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Determination of Primordial and Anthropogenic Radionuclide Concentrations in Agricultural Soil Of The United Arab Emirates Using Gamma-Ray Spectrometry

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College of Food and Agriculture

DETERMINATION OF PRIMORDIAL AND ANTHROPOGENIC RADIONUCLIDE CONCENTRATIONS IN AGRICULTURAL SOIL OF THE UNITED ARAB EMIRATES USING GAMMA-RAY SPECTROMETRY

Rahaf Moutaz Billah Ajaj

This dissertation is submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Under the Supervision of Dr. Mohammed Abdul Mohsen Alyafei

November 2017

Declaration of Original Work

I, Rahaf Moutaz Billah Ajaj, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this dissertation entitled "*Determination of Primordial and Anthropogenic Radionuclides Concentrations in Agricultural Soil of the United Arab Emirates Using Gamma-Ray Spectrometry*", hereby, solemnly declare that this dissertation is my original research work that has been done and prepared by me under the supervision of Dr. Mohammed Abdul Mohsen Alyafei, in the College of Food and Agriculture at UAEU. This work has not previously been presented or published or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my dissertation have been appropriately cited and acknowledged by appropriate academic conventions. I further declare that there is no potential conflict of interest concerning the research, data collection, authorship, presentation, and publication of this dissertation.

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Copy 1 of 7

Abstract

The United Arab Emirates (UAE) has initiated the first civilian nuclear power plant, and it will be operating four reactors between (2018-2020). The establishment of Barakah Nuclear Power Plant, which will employ the nuclear power to generate clean energy, is a significant step forward minimizing the UAE carbon footprint. Before the construction of any regulated nuclear facility, it is essential to investigate the environmental background radiation level in the country. Such an investigation is critical for providing the background data for the environmental impact assessment of the nuclear facility. The present study represents the first research effort in the (UAE) to build a database of agricultural topsoil radioactivity concentrations established using standard sampling and analytical procedures. This study determines the primordial radionuclides concentrations obtained from 145 soil samples collected from multiple agriculture farms in the United Arab Emirates. Collected soil samples were analyzed to establish radioactivity concentration levels associated with ^{226}Ra, ^{232}Th and ^{40}K. High-resolution gamma-ray spectrometry measured the activity concentrations. The results indicate that the mean specific activity concentrations (in BqKg^{-1}) were 15.34 ± 2.8, 4.18 ± 1.4 and 310.74 ± 63.9 for ^{226}Ra, ^{232}Th, and ^{40}K, respectively. Besides, the study determines the anthropogenic radionuclides concentration. Cesium-137 was detected in a little number of samples with a specific activity of 0.75 ± 0.01 BqKg^{-1}. All study collected sample activities and radiation parameters were found to be below maximal admissible values established in various international recommendations and standards. Also, the present study represents the first documented baseline concentration of the UAE soil minerals, trace, and heavy metals contents. The mean values (mg Kg^{-1}) were: Al - 8,539.7, As - 2.17, B - 47.68, Ca - 86,264.5, Cd - 0.35, Co - 10.30, Cr - 111.20, Cu - 14.32, Fe - 9,839.80, K - 2,026.80, Mg - 26,688.30, Mn - 237.40, Mo - 0.02, Na - 470.40, Ni - 60.90, P - 450.60, Pb - 4.25, S - 2,393.50, Si - 795.68, Sr - 593.70, V - 20.90 and Zn - 24.90. Further, study results were compared against international recommended levels. Also, we provided recommendations to the UAE concerned entities regarding regulating the concentrations of these elements found in the agricultural soil. Future research recommendations include extending the study scope to cover all the agricultural farms in the UAE including organic farms. The study results supported radioactivity

concentration and mineral mapping of the UAE soils using the Geographic Information System (GIS).

Keywords: Agriculture soil, Gamma spectrometry, United Arab Emirates, ^{238}U, ^{226}Ra, ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs, Nuclear, Radioactivity, GIS, ICP-OES, Minerals, Heavy Metals, Global Warming.

Title and Abstract (in Arabic)

دراسة تراكيز العناصر المشعة الطبيعية والصناعية في التربة الزراعية في دولة الإمارات العربية المتحدة باستخدام كاشف جرمانيوم عالي النقاوة

الملخص

بدأت دولة الإمارات العربية المتحدة بناء أول محطة لها للطاقة النووية السلمية، وستعمل على تشغيل أربع مفاعلات خلال الفترة (2017-2020). إن إنشاء محطة براكه للطاقة النووية التي ستعمل على استخدام الطاقة النووية لتوليد الطاقة النظيفة تعد خطوة جوهرية لتقليل الانبعاثات الكربونية في دولة الإمارات العربية المتحدة. إن هذه الدراسة هي أول بحث علمي في دولة الإمارات العربية المتحدة لبناء قاعدة بيانات لتركيز المواد المشعة في التربة الزراعية وذلك من خلال العينات القياسية و العمليات التحليلية، حيث أنه من خلال هذه الدراسة تم قياس تركيز المواد المشعة الطبيعية لعدد 145 عينة من التربة الزراعية تم جمعها من عدة أراضي زراعية من مناطق مختلفة في الدولة. كما تم تحليل نتائج قياس تركيز المواد المشعة الطبيعية لهذه العينات وتحديد مستويات تركيز المواد المشعة الطبيعية الموجودة بها (^{226}Ra, ^{232}Th, ^{40}K). تم قياس تركيز المواد المشعة الطبيعية في هذه العينات باستخدام جهاز مطيافية قياس أشعة غاما عالي الدقة حيث كانت النتائج:63.90 ± 310.74 ,Bq/Kg 1.40 ± 4.18 ,2.80 ± 15.34 على التوالي لـ: ^{226}Ra, ^{232}Th, ^{40}K. تم قياس نسبة ضئيلة من عنصر السيزيوم-137 وكان متوسط تركيزها بحوالي 2.2 Bq/kg ± 1.5. بالإضافة إلى المواد المشعة الطبيعية، تم قياس نسبة تركيز المواد المشعة الصناعية (137Cs)، كان متوسط النتائج 0.75 ± 0.01 BqKg^{-1}. إن نتائج قياس تركيز المواد المشعة الطبيعية للعينات موضوع الدراسة كانت أقل من الحد الأعلى المقبول في مختلف التوصيات والمعايير الدولية، بالإضاقة لذلك فقد وثقت هذه الدراسة أول مرجعية لتركيز المعادن في التربة الزراعية في دولة الإمارات العربية المتحدة وتشمل المعادن الثقيلة ايضاً، فكانت النتائج كالتالي بوحدة mg/Kg : Al - 8,539.7 As - 2.17, B - 47.68, Ca - 86,264.5, Cd - 0.35, Co - 10.30, Cr - 111.20, Cu - 14.32, Fe - 9,839.80, K - 2,026.80, Mg - 26,688.30, Mn - 237.40, Mo - 0.02, Na - 470.40, Ni - 60.90, P - 450.60, Pb - 4.25, S - 2,393.50, Si - 795.68, Sr - 593.70, V - 20.90 , Zn - 24.90. بالإضافة لذلك تمت مقارنة نتائج هذه الدراسة مع المستويات الدولية الموصى بها، كما تم تقديم توصيات إلى الجهات المعنية في دولة الإمارات العربية المتحدة لتنظيم تركيز هذه العناصر التي

وحدة في التربة الزراعية، وعلى أن تتضمن البحوث المستقبلية توسيع نطاق الدراسة ليشمل جميع الأراضي الزراعية في دولة الإمارات العربية المتحدة بما في ذلك المزارع العضوية. كما دعمت نتائج هذه الدراسة بخرائط تركيز المواد المشعة الطبيعية و المعادن في التربة الزراعية في دولة الإمارات العربية المتحدة باستخدام نظام المعلومات الجغرافية (GIS).

مفاهيم البحث الرئيسية: التربة الزراعية، مطياف غاما، دولة الإمارات العربية المتحدة، كاشف جرمانيوم عالي النقاوة، الراديوم-226، الثوربوم-232، البوتاسيوم-40، السيزيوم-137، نووي، إشعاعي، عناصر ثقيلة، الاحتباس الحراري، نظام المعلومات الجغرافية.

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Last but not the least, I would like to thank all those who helped me throughout the process of this project from the initiation to completion.

Dedicated to the memory of my father, Moutaz-Billah Ajaj, who always believed in my ability to be successful in the academic arena.

"You are gone, but your belief in me has made this journey possible."

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BEGe	Board Energy-Germanium Detector
EAD	Environmental Agency of Abu Dhabi
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gasses
GIS	Geographic Information System
HPGe	High Germanium Detector
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
IPCC	The United Nations Intergovernmental Panel on Climate Change
LabSOCS	Laboratory Sourceless Calibration Software
NORM	Naturally Occurring Radioactive Materials
γ-ray	Gamma Ray
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UV	Ultraviolet

Chapter 1: Introduction

1.1 Overview

Climate change and global warming have become a real universal concern. The sharp population increases with the massive growth in the urbanization are primary sources for significant emissions of greenhouse gasses (GHGs), lead to further stresses on the agricultural sector, in particular with the growing challenges of the climate change and global warming.

The United Arab Emirates (UAE) is a significant GHG producing country, which is included in the list of the 55 countries that generate at least 55% of the world's GHGs and thus involved in the top 30 countries over the world with excessive emissions. The sharp population increases with the massive growth in the urbanization are primary sources, lead to further stresses on the agricultural sector. Thus, the future of food production industry in the country became a real challenging matter.

The establishment of Barakah, which will employ the nuclear power to generate electricity, is a significant step towards minimizing the UAE carbon footprint. Barakah is sited in the western region of Abu Dhabi, and it is expected to be functional in 2018. This initiative supposed to minimize the pressure on burning fossil fuels and thus on carbon emissions through generating energy for green purposes. Therefore, the potential role of nuclear power in the UAE is reducing the CO_2 emissions in the UAE.

1.2 Statement of the Problem

The United Arab Emirates is considered a country with the prominent level of social and economic growth. Also, the UAE is a significant GHG producing country, so it is imperative to introduce a clean and efficient source of energy in the place.

The UAE government agreed to have the first safe, peaceful and sustainable nuclear power program in the region. The UAE's nuclear power plant is expected to provide 25% of the country's electricity needs and will save 12 million tons in carbon emission every year.

Before the construction of any regulated nuclear facility, it is essential to investigate the environmental background radiation level in the country. Such an investigation is critical for providing the background data for the environmental impact assessment of the nuclear facility.

On the other hand, the UAE still doesn't have baseline level for the radioactivity concentration levels. There is no any evaluation performed for the agricultural soil to identify the current radioactivity level to trace any enriching in these levels in case of any unexpected situations.

This study could be considered of as particularly important on both national and international levels for many reasons. The assessment of the agricultural soil is necessary for policymakers to evaluate the state of the soil as it could represent a risk to the human and environment.

The determination of the radioactivity concentration in the soil is essential to set a baseline level for the current situation. In case of any accidental release of any radioactive materials in the future, it is traced by comparing it to the baseline level, and the trend by time could be established. Many countries of the globe started extensive surveys for decades to establish their baseline to monitor any enrichment in the radioactivity levels.

The determination of the radioactivity concentration in the soil is crucial to estimate the public exposure and how this dose contributes to the dose rate of the population. Also, this will be useful for conducting epidemiological studies to discover any changes affected the environment.

The UAE does not have primordial and anthropogenic radioisotopic information that provides an environmental baseline. Also, there is insufficient literature available on the level of naturally occurring radioactivity in the UAE, and there is no baseline map for radioisotopes and their concentrations in the UAE soils.

1.3 Research Questions

1. What are the agricultural soil radioactivity concentration and radiation parameters?
2. Hypothesis: The agricultural soil radioactivity concentration to be below maximal admissible values established in various international recommendations and standards.
3. What are the mean concentrations of different elements with ranges of concentration of the UAE soil minerals, trace, and heavy metals contents?
4. Hypothesis: The concentration of the UAE agricultural soil minerals, trace, and heavy metals' contents need to be within the permissible levels.

1.4 Relevant Literature

1.4.1 The UAE and the Climate Change

The problems of the climate change and food security are receiving increasing attention from scientists, researchers, decision-makers and even the public community. Currently, one of the primary international goals related to this context is to ensure that food production will not be at risk for global warming and climate change (Shahin et al., 2015[a]).

However, global warming is a real threat to human food supply. According to many studies, if the earth's temperature raised only 2°C to 3°C, then the risks of hunger will raise up from 30 to 200 million hungry people. Additionally, any further increase in the earth's temperature will cause much worse figures, though having 250 to 550 million starving people (Jahan and Quddusi, 2014), and in other studies, it is expected to reach even over a billion (FAO, 2009).

