal Uranium affects the brain cholinergic system in rat following sub–chronic and chronic exposure. *Journal of Toxicology* 261: 59–67.

Brunskill, G.J. and Wilkinson, P. (1987). Annual supply of uranium–238, uranium–234, thorium–230, radium–226, lead–210, polonium–210 and thorium–232 to Lake. Experimental Lakes Area, Ontario, Canada from terrestrial and atmospheric sources. *Canadian Journal of Fisheries Aquatic Sciences* 44(1): 215–230.

Burkart, W., Danesi, P.R. and Bleise, A. (2002). Properties, use and health effects of depleted uranium. *Journal of Environmental Radioactivity* 64: 93–112.

Chen, S. B., Zhu, Y.G. and Hu, Q. H. (2005). Soil to plant transfer of 238Um 226Ra and 232Th on a uranium mining–impacted soil from south eastern China. *Journal of environmental Radioactivity*, 82: 223–236.

Chevary, S. and Likhner, D. (1968). Complex formation of Natural Uranium in Blood *Journal of Medical Radiology* 13: 53–57.

Choudhury, S., Boruak, M. and Goswami, T. (1992). Estimation of Uranium in Some Edible and Commercial Plants. *Defence Science Journal* 42(4): 241–243.

Cooke, N. and Holt, F. B. (1974). The Solubility of Some Uranium Compounds in Simulated Lung Fluid. *Health Physics* 27: 69–77

Correa, L.M., Kochhann, D., Becker, A.G., Pavanato, M.A., Llesuy, S.F., Loro, V.L., Raabe, A., Mesko, M.F., Flores, E.M., Dressler, V.L. and Baldisserotto, B. (2008). Biochemistry, cytogenetics and bioaccumulation in silver catfish (Rhamdia quelen) exposed to different thorium concentrations. *Journal of Aquatic Toxicology* 88: 4. 250 – 256.

Craft, E. S., Abu–Qare, A. W., Flaherty, M. M., Garofolo, M. C., Rincavage, H. L. and Abou–Donia, M. B. (2004). Deplete and natural uranium: chemistry and toxicological effects. *Journal of Toxicology and Environmental Health* 7: 297–317.

Dry, M. (2010). Water and carbonate balances in an alkaline Uranium extraction circuit. Arithmetek Inc. Ontario, Canada. 13pp

Duff, M.C. and Amrhein, C. (1996). Uranium (VI) adsorption on goethite and soil in carbonate solutions. *Soil Science Society of America Journal* 60: 1393–1400.

Eagles–Smith, C. A., Ackerman, J. T., Adels–Bach, T. L., Takekawa, J.Y., Miles, A. K. and Keister, R.A. (2008). Mercury correlation among six tissues for four water bird species breeding in San Francisci Bay, California, USA. *Journal of Environment Toxicology Chemistry* 27: 2136.

Ebbs, S., Brady, D J. and Kochian, L.V (1998). Role of uranium speciation in the uptake and translocation of uranium by plants. *Journal of Experimental Botany* 49: 1183–1190.

Fact sheet Uranium Mining 4, (2010). Health Effects of Uranium mining, [http://www.ippnw.org/pdf/uranium–factsheet4.pdf] site visited on 10/7/2012.

Faucher, K., Floriani, M., Gilbin, R. and Adam–Guillermin, C. (2012). Uranium–induced sensory alterations in the zebrafish Danio reri. *Journal of Aquatic Toxicology* 124–125: 94–105.

Fisenne, I.M. (1994). In: Seiler, H. G., Sigel, A., Sigel, H. (Eds.), *Handbook on Metals in Clinical and Analytical Chemistry.* Marcel Dekker, Inc., New York, Basel, Hong Kong 1994.

Gervais, R., Lien, H., Jean, W. May, V. H., Corinne, L. and Iver, J. (2003). Arbuscularmycorrhizal fungi can decrease the uptake of uranium by subterranean clove grown at high levels of uranium in soil, *Journal of Environmental Pollution* 130: 427 – 436.