The industrial revolution with the massive demand for food has created severe challenges through climate change and global warming. The massive emissions of greenhouse gasses (GHGs) and the continuous increase in the world population, which is predicted to reach over 9 billion by 2050, have all cost the earth paying a high price (Ajaj et al., 2015a, 2015b; Ajaj and Salem, 2015). Every day, massive stress factors are added to the available natural resources, especially in the food production sector, making their management and sustainability a very critical task (Salem et al., 2007; Grafton et al., 2015). It should be noted that there are no boundaries for the climate change phenomenon, and the issue is a global concern.

Due to the climate change implications, many new regions would be shifted to the semi-arid and arid areas. The agricultural productivity will be soon incapable of covering the food requirements of the 9 billion hungry people. There is a quick necessity to face the challenging situation and to cope with the increasing food demand (FAO, 2009).

It is worth mentioning that, the situation is more critical in developing countries and developing nations, that have already limitations on the environmental resources (e.g., water, land, energy), and thus have high risks of hunger and poverty (FAO, 2009). Based on the Food and Agriculture Organization of the United Nations (FAO) projects, the global demand for cereals will increase by 70% in 2050 compared to the current rates, and it would be doubled in many low-income nations. Besides, the demand for food will sharply grow in high-income countries, which have high per capita food consumption rates (FAO, 2006).

Paris Agreement 2015 was the latest global platform to decide on severe decisions and missions to eradicate poverty. The agreement emphasized that cross-regional collaboration and international strategic planning, for climate change adaptation, mitigation, and impact assessment be crucially required. The means of equity and different national circumstances should be taken into consideration.

The United Nations Intergovernmental Panel on Climate Change (IPCC) has published the fifth assessment report on 11 April 2014, titled as “Climate Change 2014: Mitigation of Climate Change”. This report highlighted that agriculture plays a fundamental role in food security and the sustainable development of the globe. Also, the report has emphasized that with the challenges of climate change there would be a significant concern in providing adequate food for the hungry people in many developing countries (IPCC, 2014). Especially, with the world population explosion, which is expected to reach 9.3 billion by 2050 (Sakschewski et al., 2014).

Therefore, it is indispensable to increase the food production capability in a sustainable manner (IPCC, 2014). At the same time, any factor that can adversely affect the food production system, as the climate change, would be a significant constraint to the global food security (Wang and Feri, 2011).

Indeed, plants are not migratory living organisms. They are living in one place throughout the years, and hence, cannot escape from the surrounding environmental stresses, such as high temperatures (Salem et al., 2004), water limitations, high sun exposures and air pollutants (Wang and Feri, 2011).

The stratospheric ozone depletion, which is the result of air pollution, has increased the concerns towards ultraviolet-B (UV-B) radiation (Grene, 2002). As an environmental abiotic stress factor, UV-B radiation has a considerable effect on the plant growth and performance. Such implications have to be investigated, evaluated and mitigated (Tevini and Teramura, 1989; Julkunen-Tiitto et al., 2005; Mewis et al., 2012).

According to many recent studies, future temperatures could be increased by climate change, up to 5.9°C by the year 2100, in comparison with today's temperatures (AlFarra and Abu-Hilileh, 2012). Such critical situation could directly threaten the availability of many plant species in the desert region, which are already surviving under many surrounding abiotic stress factors.

In the United Arab Emirates (UAE), which is located in the arid region of the world (Shahin and Salem, 2014[a]; Shahin and Salem, 2015[b]), the implications of climate change can have severe impacts on the limited available natural resources (EAD, 2012). Especially, if the current sharp expansion in the industrial activities, urbanization, and population have all been taken into considerations. Thus, it could be highly projected that this desert region could be much more susceptible and sensitive to any further environmental challenges.

Honestly, it was explicitly mentioned in the Corporate Strategy 2011 – 2015, published by the Environmental Agency of Abu Dhabi (EAD), that the UAE must reduce its carbon dioxide (CO_2) emissions. This is crucially needed; to ensure clean air, protect and conserve wildlife and natural resources and minimize climate change and its impacts.

1.4.1.1 The UAE Environmental and Climatological Conditions

The United Arab Emirates (UAE) contains seven emirates that extend across approximately 83,600 km^2, and a total population estimated to be 9,156,963 in 2015 (The World Bank, 2016). It is bordering the Gulf of Oman and the Arabian Gulf, between Oman and Saudi Arabia (Ministry of Information and Culture, 2010).

The UAE's climatic characteristics reflect the appearance of arid regions. Summer is hot and humid, with temperatures reaching 48°C in coastal cities, and could reach up to 50°C in the southern parts. The humidity levels are high in the coastal lines, reaching 90 to 100 % (Radhi, 2009). Also, the annual rainfalls are poor with average figures not exceeding 160 mm (MEW, 2005).

The UAE depends on limited freshwater resources. Mainly, there are only three freshwater resources. The groundwater (4,052 million m^3, contributing to 70% of the freshwater resources). The desalinated seawater (950 million m^3, contributing to 24% of the freshwater resources). The treated wastewater (319 million m^3, contributing to 6% of the freshwater resources), as illustrated in Figure 1 (Shahin and Salem, 2015[b]). It worth mentioning that, the agricultural sector consumes more than 83% of the total water demand in the country (Murad et al., 2007).

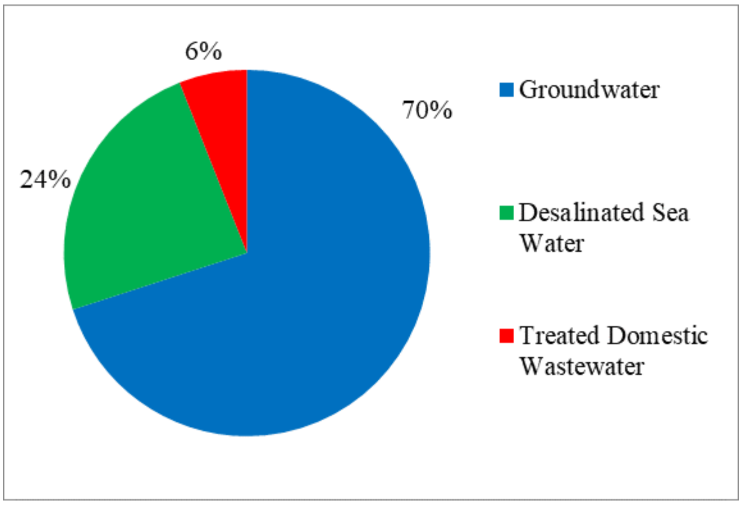


Figure 1: Water resources in the UAE

The soil texture in the UAE is classified as sandy soil (Mohammed and Shahin, 2011). This type of soil has low water holding capacity, high water permeability rate, little nutrients, and thus low fertility rate (Shahin and Salem, 2014[b]; Shahin and Salem, 2014[c]; Shahin and Salem, 2014[d]).

Indeed, the climate change and it influences are severely affecting the arid regions. The concerned parties in the UAE have stated that the temperatures in the country could be much increased by the end of the 21st century (EAD, 2012). The international panel on climate change has also confirmed this prediction. The panel stated that there would be a steady increase in the ambient temperature at the end of the 21st century (IPCC, 2007; IPCC, 2014).

A study conducted in 2009 predicted that compared to the temperature levels recorded during the period 1961 to 1990, the annual average temperatures in the UAE would be raised up to about 1.6°C to 2.9°C by the year 2050. Moreover, the temperatures could be further increased by approximately 2.3°C to 5.9°C by 2100 (Radhi, 2009). Besides, the global average CO_2 concentrations are estimated to be around 470 ppm (Ding et al., 2009).

1.4.1.2 Food Production Sector in the UAE

First, it is worth mentioning that, the UAE is not an agricultural country. All the available agricultural activities are depending on irrigation systems (Shahin and Salem, 2014[f]). Honestly, the agricultural sector is just covering a partial amount of the sharp growing agricultural demands. This could do through providing some varieties of fruits and vegetables, such as dates, tomato, cucumber, lettuce, onion, and potato. Most of the agricultural commodities, which consume high amounts of water, are imported. Thus, the term "food security" does not mean a full self-sufficiency, while it just says a partial food sufficiency (Shahin and Salem, 2014[f]; Shahin and Salem, 2015[c]).

In the UAE, the continuity of the agricultural sector is a very critical task. The main reasons are the growing agricultural demands, on the insufficient available freshwater resources. The population in the country is sharply increasing, as illustrated in Figure 2. which is expected to jump from 9,346,129 in 2013 to around 12 and 15.5 million by 2030 (Shahin and Salem, 2014[e]) and 2050 (United Nations, 2011), respectively.

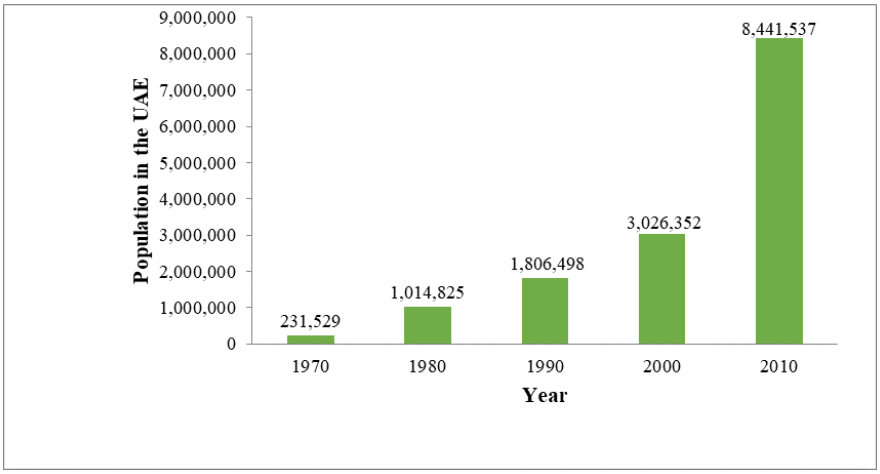


Figure 2: The population growth in the UAE

At the same time, there are significant concerns that the groundwater aquifers in the UAE will soon dry out. This is based on the massive extraction levels from the groundwater aquifers comparing to refilling rates (Shahin and Salem, 2015[c]).

Also, the vast expansion in the urbanization is costing the country enormous amounts of water, required to cover the growing irrigation requirements of the forestry and the landscaping sectors. This creates a severe competition with the crop production sector on the limited freshwater resources (Shahin and Salem, 2014[g]).

All previously mentioned challenges make the future of the food production sector in the UAE in a severe critical situation. According to a recent study, the total predicted crop irrigation requirements, supplied by the groundwater resources, are estimated to be at least 2,826 million m^3 annually by 2030. Which is doubled compared to the harvest irrigation requirements that was expected in 2007 (Shahin and Salem, 2015[c]).

Based on all previously mentioned severe difficulties related to the food production sector in the UAE, it is very crucial to identify the main significant challenges related to this context, as represented in Table 1. The same will significantly support the decision makers, scientists, researchers and the regular community member to mitigate any possible implications.

Table 1: Major expected stress factors related to food security in the UAE by 2030 and 2050

Stress factor	2030	2050	References
Population growth (Million)	12	15.5	(United Nations, 2011; Shahin and Salem, 2014[e])
Groundwater in Abu Dhabi (Million m^3)	0.0	0.0	(EAD, 2009; Shahin and Salem, 2015[c])
Temperatures increasing (Degree Celsius)	< 1.6	1.6 to 2.9	(Radhi, 2009)

1.4.1.3 Climate Change Influences on the Agricultural Sector

In fact, environmental and climatological stresses are severe threats to both agriculture and food security. The crop loss caused by these stress factors are having the capability to reduce the average yield of major crops to less than 50% (Wang et al., 2003).

Because of the enormous emissions of greenhouse gasses (GHG), specific environmental stresses, such as high temperatures, ozone layer depletion and excess levels of ultraviolet radiation, are becoming more predominant. It worth mentioning that, these abiotic stress factors have negative impacts on crop yields (Wang and Frei, 2011).

The continuous increasing of GHG is indirectly cooling the stratospheric ozone layer. Thus, leading to ozone depletion (Zlatev et al., 2012). The consumption creates serious concerns related to elevated levels of ultraviolet-B (UV-B) radiation (280-320 nm) (Grene, 2002).

Mainly, there are three types of ultraviolet, which are UV-A, UV-B, and UV-C (Zlatev et al., 2012). Although ultraviolet radiation (Type B) is representing only less than 0.5 % of the total solar radiation, however, this amount is entirely absorbed by the ozone layer. Thus, as the depletion of the ozone layer increase, then the daily influence by the UV-B would increase as well (Ormord et al., 1995).

The solar UV-B can damage the living organisms (Jansen et al., 2012). High levels of UV-B radiation is responsible for collective biologically damage effects in plants. The high-energy UV-B has direct effects on plants; including the damage toTh DNA and severe changes in the membrane and protein denaturation (Zlatev et al., 2012).

Ultraviolet (UV) radiation has such a noticeable effect on the plant species. It has been recognized as a standard strain for plants during their growth and development (IPCC, 2007). The high levels of the UV-B radiation would straightforwardly influence the plant tissues. It could alter the plant physiology and thus affects the vegetation growth and development of the plant species. For example, it could modify the leaf and the pollen characteristics, biomass production and flowering morphology and timing (Fagerberg and Bornman 2005; Hectors et al. 2007; Salem et al., 2007).

It is predicted that the amount of UV-B will keep increasing in the range of 5-10 % over temperature latitude within the coming ten years (Lidon et al., 2012). Then, exposing the plants to the UV-B radiation induced changes in leaf and plant morphology.

Modifications could be noticed by a decrease in plant height, leaves, and roots, as well as, the area of the leaves (Zuk-Golaszewska et al., 2003). However, it has been noticed that different types of plants have different capabilities to respond to varying levels of UV-B irradiation (Matthew et al., 1996). Some studies declare that the content of the chlorophyll varied between different types of plants, and such variations may affect the plant competition for light absorption (Barnes et al., 1988).

As mentioned previously, the UAE is already suffering from harsh environmental and climatological stresses. Consequently, the threat of climate change would significantly affect the agricultural productivity in this region of the world and would influence the food security issues. The rapid increase in population with the vast expansion in the urbanization resulted in additional warming up of the climate in the UAE. This is in addition to the atmospheric air pollution and the increase in GHG emissions, which all together lead to the much tricky situation.

A study conducted in 1996 by the United States Environmental Protection Agency (EPA) declared that the percentage of the increase in the average annual UV-B had reached about 1.2% over the past 20 years in the UAE (EPA, 2012).

The Environmental Agency of Abu Dhabi (EAD) confirmed that the Emirate's per capita emissions of GHG are currently among the highest in the world, at around 48.5 ton per year (Wang and Frei, 2011). Besides, the annual CO_2 emissions have been than doubled in the UAE since 1990 (AlFarra and Abu-Hilileh, 2012).

The UN Climate Change Conference, which was held in Paris from 30 November to 11 December 2015, was a global agreement on the reduction of climate change implications (Hermwille et al., 2015). In fact, 195 participating nations agreed on the final global agreement, which includes the reduction of the carbon emissions and GHGs. According to Article 2, the mission is to keep the global average temperature 2°C below pre-industrial levels" and to limit the temperature increase to "1.5°C above the pre-industrial levels". Also, the Article is emphasizing that emissions reduction has to be achieved in the manner of sustainable development and the context that it does not threaten food security (Proposal by the President., 2015; Kuzmenko et al., 2016).

It is worth mentioning that, the convention will be binding if at least 55 members of its countries have ratified the Agreement. Indeed, achieving the same is a difficult task for many nations, including the United States, and thus has many doubts whether it would become true or not. Notably, the convention has no enforcement mechanism and has no implementing measures (Proposal by the President., 2015).

In fact, the primary challenge is how the nations will provide more food and adequate accommodation for the growing population in conjunction with the urbanization, while at the same time, keeping low carbon emissions and conserving the carbon reservoirs and sinks (e.g., forests) (Smith et al., 2010).

Therefore, to best adapt and mitigate climate change implications, the agricultural land management and decisions related to land priority use would become crucial tasks, especially for developing nations (e.g., South Asia and Sub-Saharan Africa) and countries located in the arid regions (Smith et al., 2010).

The UAE, as a major oil-producing country, is included in the list of the 55 countries that produce at least 55% of the world's greenhouse gas emissions (Rhodes, 2016). Also, the UAE is included in the top 30 countries over the world with excessive emissions. Emissions and allowances increased sharply over years as illustrated in Table 2. Emissions growth rate from 1996 to 2005 was 13.10%. Based on these figures, the subsidies and quotas were predicted, for the period from 2006 to 2050, to be 219.50 MtC and −312.28 MtC, respectively. Based on the results of the same study, the emissions from 2006 to 2050 were predicted to reach 1364.31 MtC, while the emissions per capita, during the same period, are expected to be 332.43 MtC. Since the cumulative emissions per capita for the period between 1900 to 2005 is 429.79 tC, cumulative emissions per capita from 1900 to 2050 is expected to be 762.22 MtC (Ding et al., 2009).

Table 2: The emissions and allowances in the UAE over the years (Source: Ding et al., 2009)

Years	Emissions (MtC)	Allowances (MtC)
1900-1949	0.0	2.17
1950-1989	211.51	22.79
1990-2005	394.56	49.34

1.4.2 Radioactivity Concentration of the Agricultural Soil of the UAE

There is a growing demand for agricultural soil data information from scientists, researchers, and decision-makers to assess soil characteristics at both national and international levels. The agricultural soil is of particular concern because it is a direct threat to human and environment (Guidotti et al., 2015). The information about these nuclides is paramount in many fields of science (Rani et al., 2015).

The soil is hugely variable in physical and chemical composition. It consists of organic, inorganic and radionuclides materials and compounds (Akhtar et al., 2005). The soil is considered a primary indicator of the radiological status of the environment as it is transferred pathway for radionuclides to plants and animals (Saleh et al., 2013).

There are different concentrations of radionuclides in various soil levels and types in the world (Tufail et al., 2006). There are three types of environmental radionuclides: radionuclides with the primordial origin, a decay product of primordial radionuclides, and anthropogenic radionuclides (Almayahi, 2012).

Naturally Occurring Radioactive Material (NORM), also called terrestrial or primordial radionuclides, are present in the earth's crust. NORM is found in soils, plants, rocks, groundwater and even within the human bodies (Almayahi, 2012; Yildiz et al., 2014; Rani et al., 2015). Primordial radionuclides are formed by the process of nucleosynthesis in the stars. These radionuclides are characterized by half-lives comparable to the age of the earth (Tufail et al., 2006).

Radionuclides are distributing according to the geological and geographical condition (Ele Abiama et al., 2010). The natural background depends on the soil and sediment formation, rock type and transport process (Mohery et al., 2014). The level of natural radionuclides is related to the content of the rock and the soil origin (Tufail et al., 2006). There are many classifications for the soil. It could be saline, saline-sodic, and sodia (Akhtar et al., 2005). Studies show that the highest radionuclide activity concentration occurs in a clay soil and the lowest in sandy soil.

The variation in the rock's radioactivity is useful for geological mapping, identifying the distribution of radiation exposure and for environmental monitoring (Gaafar et al., 2016). If the soil is derived from a granite's rock, then it would have a higher radioactivity activity than a soil arising from another rock type (Saleh et al., 2013).

The natural radionuclide background depends on the soil and sediment formation, rock type and transport process (Mohery et al., 2014). Naturally Occurring Radioactive Material (NORM) occurs mainly from primordial radionuclides such as uranium ^{238}U, thorium ^{232}Th, potassium ^{40}K and any of their decay products (Gaafar et al., 2016; Tufail et al., 2006; Yildiz et al., 2014).

Minerals that contain uranium, potassium, and thorium are considered radioactive (Gaafar et al., 2016). These minerals are such as monazites and zircons

(Saleh et al., 2013). These radionuclides have long half-lives, comparable to the age of the earth, so they need a longer time to decay to attain the stable state (Ele Abiama et al., 2010; El-Samad at al., 2013).

Besides NORM contribution source, the use of phosphate fertilizers for agricultural purposes enriches the radioactivity in the soil (Boukhenfouf and Boucenna, 2011). To achieve a high-quality agriculture productivity, chemical fertilizers such as nitrogen (N), phosphorus (P), potassium (K) and sulfate-based fertilizers are applied. Formulas and concentrations varied per the soil and the cultivation need (Boukhenfouf and Boucenna, 2011).

Phosphate is widely used as a source for manufacturing phosphate fertilizer (Gaafar et al., 2016). Phosphate ores of sedimentary origin have higher concentrations of the radionuclide of uranium (Gaafar et al., 2016) and daughters' radionuclides of ^{238}U (Boukhenfouf and Boucenna, 2011). Treating the phosphate with sulfuric acid, to produce phosphate fertilizer, will enrich the uranium content up to 150% of the ore (Gaafar et al., 2016). The ^{232}Th has a minor contribution to radioactivity in phosphate. Phosphate ores contain about 1500 Bq/kg of uranium and radium, although some phosphates contain up to 20,000 Bq/kg of Triuranium octoxide (U_3O_8) which is a compound of uranium (Gaafar et al., 2016). The use of phosphate fertilizer in agriculture is considered a possible exposure to radiation the public (Gaafar et al., 2016).

The use of fertilizers has a slight effect on radioactivity concentration due to dilution of fertilizers used in a lot of agricultural areas, however, overusing for extended periods of time could increase the radioactivity concentration in the soils and affect the health (Milica et al., 2013).

Naturally occurring radionuclides in soil generate background radiation exposure to the public (Karahan and Bayulken, 2000). Which is considered the most significant contributor to the external dose received by human beings (Akhtar et al., 2005; Saleh et al., 2013; Mohery et al., 2014).

About 85% of the radiation dose received is from primordial and cosmic radiation (El-Samad at al., 2013). About 95% of external gamma dose rate come from naturally occurring radionuclides incorporated into the soil (Saleh et al., 2013).

In most places, the natural radioactivity slightly varies; however, some areas deviate from reasonable level because of the high concentration of these radionuclides (Ele Abiama et al., 2010; Boukhenfouf and Boucenna, 2011). Natural radioactivity in soil may vary from one place to another (Boukhenfouf and Boucenna, 2011).

There are different concentrations of radionuclides in various soil types and levels and kinds in the world (Tufail et al., 2006). By the way, the average exposure in the United States and Europe are about 0.5 mSv/year while it reaches a high as 450 mSv/year in Ramsar, Iran (Almayahi, 2012). High background radiation levels are under investigation in Australia, Brazil, China, France, India, Italy, Niue Island, Switzerland and other countries (Saleh et al., 2013).

The presence of radioactive isotopes in water is due to dissolution when water comes in contact with the rocks and soil sediments which contain uranium and thorium. The most important naturally occurring radionuclides present in water are ^{226}Ra and ^{228}Ra which are generated by ^{238}U and ^{232}Th (Al-Jaseem et al.,2016). Radium ^{226}Ra is considered as moderately soluble in water and can enter the groundwater by the suspension of the aquifer materials, desorption from rock or sediment surfaces and ejection from minerals radioactive decay. Radon ^{222}Rn naturally occurring gas ($T_{1/2}$=3.8d) can seep through water, soil surfaces and structural barriers (Almayahi et al., 2012).The radioactivity concentration in the water is one factor which determines the quality of drinking water. So, water is also analyzed to estimate the contribution of the radioactivity content in water used for irrigation (Al-Jaseem et al., 2016).

Human activities could change the natural concentration of radionuclides in the environment (Montes, 2012). The anthropogenic radionuclides also called artificial radionuclides, have gained considerable importance because of the previous testing of nuclear weapons and accidents in nuclear reactors (e.g., Chernobyl accident in 1986) (Yildiz et al., 2014). Randomly distributed nuclear fission products are absorbed and retained by soil. Cesium isotopes like Cs-137 are the most significant fallout from the atmosphere on vegetation and are the primary source of soil contamination (Akhtar et al., 2005; El-Samad at al., 2013).

At present, the United Arab Emirates (UAE) does not have a primordial radioisotopic database that could serve to establish an environmental baseline of the radioisotopes and their concentrations in UAE soils. Further, there is insufficient literature available on the level of naturally occurring radioactivity in the UAE. The need for such a baseline presents as the UAE has initiated a civilian nuclear power program.

In this regard, before the operation of any nuclear power plant, it is crucial to establish the environmental background radiation level in the country that is located within its environmental impact assessment.

1.4.3 Elemental Fingerprint of Agriculture Soils of the UAE

The soil is an essential natural resource for any civilization. It provides a stable construction foundation for buildings and railroad tracks. The soil is also a habitat for billions of living organisms and a natural storehouse of nutrients and water (EAD, 2012). Also, the soil is the foundation for food production, purifying water, flood control, climate regulation, and sustaining the natural and cultural history (Bini, 2009).

A healthy agricultural soil performs multi-functional purposes. First, it provides a pleasant shape for the landscape. Second, it contains food, fiber, animal feed and biofuel. Third, it offers regulatory service through water filtration, transformation, and storage. Fourth, it controls and maintains nutrients and energy cycles between the atmosphere, groundwater and vegetation cover. Fifth, it acts as a gene pool for sustaining biodiversity (Schulte et al., 2014).