Gilman, A. P., Villeneuve, D. C., Secours, V. E., Yagminas, A. P., Tracy, B. L., Quinn, J. M., Valli, V. E., Willes, R. J. and Moss, M. A. (1998). Uranyl nitrate: 28–day and 91–day toxicity studies in the Sprague–Dawley rat. *Journal of Toxicological Science* 41: 117–128.

International Crops Research Institute for the Semi–Arid Tropics (ICRISAT). 2007. Pearl Millet Crop Management and Seed Production Manual. Rajasthan, India.

ISO 2171. (2007). Cereal, Pulse and by products–determination of ash yield incineration.

Kabata–Pendias, A. and Pendias, H. (2001). Trace elements in soils and plants. Third Edition CRC Press 2000 eBook ISBN: 978–1–4200–3990–0

Kotec, (2005), Uranium, Human Health Fact Sheet, [www.evs.anl.gov/pub/doc/Uranium.pdf] site visited on 05/4/2012.

Kurttio, P., Auvinen, A., Salonen, L., Saha, H., Pekkanen, J., Mäkeläinen, I., Väisänen, S., Penttilä, I. and Komulainen, H. (2002). Renal effects of uranium in drinking water. *Environmental Health Perspective* 110(4): 337–342.

La Touche, Y.D., Willis, D.L. and Dawydiak, O.I., (1987). Absorption and biokinetics of U in rats following an oral administration of uranyl nitrate solution. *Journal of Health Physics* 53: 147–162.

Lakshmanan, A. R. and Venkateswarlu, K. S. (1988). Uptake of uranium by vegetables and rice. *Journal of Water, Air, and soil Pollution* 38: 151–155.

Lamas, M. D. C. (2005). Factors affecting availability of uranium in soils. Landbauforschung Volkenrode Sonderheft 278, Germany, Braunschweig.

Laroche, L., Henner, P., Camilleri, V., Morello, M. and Garnier–Laplace, J. (2005). Root uptake of uranium by higher plant model – bioavailability from soil solution. *Journal of Radioprotection* 40: 33 – 39.

Leach, L. J., Yuile C., Hodge, H., Sylvester, G. E. and Wilson, H. B. (1970). A Five Years Inhalation Study with Natural $U0_2$ Dust. I – Retention and Biologic Effects in the Monkey, Dog, and Rat. *Health Physics* 18: 599–612.

Leach, L. J., Yuile, C.L., Hodge, H.C., Sylvester, G.E. and Wilson, H.B. (1973). A Five–year Inhalation Study with Natural Uranium Dioxide (U02) Dust – II, Postexposure Retention and Biologic Effects in the Monkey, Dog and Rat. *Journal of Health Physics* 25: 239–258.

Lemercier, V., Millot, X., Ansoborlo, E., Menetrier, F., Flury–Herard, A., Rousselle, C. and Scherrmann, J. M. (2003). Study of uranium transfer across the blood–brain barrier. *Radiation Protection Dosimetry* 105: 243–245.

Lu, S. and Zhao, F. (1990). Nephrotoxic limit and annual limit on intake for natural U. *Journal of Health Physics* 58(5): 619–623.

Mao, Y., Desmeules, M., Schaubel, D., Bérubé, D., Dyck, R., Brûlé, D. and Thomas, B. (1995). Inorganic components of drinking water and microalbuminuria. *Journal of Environmental Research* 71(2): 135–140.

Mbogoro, D.K. and Mwakipesile, A. (2010). Economical and Ecological Research of Bahi Swamp. Civil Education is the solution for poverty and Environmental management (CESOPE) final report. 44pp

McGeer, J.C., Szebedinszky, C., McDonald, D.G. and Wood, C.M. (2000). Effects of chronic sublethal exposure to waterborne Cu, Cd or Zn in rainbow trout. 2: Tissue specific metal accumulation. *Journal of Aquatic Toxicology*. 50: 245–256.