Varied factors can adversely affect soil quality such as soil compaction, soil erosion, pollutant inputs and soil acidification. Once soil quality becomes degraded or damaged, it is challenging and costly for it to be recovered. Consequently, ensuring soil functions and protection has a significant role in the sustainable use of natural resources, and the same is a fundamental task for politicians, government, the private sector, researchers and every individual in the society (Bini, 2009).

Desertification has been a primary global concern during the 20th century and remains on top of the international agenda in the 21st century. According to the UN Environmental Program (UNEP) report, a quarter of the Earth's land is threatened by desertification, which affects about one-fifth of the global population (Tolba et al., 1992). The susceptibility of land to desertification is mainly due to climate, the state of the soil, water, natural vegetation, and how these resources are used by human communities and their livestock. Worldwide, an additional 200,000 Km^2 of productive lands is reduced annually by desertification (Abdelfattah et al., 2009).

Soil testing is an essential tool for evaluating whether soil statues are appropriate for different types of agriculture activities. Also, it could identify a proper nutrients management. Besides, it is an efficient way to determine a sustainable way to have a health crops in sound quality (Brady and Weil, 2002).

There are many different laboratory testing methods used for this purpose. Most soil test results do not vary significantly from year to year. However, some soil and environmental conditions can lead to differences in measurements (e.g., pH). Soil depth plays a vital role in soil nutrients concentration and thus soil test results. An appropriate soil sampling depth is determined based on the purpose of the soil test. For example, to test for plant nutrient requirements before planting, the recommended soil sampling depth ranges down to the root active zone (e.g., 6 to 12 inches) (Jones, 2001; Horneck et al., 2011).

A healthy soil includes specific amounts of elements which can guarantee growing healthy crops and production of the best yields. Their essential elements for plant growth can be divided into two categories, macronutrients, and micronutrients. Macronutrients are used in relatively large amounts (>0.1% of dry plants tissue). The sources of these nutrients are mostly soil solids such as Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulfur (S). Others nutrients come from air and water such as Carbon (C), Hydrogen (H) and Oxygen (O). Micronutrients are used in relatively lesser amounts (<0.1% of dry plants tissue). The sources of these nutrients are soil solids such as Iron (Fe), Manganese (Mn), Boron (B), Copper (Cu), Chlorine (Cl), Cobalt (Co), Molybdenum (Mo), Nickel (Ni) and Zinc (Zn). Also, other types of soil nutrients are taken up by plants that are not essential for plant growth. These nutrients are such as Sodium (Na), Silicon (Si), Iodine (I), Fluorine(F), Barium (Ba) and Strontium (Sr) (Brady and Weil, 2002; Horneck et al., 2011).

The UAE soil texture is defined as sandy soil (Mohammed and Shahin, 2011), and consequently have high water penetrability rate, low water holding capacity, low water moisture content, poor minerals and nutrients availability, and thus little fertility rate (Shahin et al., 2009).

According to the soil survey of the Northern Emirates of the country (2012), the soil of the UAE is one of the most challenging soils around the world. It is very fragile, sensitive and very slowly renewable. Indicators of land degradation in the country are increasing salinization, sand movements, waterlogging, loss of productive topsoil, exposure of the hardpan, surface gravel lag, landfilling, compaction and loss of biodiversity (Shahid, 2007).

In the UAE, the land degradation is caused by different facts including its geographical location in an arid region and harsh environmental conditions. The leading causes of land degradation in the country are a low precipitation rate, high evaporation rate, irrigation with saline/brackish water, intensive use of groundwater, uncontrolled overgrazing, wind erosion, sand violation, excavation for construction material, off-road vehicular maneuvering, and urbanization (Abdelfattah et al., 2009).

Soil sampling and testing have several purposes. First, it is a diagnostic tool to determine the soil status for agricultural production and the possibility of growing specific desert habitat crops. Second, it is a diagnostic tool to identify plant nutrition problems and the necessity for adding fertilizers. Third, it is a monitoring tool to observe soil chemical changes and trends. Fourth, it is a tool for soil engineering and urban management. Fifth, it is a testing tool for identifying the occurrence and concentration of soil contaminations. Sixth, it is a useful way to estimate soil carbon stocks and potential carbon credits. Seventh, it is an essential method to perform soil characterization and soil mapping, which is necessary for land management and assessment (Hazelton and Murphy, 2016).

The study aims to provide the first inclusive fingerprint for mineral and heavy metal concentration determination and distribution in 100 UAE agricultural farms. Also, it is intended to determine the distribution variance of these minerals and heavy metals at these farms using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). The study results were enriched using the Geographic Information System (GIS) to provide a mineral mapping of the UAE agricultural soils. The results of this study provide a tool for understanding the general status of the UAE agricultural soil regarding elements availability, assistance to policymakers for improving legislation and regulations related to land use, thus enhancing agricultural soils productivity and the status of the national food security.

Chapter 2: Materials and Methods

2.1 Study Location

The United Arab Emirates (UAE) comprise of seven Emirates covering approximately 83,600 km^2. The total population was estimated to be 9,267 million in 2016 (Worldmeters, 2017). The UAE borders the Arabian Gulf and the Gulf of Oman, between Sultanate of Oman and the Kingdom of Saudi Arabia. The climate is characterized by high temperatures reaching 46°C. The rainfall rate is sparse with yearly average precipitation of about 160 mm (MEW, 2005). The soil texture is mainly sandy (Ajaj et al., 2015a). This type of soil has low water holding capability, high water permeability rate, low nutrient value***s*** thus a low fertility rate (Ajaj & Salem, 2015). Referring to the 2012 UAE soil survey of the Northern Emirates the soil is considered as one of the most challenging soils around the world for agricultural purposes. It is very fragile, sensitive and slowly renew***s***. Indicators of land degradation in the country are salinization, sand movement, waterlogging, loss of productive topsoil, exposure of hardpan, surface gravel lag, landfilling, compaction and loss of biodiversity (Shahid, 2007).

2.2 Survey Design

The target population for this study was agriculture topsoil distributed within the UAE. A total of 145 samples were collected. At every sampling site, five soil samples were collected from a 9x9 m square area grid, each square subdivided into nine cells of 3x3 m (Figure 3) (Senthilkumar et al., 2010; Lu at al., 2012; Guidotti et al., 2015). For tracking the location of each collected sample, a GPS device was used to record its exact location.

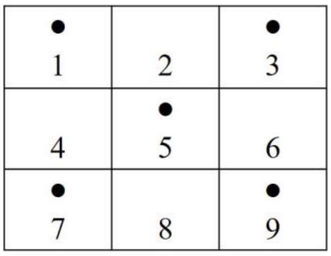


Figure 3: Sampling design

2.3 Soil Sampling

All samples were collected during the January-March 2016 period from different agriculture farms in the UAE with granted private/government permission**(s)**. All the collected samples were from the surface layer at a (30 cm**)** depth – the recommended depth of interest for agricultural practices (Guidotti et al., 2015). For each sample, a total of (2-3 Kg) was thoroughly mixed and placed in a sampling bag at the sampling location (Senthilkumar et al., 2010). The collected samples were used for the analysis by Gamma Spectroscopy and ICP-OES.

2.4 Gamma-Ray Spectroscopy Analytical Methods

2.4.1 Soil Sample Preparation

All soil samples were dried at 80°C for 24 hours (Figure 4) to retain unstable polonium or cesium radionuclides (Ha midalddin, 2014). Each dried sample was then sieved using a sieve of (1-mm). A mesh was used to remove stones, gravel as well as plant root***s*** and leaves (Figure 5). Each homogenized fine-grained sample was packed in a (1.1 L) Marinelli beaker**,** sealed and stored for one month (4 weeks) to allow for the establishment of secular equilibrium between ^{226}Ra and its progeny (Figure 6) (Senthilkumar et al., 2010; Hamidalddin, 2014).

Figure 4: Drying system

Figure 5: Soil preparation (sieving)

Figure 6: Soil samples stored to reach secular equilibrium

2.4.2 Mechanism of Gamma Spectrometer Detection System

The detection of any radiation depends upon the production of charged secondary particles which were collected to produce an electrical signal. To achieve the mission of reporting specific gamma-emitting nuclide in the environment, it is crucial to have an understanding of the operation of the gamma spectrometer. Understanding how to interpret the information produced by the gamma spectrometer will ensure that the result is complete, valid and accurate (Ryde, 1995).

Gamma Isotopic analysis is a method which detects minuscule quantities of radioactive materials. The instrument used in the analysis is "gamma spectrometer." Gamma spectrometer is an analytical instrument used to detect gamma-emitting radionuclides. The graphical representation of the number of counts in each channel is a "gamma spectrum," and the written summary report is "gamma scan" (Knoll, 1999) (Ryde, 1995).

There are three primary germanium detectors commonly knows. Ge(Li) which is the first commercial in 1965, HPGe or High Germanium with an impurity of about 1x1010 atom/cc and Ge has approximately 1.2x1023 atom/cc which is used in the current study. Another type is the Crystal grown using Czocharlski method (Erdtman & Soyka[a], 1979).

All the soil samples in the current study were analyzed using a Board Energy-Germanium "BEGe" planar detector with a relative efficiency of 19.5% and FWHM 1.6 KeV at 1332 KeV. Graded shield surrounded the detector. The outer jacket consists of (2.54 mm) thick low carbon steel, bulk shield (5 cm) thick low background lead and graded lining (1.27 mm) tin and (1.27 mm) copper. Figure (7) represents a Cross-

Sectional View of the detector used in the study (Erdtman & Soyka[b], 1979). The detector Specification and performance data are given in the appendix.

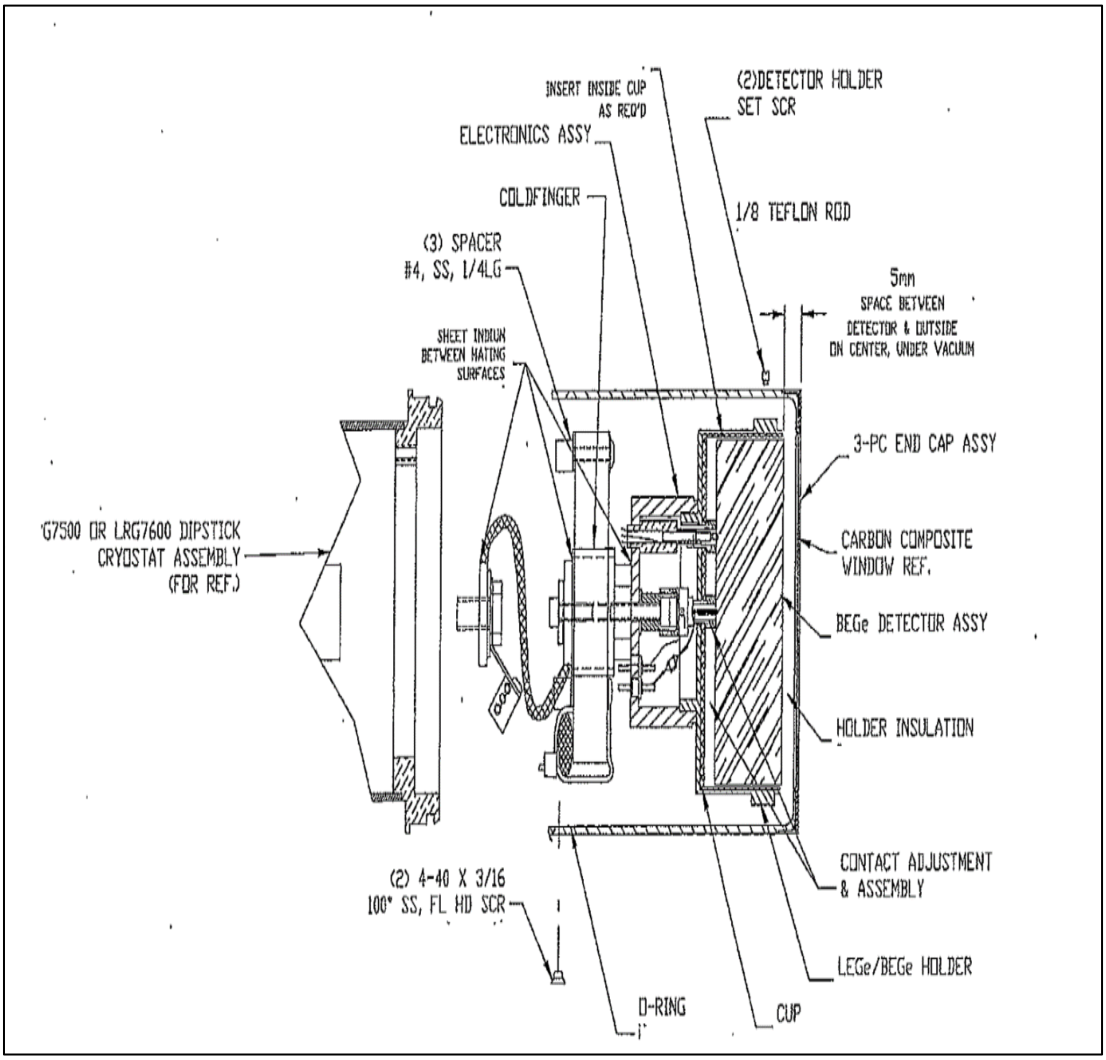


Figure 7: Cross-sectional view of the broad energy germanium detectors (BEGe)

The laboratory gamma background at the laboratory was taken under the same conditions of the sample measurements and subtracted from the measured γ-ray spectra of each sample to get the net value**.** An empty polyethylene Marinelli beaker was placed in the detection system (Chivers, 2008) during the background measurements.

Each soil sample was analyzed using the BEGe for 24 hours (Figure 8). The present study objectives are to analyze agriculture soil samples to identify:

- Natural Occurring Radioactive Material (^{238}U, ^{226}Ra, ^{232}Th and ^{40}K).
- Any anthropogenic nuclides (^{137}Cs).

The following radionuclides were identified and measured in the current study:

- ***^{238}U- series***

The secular equilibrium between the parent nuclide ^{238}U and its short-lived daughters of ^{234m}Pa and ^{234}Th is considered to be able to analyze ^{238}U. Thus, the gamma emitting radionuclides used were ^{214}Bi (609.31 KeV) and ^{214}Pb (351.93 KeV). The ^{226}Ra value was estimated by combining the activity concentration of ^{214}Pb and ^{214}Bi (Agbalagba et al., 2012; Guidotti et al., 2015).

- ***^{232}Th-series***

The ^{232}Th is considered to be in equilibrium in most environments. The gamma emitting radionuclides ^{208}Tl (2614.53 KeV), ^{228}Ac (911.20 KeV), ^{212}Bi (727.33 KeV), ^{208}Tl (583.19 KeV) and ^{212}Pb (238.63 KeV) were used for analysis of the soil samples (Guidotti et al., 2015).

- ***^{40}K***

The radioactivity concentration of ^{40}K was determined by measuring the gamma transition at (1460.83 KeV) (Agbalagba et al., 2012) (Guidotti et al., 2015).

- ***^{137}Cs***

The radioactivity concentration of ^{137}Cs was determined by measuring its gamma ray-key line at (661 Kev) (Agbalagba et al., 2012).

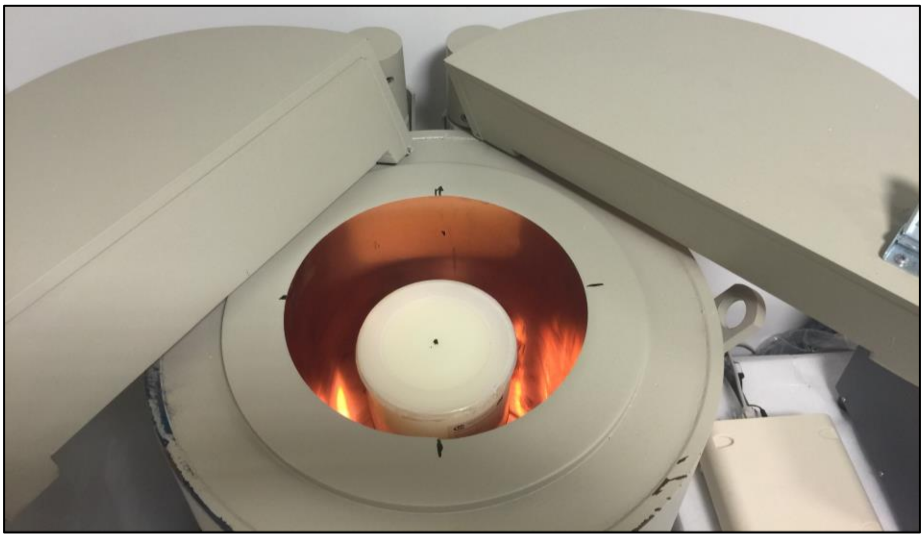


Figure 8: Broad energy germanium detectors (BEGe)

2.4.3 Theoretical calculation

- ***The specific activity concentration***

The specific activity concentration of the radionuclides is estimated using the following relation:

$$C\ \left(\frac{Bq}{Kg}\right) = \frac{R_n}{I_\gamma \times \varepsilon_{Pf} \times M_s} \qquad \text{(Eq. 1)}$$

Where (R_n) is the net gamma counting rate (counts per second), ε_{Pf} the peak efficiency of the detector for the specific γ-ray energy, (I_γ) is the intensity of the γ-line in a radionuclide and (M_s) is the sample mass (kg) (Thabayneh and Jazzar, 2012; Ademola et al., 2014). As per UNSCEAR (2000), the worldwide revised average activity concentration values are 35 $BqKg^{-1}$ for ^{226}Ra, 30 $BqKg^{-1}$ for ^{232}Th and 400 $BqKg^{-1}$ for ^{40}K.

- ***Radiological effect***
  - ***The radium equivalent activity index (Ra_{eq})***

To calculate the activity levels of ^{226}Ra, ^{232}Th, and ^{40}K and to assess the hazard, the Radium Equivalent Activity Index (Ra_{eq}) is mathematically introduced by (UNSCEAR, 2000):

$$Ra_{eq} = C_{Ra} + (1.43\ C_{Th}) + (0.077\ C_K) \qquad \text{(Eq.2)}$$

Where(C_{Ra}), (C_{Th}) and(C_K) are the average activity concentration in a sample in (BqKg^{-1}) for ^{226}Ra, ^{232}Th, and ^{40}K respectively (Sinkaye and Emelue, 2015). The maximum value of(Ra_{eq}) in soil must be less than 370 BqKg^{-1} as recommended by the Organization for Economic Cooperation and Development (Khan et al., 2011).

- ***The absorbed dose rate (D_r)***

The absorbed dose rate (D_r) due to gamma radiation in the air at 1 m above the ground surface for a uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) is calculated according to the following formula (UNSCEAR 2000; Ademola et al., 2014):

$$D_r\left(\frac{nGy}{h}\right) = DCF_{Ra} \times C_{Ra} + DCF_{Th} \times\ C_{Th} + DCF_K \times C_K \quad \text{(Eq.3)}$$

The Dose Conversion Factors (*DCF*) used to compute the absorbed γ-dose rate (D_r) in air per unit activity concentration are as follows:

$$DCF_{Ra} = 0.427 \text{ nSv/h/Bq·Kg}^{-1}$$

$$DCF_{Th} = 0.662 \text{ nSv/h/Bq·Kg}^{-1}$$

$$DCF_K = 0.043 \text{ nSv/h/Bq·Kg}^{-1}$$

The average world value for the absorbed dose rate is 60 $nGyh^{-1}$ (UNSCEAR 2000) (Lu et al., 2012).

- ***The total annual effective dose equivalent (D_{eff})***

The outdoor annual effective dose rates are calculated by the following formula (UNSCEAR, 2000):

$$(D_{eff})_{Outdoor}\left(\frac{mSv}{yr}\right) = D_r \left(\frac{nGy}{hr}\right) \times DCF \times O_f \times T \qquad \text{(Eq. 4)}$$

Where O_f is the occupancy factor. The *DCF* received by adults is 0.7 $SvGy^{-1}$, and the O_f can be assumed to be 0.2, i.e., expects 20% of the time is spent outdoor**s**. (Ravisankar et al., 2012; Lu at al., 2012; Bala et al., 2014).

The indoor annual effective dose equivalent to (O_f) occupancy factor assumes that 80% of the time is spent indoor*s*. The $(D_{eff})_{Indoor}$ is given by (Khan et al., 2011):

$$(D_{eff})_{Indoor}\left(\frac{mSv}{yr}\right) = D_r \times DCF \times O_f \times T \qquad \text{(Eq.5)}$$

The total annual effective dose (indoor & outdoor) from terrestrial radiation is given by:

$$D_{eff}\left(\frac{mSv}{yr}\right) = (D_{eff})_{Outdoor}\left(\frac{mSv}{yr}\right) + (D_{eff})_{intdoor}\left(\frac{mSv}{yr}\right) \qquad \text{(Eq.6)}$$

The worldwide annual effective dose from natural sources for standard background areas is estimated to be 0.41 $\boldsymbol{mSvy^{-1}}$, where the outdoor annual effective dose is 0.07 $\boldsymbol{mSvy^{-1}}$ and the indoor annual effective dose is 0.34 $\boldsymbol{mSvy^{-1}}$ (UNSCEAR, 2000)**.** The International Commission on Radiological Protection (ICRP) has recommended an annual effective dose equivalent limit of 1 $\boldsymbol{mSvy^{-1}}$ for individual members (ICRP, 1993).

- ***The Hazard Index***

The External Hazard Index (H_{ex}) is calculated to evaluate the risk of the natural gamma radiation hazard associated with the naturally occurring radionuclides in specific building materials (Sharma et al., 2016). The values of the Index must be less than unity in order to the radiation exposure of the population to natural radioactivity (Senthilkumar et al., 2010; Ademola et al., 2014; Bala et al., 2014):

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} < 1 \qquad \text{(Eq.7)}$$

Another measure, called Internal Hazard Index (H_{in}) describes the risk from radium ^{226}Ra and its decay products to the internal respiratory organs, is used for safety requirements by reducing the acceptable activity concentration of ^{226}Ra to half of the normal limit, and it must be less than 1.0 (Ademola et al., 2014) (Saleh & Shayeb, 2014).

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} < 1 \qquad \text{(Eq.8)}$$

The values of the indices (H_{ex}, H_{in}) must be less than one for the radiation hazard to be negligible (Thabayneh,& Jazzar, 2012).

- ***Gamma Representative Level Index ($\boldsymbol{I_y}$)***

Another index used for estimation of gamma radiation hazard associated with natural radionuclides in soil is called the Gamma Representative Level Index (I_y) (Ademola et al., 2014; Chandrasekaran et al., 2015):

$$I_y = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \leq 1 \qquad \text{(Eq.9)}$$

The value of I_y must be less than unity in order to keep the radiation hazard unimportant (Agbalagba et al, .2012). Values of $I_y \leq 1$ correspond to an annual effective dose of less than or equal to (1 mSv), while $I_y \leq 0.5$ corresponds to annual effective dose less or equal to (0.3 mSv) (Chandrasekaran et al., 2015).

2.4.4 Analysis Software

There are various vendors supply different analysis software. The software used in this study contains five analysis engines to analyze a spectrum. The analysis methodology used is Library – detected peak search. This method is suitable for low-level counting which applies for this study. Libraries contain info about all gamma lines of nuclides and could be updated to specific nuclides of interest. The Genie 2000 spectroscopic software used for data acquisition and analysis (Kocher, 1981).

2.4.5 Quality Control Activities

The gamma-ray spectrum affords information as many pulses measured or listed within small successive pulse height ranges. Detector calibration explains gamma spectrum regarding energy rather than channel numbers or pulse height in units of voltage and amount of radionuclides in radioactivity units rather than the count of some pulses listed in the channels. The list of the gamma-ray for each radionuclide, probability of emission for those radionuclides and half-life of the radionuclides data should be available to perform the proper calibration (Debertin and Helmer, 1988).

For accurate analysis, specific quality control activities should be performed on a regular basis. Such as background counting (weekly), efficiency and energy quality control checks (daily), and system environmental control such as dust and temperature (daily) (Debertin and Helmer, 1988).

2.4.5.1 Energy Calibration

Energy calibration is necessary to identify the nuclides. It is considered as the first calibration to be performed, and it should be done before the efficiency calibration. Calibration is needed for the x-axis. The calibration defines unknown channels for units of energy (KeV). Once calibration is performed, the gamma emitters are identified by their fingerprints. The fingerprints represent the energy lines for specific nuclide. Shape calibration is built into the energy calibration routine, and it specifies peak to shape and peak broadening. Energy calibration ensures peaks in the spectrum appear at the correct energies. Thus, the algorithm will be able to identify the nuclides (NRC, 1981; Knoll, 1999).

Calibration graph includes 8991 channels with 3000 KeV. General equation:

$$y = mx + b \qquad \text{(Eq. 10)}$$

$$y = 0.3662x + 0.01 \qquad (Eq. 11)$$

Where slope m = 0.3662 Kev per channel and y-intercept b = 0.01 KeV. The user decides the acceptance criteria. The peak on spectrum must be within ± 1 KeV of the true energy in nuclide library to identify the nuclide. There must be enough counts in peaks to create a good peak shape (Kocher, 1981). Some vendor packages calibrate peak width (FWHM) and peak shape as part of the energy calibration. Figure 9 represents the energy calibration performed in the current study.