Merritt, R.C. (1971). The Extractive Metallurgy of Uranium. Colorado School of Mines Research Institute, Golden, USA.

Miller, A., Stewart, M., Brooks, K., Shi, L. and Page, N. (2002). Depleted uranium–catalysed oxidative DNA damage: Absence of significant alpha particle decay. *Journal of Inorganic Biochemistry* 91(1): 246–252.

Mukesh, K., Sangeeta, P. and Surinder, S. (2009). Uranium analysis in some food samples collected from Bathinda area of Punjab. *India, Indian Journal Physics* 83 (7): 1045–1050.

Mvos (2008). Assessing soil and plant parameter affecting uranium availability and plant uptake [www.sckcen.be] site visited on 21/4/2012.

Nancy, W. S. (2004). Radioactive substances in ground water, such as radium, uranium [www.nj.gov/dep/rpp/downlord/urwater.pdf] site visited on 13/4/2012.

National Bureau of Statistics, (2012). Population and Housing Census Report. The United Republic of Tanzania 264pp.

Owen, D. E. and Otton, J. K. (1995). Mountain wetlands: efficient uranium filters – potential impacts. *Ecological and Engineering* 5: 77–93.

Pavlakis, N., Pollock, C., McLean, G. and Bartrop, R. (1996). Deliberate overdose of uranium: *Toxicity and treatment Nephron Journals* 72: 313–317.

Pellmar, T. C., Fuciarelli, A. F., Ejnik, J. W., Hamilton, M., Hogan, J., Strocko, S., Emond, C., Mottas, H. M. and Landauer, M. R. (1999). Distribution of uranium in rats implanted with depleted uranium pellets. *Journal of the society of Toxicology* 49(1): 29–39.

Priest, N. (2001). Toxicity of depleted uranium. *The Lancet.* 357: 244–246

Reichenbanch, J. (2002). Deplated Uranium: sources, exposure and health effects, World Food Organisation report. Geneva 145pp

Sarik, L., Conkic, J., Bikit, I., Stojanovic, M. and Babic, M. (2012). Concentration of uranium in root–crops, bulbous and tuberous plants. International Society for Horticultural Science. [http://www.actahort.org/members/showpdf] site visited on 11/7/2012.

Sasmaz, A. and Yaman, M. (2008). Determination of Uranium and Thorium in soil and Plant parts around abandoned lead–zink–copper mining area. *Communication in Soil Science and Plant Analysis* 39: 2568–2583.

Schullery, S. E. and Miller, R. H. (1977). Binding of Uranyl to Phosphatidylcholine Liposomes: Liposome Aggregation Effect on Surface Area. *Archives of Biochemistry and Biophysics* 468: 451–460

Sethy, N. K., Tripathi, R. M., Jhal, V. N., Sahoo, S. K., Shukla, A. K. and Puranik V. D. (2011). Assessment of Natural Uranium in the Ground Water around Jaduguda Uranium Mining Complex, India. Environmental Assessment Division, Bhabha Atomic Research Centre, Health Physics Unit, Jaduguda Mines, Jharkhand, India; Bhabha Atomic Research Centre, Mumbai, India.

Shahandeh, H. and Hossner, L. R. (2002). Role of soil properties in phytoaccumulation of uranium. *Journal of Water Air and Soil Pollution* 141:165–180.

Sheppard, M. I. (1980). The environmental behaviour of Uranium and Thorium. Atomic Energy of Canada Report.

Sheppard, S. and Evenden, W. (1987). Review of effects of soil on radionuclide uptake by plants. Research report prepared for the Atomic Energy Control Board. Ottawa, Canada.

Shtangeeva, I. (2010). Uptake of uranium and thorium by native and scaltivated plants. *Journal of Environmental Radioactivity*.101: 458–463.