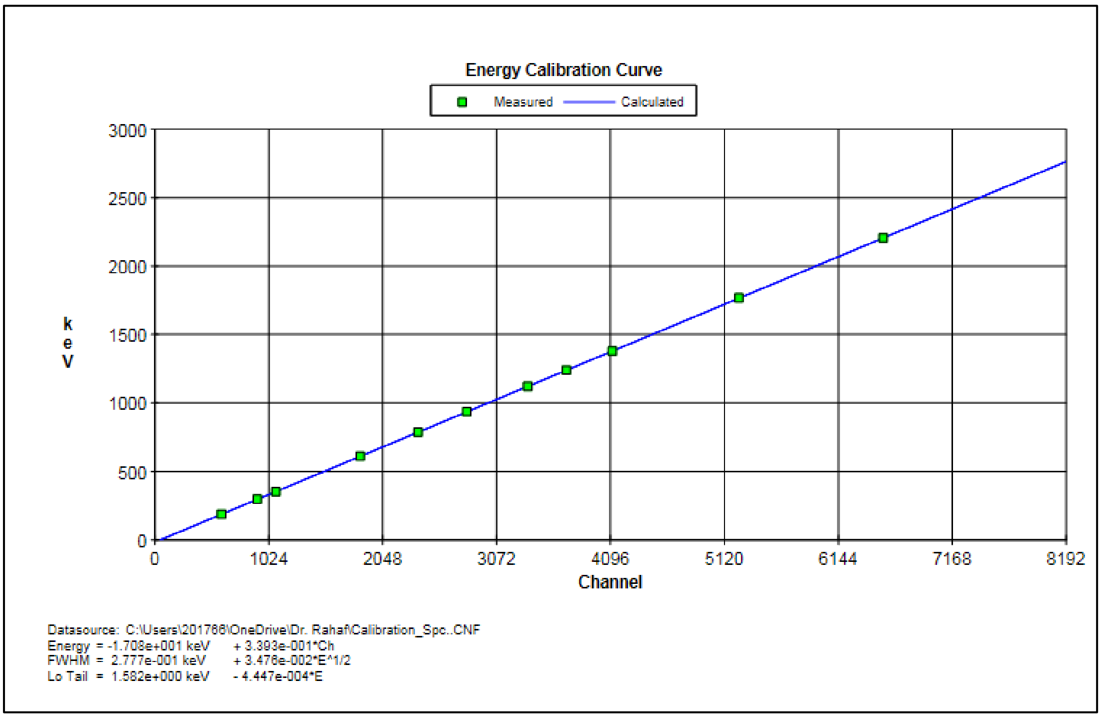


Figure 9: Energy calibration

2.4.5.1.1 Peak Width Calibration - FWHM Calibration

FWHM represents the full width half maximum. FWHM calibration is part of the energy calibration, and it could not be done without an energy calibration. It has units of KeV. It can also be in units of channels since channels are proportional to energy. This calibration needs sufficient counts in the peak for good peak shape. The FWHM calibration correlates peak width to peak energy (Knoll, 1999). The general FWHM equation:

$$y = a\,x^2 + m\,x + \ b \qquad (Eq.12)$$

Where, the calibration graph includes 8192 channels for about 2000 KeV. The Slope m = 0.000981 channel width per channel. The y-intercept b = 4.1178 channel's width and quadratic a=-5.651e-8 channel width per channel. Once the energy calibration and

FWHM calibration is done, the x-axis (channels) it will be evaluated in units of energy (KeV), and the peak width will be assessed in units of Kev (Knoll, 1999).

2.4.5.2 Efficiency Calibration

The next step is to identify the nuclides present in the known sample. The spectrum's y-axis is "counts" which will be translated to the activity of nuclides. Thus, we should define the relationship between the counts and disintegrations. The relationship between counts and disintegrations is defined as the generic counting efficiency (Kocher, 1981).

$$\varepsilon = \frac{c}{d} = €_{\gamma} \times abn_{\gamma} \qquad (Eq. 13)$$

Where ε is generic counting efficiency for a detector. The number of counts registered by the detector per each disintegration of a nuclide, counts per disintegration, or (cps/dps), c is the number of counts registered by a detector (counts) and d is the number of atomic undergoing decay or number of atomic disintegrations of a nuclide (disintegrations). $€_{\gamma}$ is the detector's gamma efficiency which represents the number of fill energy counts registered by the detector on the spectrum from each gamma of particular energy emitted by the source. abn_{γ} is the gamma ray abundance which represents the number of gamma e-ray of one energy emitted per disintegration of an atom (gamma intensity) (ANSI, 1989).

In practice, we do not calculate generic counting efficiency because the gamma-ray abundances are in the library, and the detector's gamma efficiency is calculated separately. Mathematically, calculating nuclide activity from peak area is calculated by the following equation (Knoll, 1999):

$$A = \frac{C}{V \times T \times abn_{\gamma} \times €_{\gamma} \times D} \qquad (Eq. 14)$$

Where A is the activity if the nuclide $BqKg^{-1}$, C is net peak area or counts, V is sample mass or volume in Kg, T is count time in seconds, abn_{γ} is gamma-ray abundance which represent gammas emitted per nuclide disintegration (γ/dis), $€_{\gamma}$ is detector's gamma efficiency (counts/ γ), and D is decay from time of sampling (Knoll, 1999) .

2.4.5.2.1 Efficiency Calibration Software "LABSOCS"

LabSOCS is a software which calculates efficiency for samples by integrating the response over the volume of the given source. There is much some other software which has the same technique. This software was used as a friendly tool to calculate accurate efficiency calibration for a broad range of geometries samples with no radioactive source need; this will eliminate the cost of purchasing radioactive source and radioactive waste disposal. The calibration is accurate at any angle from the detector within a few percent; the range is valid from zero distance up to 500 meters and from 50 KeV up to 7000 KeV (NRC, 1981).

This tool operates on any size or type of germanium detector. It is accustomed to laboratory applications where multiple shaped containers are used repetitively. Also, it includes predefined geometry templates for familiar laboratory container shapes, a library of conventional containers, and tools for the user to create new containers (Debertin and Helmer, 1988).

It is a perfect tool to adapt sample characteristics such as density, container and wall thickness. The sample can be point-like up to 500 meters in size. The system includes a library of conventional matrix/absorber materials and tools to create new materials. Also, custom templates can be provided to meet particular application needs.Results processed speedily, and the resulting calibrations may be stored, recalled, and used just like those generated by the traditional calibration (Ryde, 1995).

In the current study, the LABSOCS mathematical efficiency tool was used for determining energy efficiency curves on a weekly basis. To have a precise calculation of efficiency for the sample, the geometry composer in LabSOCS was used to define the sample geometries for HPGe gamma spectroscopy analysis (Erdtman & Soykab, 1979). The Modified template was used created to define sample geometries. The geometry was demarcated by stipulating the size and shape of the sample and its container, the materials from which they were made and the type of the detector that will use for the analysis of the samples.

The soil samples analyzed were different in density, and there was some variance in the height of the samples in Marinelli Beakers. So, specific correction applied and sixteen different calibration curves created.Four different heights identified (10.4 , 9.5, 8.4 and 6.7 cm) with four different densities (1.2, 1.4, 1.6 and 1.8 (gm/cm^3). The calibrations curves are included in the appendix.

2.4.6 Marinelli Beaker Specifications

Each soil sample was counted for 20 hours. Samples were kept in Marinelli Beakers. The Marinelli Beaker Model 132G-E was used in the current study.

The specifications of the beaker identified given in Table 3 and showed in Figure 10.

Table 3: Marinelli beaker specifications

Marinelli Beaker Details	**Dimensions/ Details**
Maximum Height	13.0 cm (5.1 inches)
Maximum Diameter	17.0 cm (6.7 inches)
Minimum Well Diameter	8.4 cm (3.32 inches)
Height of the Well	7.1 cm (2.8 inches)
Freeboard Volume @ 1”	1.1 liters
End Cap Diameter	8.3 cm (3.25 inches)
Beaker Material	Polypropylene
Lid Material	Polyethylene (L-5)

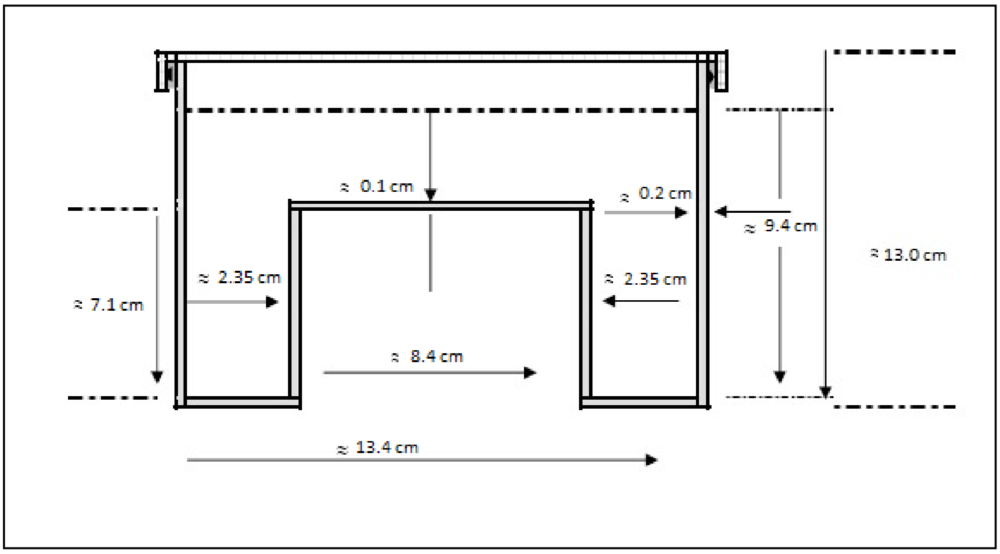


Figure 10: Marinelli beaker dimensions

2.4.7 Standard Source

The source is needed for efficiency calibration. Energies of the photons, nuclides used and the activity of the nuclides must be known. Each source has its certificate. The certificate contains information about the nuclides types, half-lives, activity, uncertainty, mass, density volume, reference data and time (Kocher, 1981).

Energy calibration was conducted in the current study by using ^{226}Ra at 11 energy points (186.21, 295.22, 351.93, 609.31, 785.96, 934.06, 1120.29, 1238.11, 1377.67, 1764.49, and 2204.21 KeV) (Knoll, 1999; Erdtman & Soykab, 1979). The calibration source certificate attached in the appendix.

2.5 ICP-OES Analytical Methods

2.5.1 Sample Preparation

All samples were dried at a specific temperature (80°C) for 24 hours, and then each was sieved to 1 mm to remove any exotic materials (Hamidalddin, 2014). The CEM Mars 5 microwave digestion system, represented in Figure 11, was used to prepare the samples to be analyzed by the ICP-OES.

Figure 11: The CEM mars 5 microwave digestion system

The digestion procedure was according to the recommendation given in the USEPA method 3015A guidelines (USEPA, 1998). From each soil sample a 0.5 mg sample that was taken weighted into the microwave digestion vessels. Concentrated nitric acid (HNO_3) and 2 ml of hydrochloric acid (HCL) were added to the vessels to destroy any organic matter and to solubilize recoverable elements. Each vessel was then capped and placed carefully into the microwave digestion system. Figure 12 shows the vessel holder. Table 4 represents the settings used for the microwave digestion of the soil samples for each of the 12 vessels.

Figure 12: Vessel holder

Table 4: Settings of the microwave digestion of soil samples

Conditions	Settings
Power	1.2 KW
Plasma gas flow	15 L /min
Auxiliary gas flow	1.5 L/min
Spray chamber type	Glass cyclonic (single pass)
Nebulizer flow	0.75 L/min
Nebulizer type	Seaspray
Pump rate	15 rpm
Sample uptake delay	30 sec.
Replicate read time (S)	10 sec.
Number of replicates	2
Rinse Time	10 sec.
Instrument stabilization delay	15 sec.

2.5.2 Analytical Method

A Varian ICP-OES, model 710-ES with simultaneous axially viewed plasma and full PC control of instrument settings and compatible accessories was used to determine the dominant minerals in the soil samples. The study determined the availability of 22 soil elements, including Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, V, and Zn. The soil samples were collected from agricultural farms located all over the UAE. The ICP-OES instrument operating parameters are illustrated in Table 5.

Table 5: ICP-OES instrument operating parameters

Max. Power (W)	**% Power**	**Ramp (min)**	**Temp. (°C)**	**Hold (min)**
1600	100	20:00	220	15:00

As a summary of the analytical method used, a portion of homogeneous soil samples was precisely weighed and treated with acids to destroy all organic matter and to solubilize the recoverable elements. After cooling, each sample was made up to the volume using deionized water and filtered.

The sample solution was then aspirated through a nebulizer, and the resulting aerosol was transported to the plasma torch where excitation occurs. Emission spectra specific for each element were produced by a radio-frequency inductively coupled plasma. A grating spectrometer dispersed all spectra, and intensities of the line spectra were checked at definite wavelengths by a charged coupled detector.

To correct a blank signal or a matrix effect, a fitted background correction was used. In cases of line broadening, a background correction measurement was not required to avoid degrading the analytical result (Robinson and Calderon, 2010).

The general outline of the whole study process is illustrated in Figure 13. The process started with soil sample location data, to sample data collection, to analysis, ending with results, discussion, and GIS mapping.

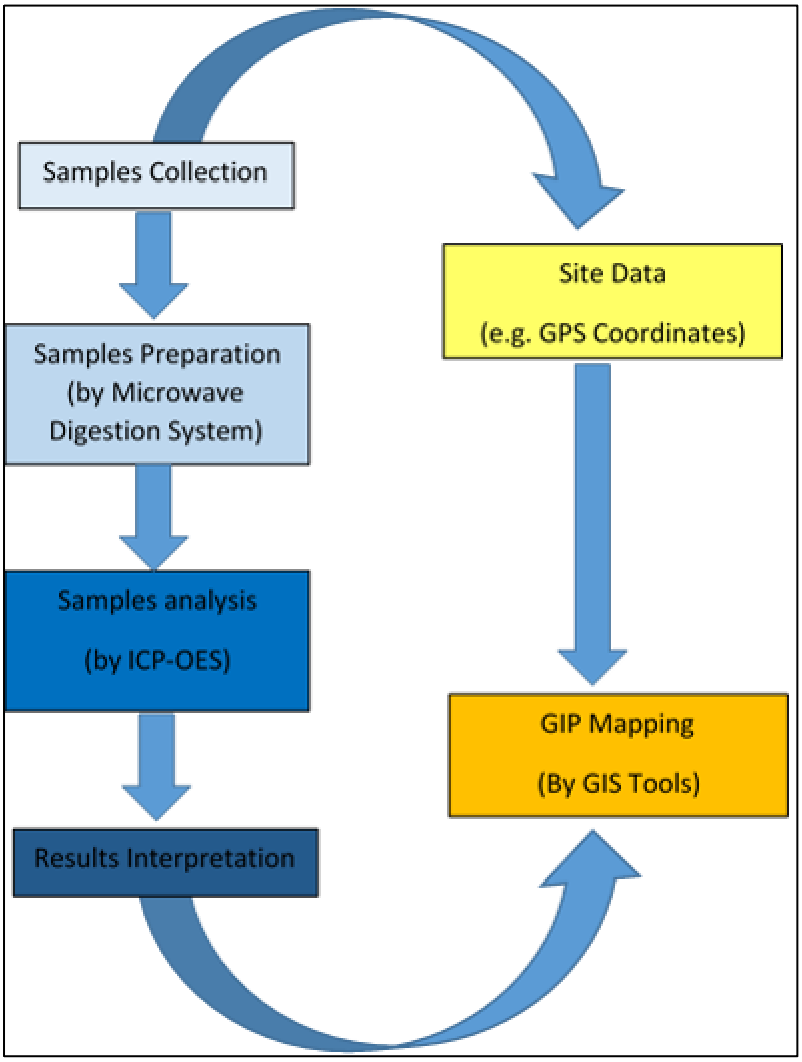


Figure 13: Analytical method diagram

2.5.3 Reagents and Materials

All acids used in the standard preparation activity were high purity grade. All samples were concentrated with hydrochloric acid and nitric acid. The deionized water of Millipore integral 5 or equivalent and argon gas (99.999 purity or more) were added. The volumetric pipettes (5, 10, 20 and 25 ml) were calibrated. Volumetric flasks of class A (100 and 500 ml) were used. The Standard solutions (1000 mg/l) included Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, V, and Zn.

These solutions were used with a mixed calibration check standard solution of 100 µg/ml.

2.5.4 Theoretical Calculation

For each soil sample, the mean concentration results of each of the 22 determined minerals were taken from the average concentrations of 2 replicates multiplied by the dilution factor (DF). The DF was measured from the final makeup volume (MV) of the digested sample divided by the weight of the sample (W), (Eq. 15).

For each element in each sample, the standard deviation (SD) was calculated according to Equation 16 (Eq. 16). In the equation, R_1 and R_2 refer to the total replicate in sample number 1 and 2, respectively, while R relates to the number of replicates. The SD results were a useful tool to compare the elementary levels of the two injected replicates of the same soil sample. However, each soil sample has a different elementary composition according to the geographical reference. Thus the final SD results for the concentration of each element were not a useful tool in this case. Other statistical tools were used (e.g., minimum, maximum and median):

$$\mathrm{DF} = \frac{MV}{W} \qquad \text{(Eq. 15)}$$

$$SD = \sqrt{\frac{(R_1 - Mean)^2 + (R_2 - Mean)^2}{R}} \qquad \text{(Eq. 16)}$$

2.5.5 Calibration Standards

Building the calibration curve was done using five concentrations of the calibration standards (0.01, 0.1, 1.0 to 10, 10, 50). Further details about constructing the calibration standards are illustrated in Table 6.

Table 6: The calibration standards utilized to draw the calibration curve

Standard No.	Concentration of the standard (μg/ml)	Volume taken (ml)	Volume made up (ml)	Concentration of calibration standard (μg/ml)	Shelf life of standard (Months)
1	0.10	10	100	0.01 (optional)	Prepare fresh
2	1.0	10	100	0.10	Prepare fresh
3	10	10	100	1.0	1
4	50	20	100	10	6
5	50	-	-	50	6

The calibration blank (CB) was prepared by diluting 1 ml of concentrated nitric acid (HNO_3) in 100 ml deionized water. Sufficient quantities were ready to flush the system between standards and samples. The reagent blank (RB) contained the same volumes of all reagents used in the processing of the samples and the same acid concentration in the final solution.

The ICP Expert software was used to build the calibration curves for each element, which allowed selecting the analyte elements with corresponding wavelengths, sensitivities, interferences and linear regression equation. Checking calibration curves was accomplished by calibration mixed standards. The analysis of trace elements (e.g., Sr) was carried out within the linear range, through diluting the sample to fall within the calibration range (Robinson and Calderon, 2010).

Chapter 3: Results

3.1 The Primordial Radionuclides Concentrations of the Agricultural Soil of the UAE and the radiological parameters

The mean specific activity concentration for the soil samples in the present study have been calculated and summarized in Table 7.

Table 7: The mean specific activity concentration and radiological effects values in the agricultural soil of the UAE

Mean Specific Activity Concentration (Bq/Kg)		
^{226}Ra	^{232}Th	^{40}K
15.34 ± 2.80	4.18 ± 1.40	310.74 ± 63.90

The values of the radiological parameters for the soil samples in the present Study have been calculated and summarized in Table 8.

Table 8: Radiological parameters for the soil samples

Radium Equivalent Activity Index (Bq/Kg)	Absorbed Dose Rate (nGy/h)	Outdoor annual effective dose equivalent (mSv/y)	Indoor annual effective dose equivalent (mSv/y)	Total Annual Effective Dose Equivalent (mSv/y)	External Hazard Index	Internal Hazard Index	Gamma Level Index
45.24 ± 5.35	22.68 ± 1.40	0.03	0.19	0.21	0.12	0.16	0.35

The specific activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the UAE agricultural soil are represented in Figures (14, 15, and 16).