SIDA (2012). Annual Workshop report, Windhoek, Namibia. 3pp

Simion, C. A., Cimpeanu, C., Barna, C. and Duta, E. (2006). The uranium determination in commercial iodinated salt. *Journal of Environment Physics* 51, Nos. 7–8, P. 845–849

Singh, K. P. (1997). Uranium uptake by plants. *Current Science* 73(6): 532– 535.

South and West Devon Health Authority, (2001). Uranium in Drinking water, Fact sheet. 4pp

Strumińska–Parulska, D.I., Boryło, A. Skwarzec, B. and Fabisiak, J. (2013). Polonium, uranium and plutonium bioaccumulation in marine birds, Biomonitoring of Ecosystems II, 16th International Conference on Heavy Metals in the Environment, EDP Sciences publishers.

Swai, W. O., Mbwambo, S. J. and Magayane, F. T. (2012). Gender and adaptation Practices to the Effects of Climate Change in Bahi and Kondoa District Dodoma Region, Tanzania. *Journal of Sustainable Development* 5. No 12.

Swanson, S.M. (1985). Food chain transfer of Uranium–Series radionuclides in northern Saskatchewan aquatic system. *Journal of Health Physics* 49: 747–770.

Tasat, D. R., Orona, N. S., Bozal, C., Ubios, Q.M. and Cabrini, R.L. (2012). Intracellular Metabolism of Uranium and the Effects of Bisphosphonates on Its Toxicity. In; *Cell Metabolism - Cell Homeostasis and Stress Response*; Edited by (Bubulya, P.) ISBN: 978-953-307-978-3. 208pp [http://www.intechopen.com/books/cell–metabolism–cell–homeostasis–and–stress–response/intracellularmetabolism–of–uranium–and–the–effects–of–bisphosphonates–on–its–toxicity].site visited on 05/6/2013.

Taylor, D.M. and Taylor, S.K. (1997). Environmental uranium and human health. *Review Environmental Health* 12: 147–157.

USDE (1998). Phytoaccumulation of Chromium, Uranium and Plutonium in Plants Systems [http://www.pu.org] site visited on 25/04/2012

USAEPI (2005). Summary Report to Congress–Health and Environmental Consequence of Depleted Uranium Use by the U.S. Army. [http://www.fas.org/man/dod–101/sys/land/docs/du.html] site visited on 04/8/2012.

UNEP (2001). Deplated Uranium in Kosovo. Post Conflict Environmental Assessment. Switzerland. 188pp.

UNSCEAR (2000). The 2000 Report to the General Assembly with Scientific Annexes. New York.

Vandenhove, H., Van Hees, M., Wouters, K. and Wannijn, J. (2007). Can we predict uranium bioavailability based on soil parameters? Part 1: Effect of soil parameters on soil solution uranium concentration. *Journal of Environmental Pollution* 145: 587–595

Wade, P. and Coetzee, H. (2008). Risk Assessment of Uranium in Selected Gold mining Areas in South Africa. In; *Uranium mining and Hydrogeology* 147 Germany.books.google.co.tz. CRC Press Washington, D.C.:.

World Health Organisation, (WHO) (2001). Depleted Uranium, Sources, Exposure and Health Effects.WHO, Geneva, Switzerland.

Zamora, M. L., Tracy, B. L., Zielinski, J. M., Meyerhof, D. P. and Moss, M. A. (1998). Chronic Ingestion of Uranium in Drinking Water. *Journal of Toxicological Sciences* 43: 68–77.

Zamora, M., Zielinski, J., Meyerhof, D. and Tracy, B. (2002). Gastrointestinal absorption of uranium in humans. *Health Physics* 83(1): (35–45.

Zamora, M., Zielinski, J., Moodie, G., Falcomer, R., Hunt, W. and Capello, K. (2009). Uranium in drinking water: Renal effects of long–term ingestion by an aboriginal community. *Archives of Occupational and Environmental Health* 64(4): 228–241.

Zweers, G., De Jong, F., Berkhoud, V. and Van Den Berge, J.C. (1995). Filter feeding in flamingos. *Journal of Avian Biology* 97: 297–324.

SPE