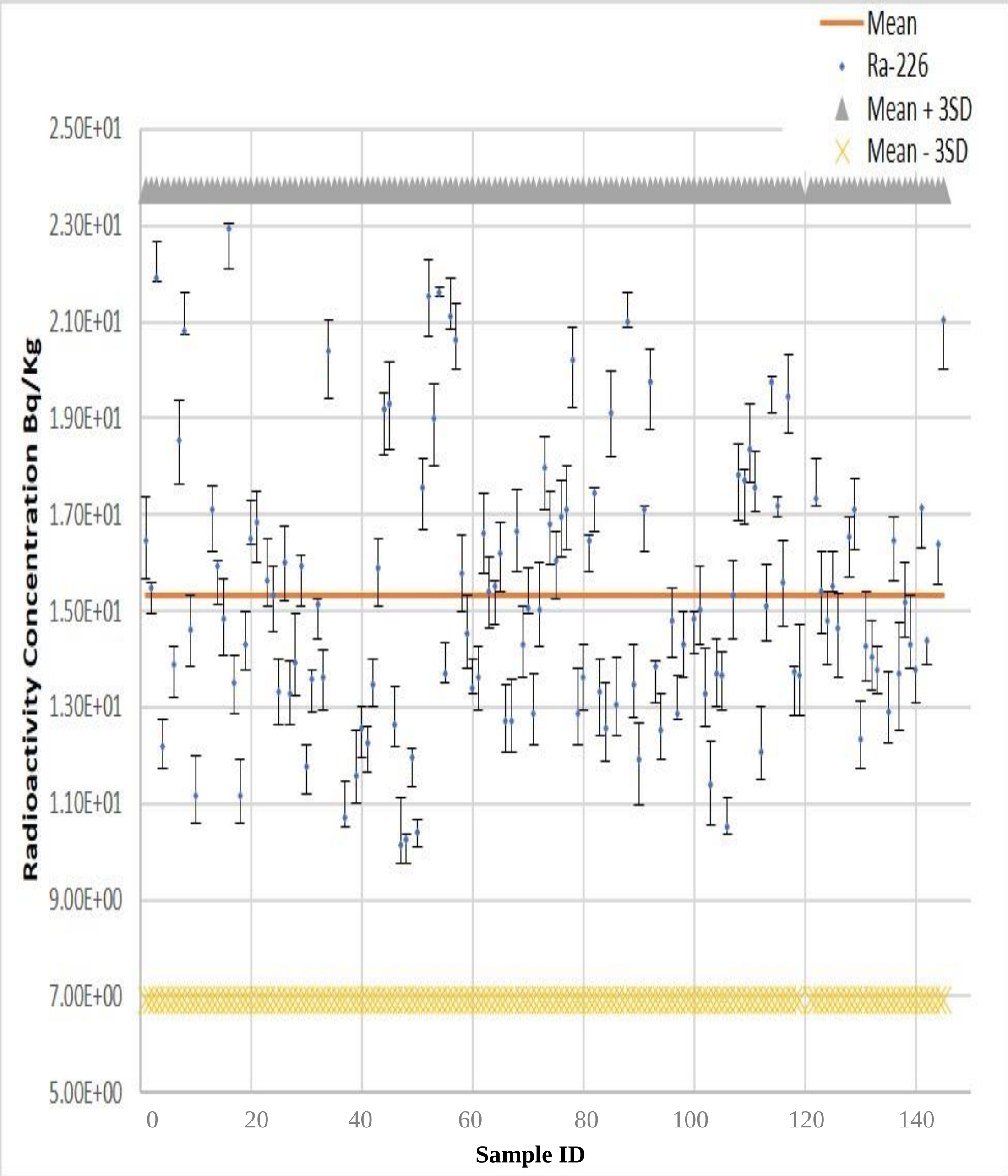


Figure 14: The specific activity concentrations of ^{226}Ra

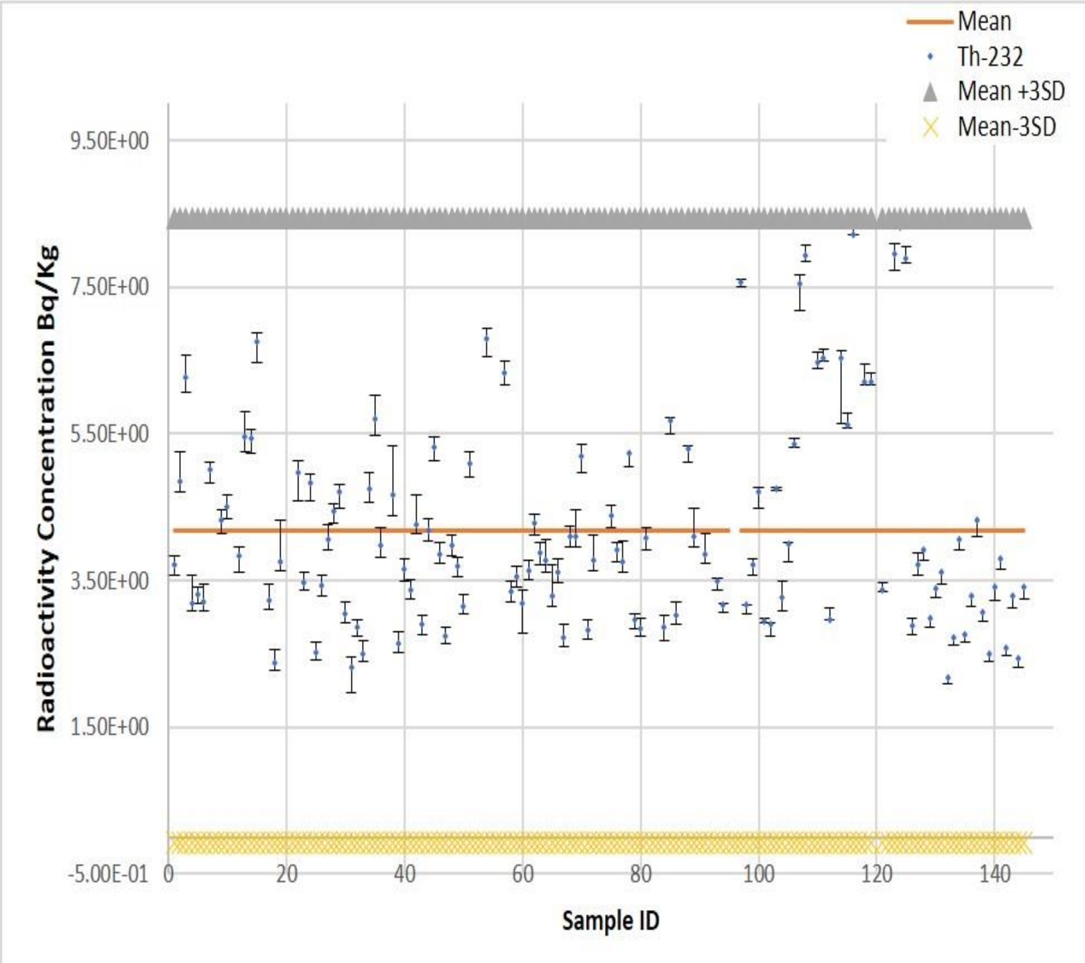


Figure 15: The specific activity concentrations of ^{232}Th

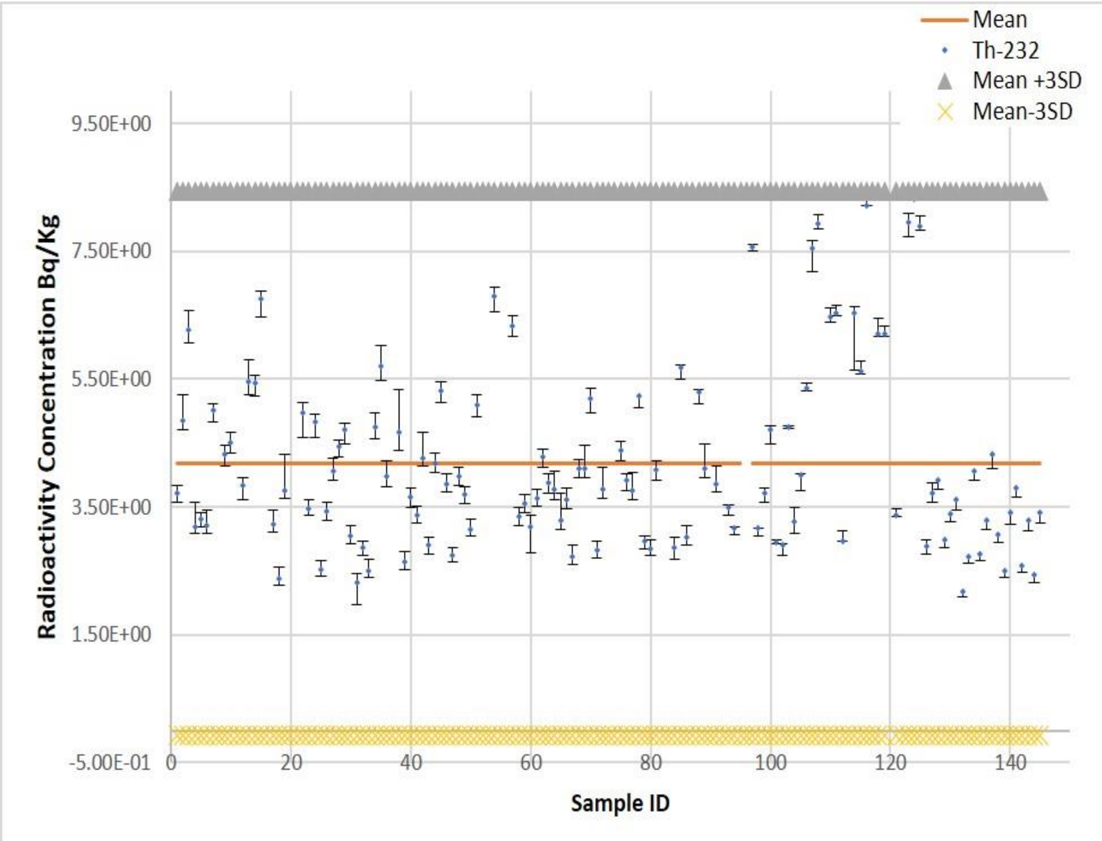


Figure 16: The specific activity concentrations of ^{40}K

The results indicate that there is a positive correlation between ^{226}Ra vs. ^{40}K and ^{226}Ra vs. ^{232}Th and ^{232}Th vs. ^{40}K activities in the samples (Figure 17,18 & 19).

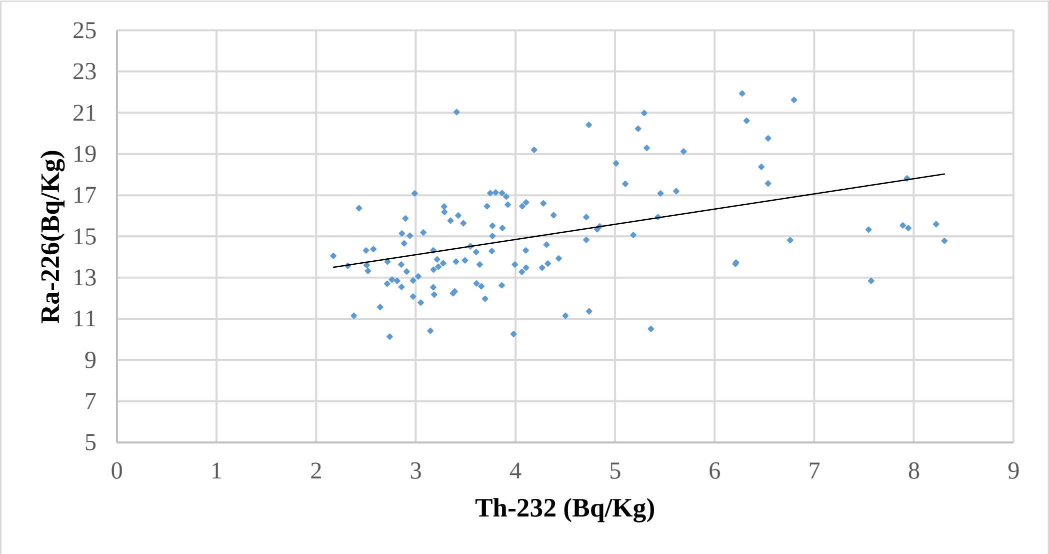


Figure 17: Correlation between ^{226}Ra vs. ^{40}Th

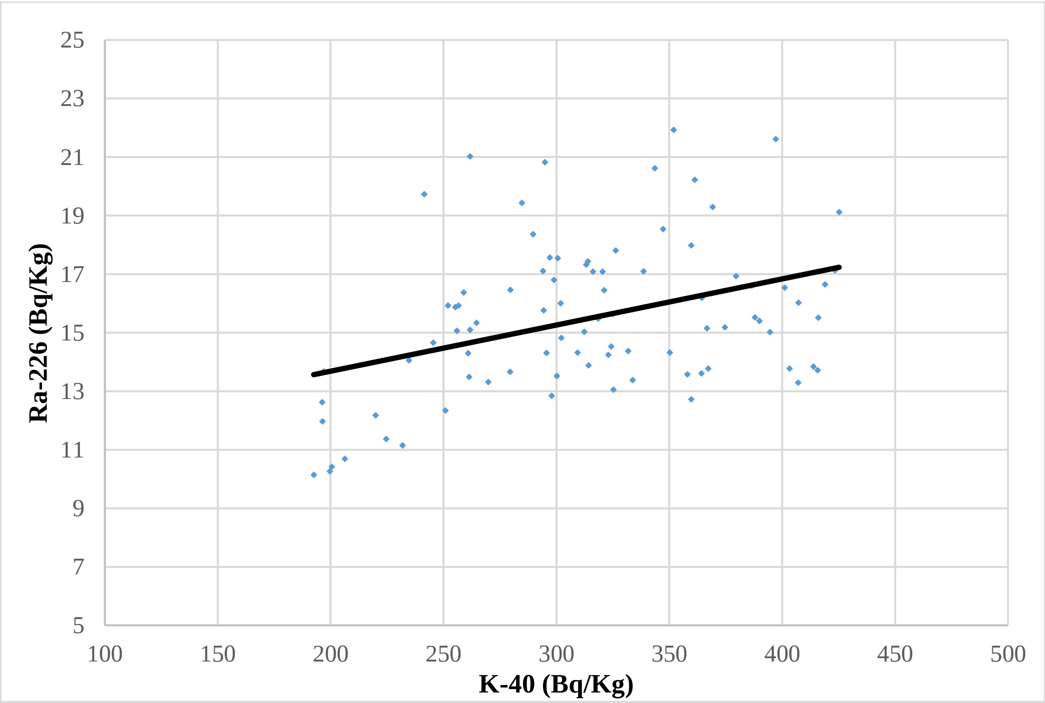


Figure 18: Correlation between ^{226}Ra vs. ^{40}K

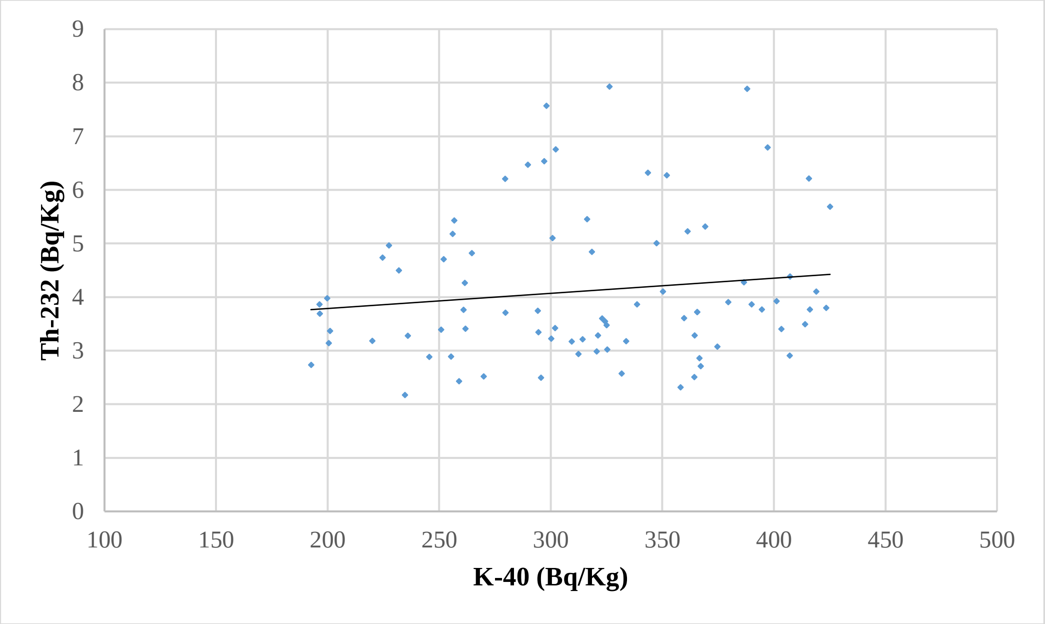


Figure 19: Correlation between ^{232}Th vs. ^{40}K

Figure 17 shows a relatively poor positive correlation between ^{226}Ra and ^{232}Th, with a Pearson correlation coefficient of 0.232 with a significant probability level of 0.01 (2-tailed). Figure 18 Shows a strong positive correlation between ^{226}Ra and ^{40}K, with a Pearson correlation coefficient, is 0.949 with a significant probability level of 0.007. Figure 19 demonstrates the correlation between ^{232}Th and ^{40}K. This show a strong positive Pearson correlation coefficient of 0.809 with a significant probability level of 0.025 (2-tailed). In general, the positive correlation is a good indicator of the activity concentration of one radionuclide with the other radionuclide (Dhawal et al., 2014).

3.2 The Anthropogenic Radionuclides Concentration of Agricultural Soil of the UAE

All the soil samples were analyzed to detect the anthropogenic radionuclides. Only 68 soil samples did show a low amount of ^{37}Cs. The determination of the presence of anthropogenic radionuclide (^{137}Cs) from the soil samples is 0.75 ± 0.01 Bq/Kg as illustrated in Figure 20. The measured activity concentration ranged from 0.2-3 Bq/Kg.

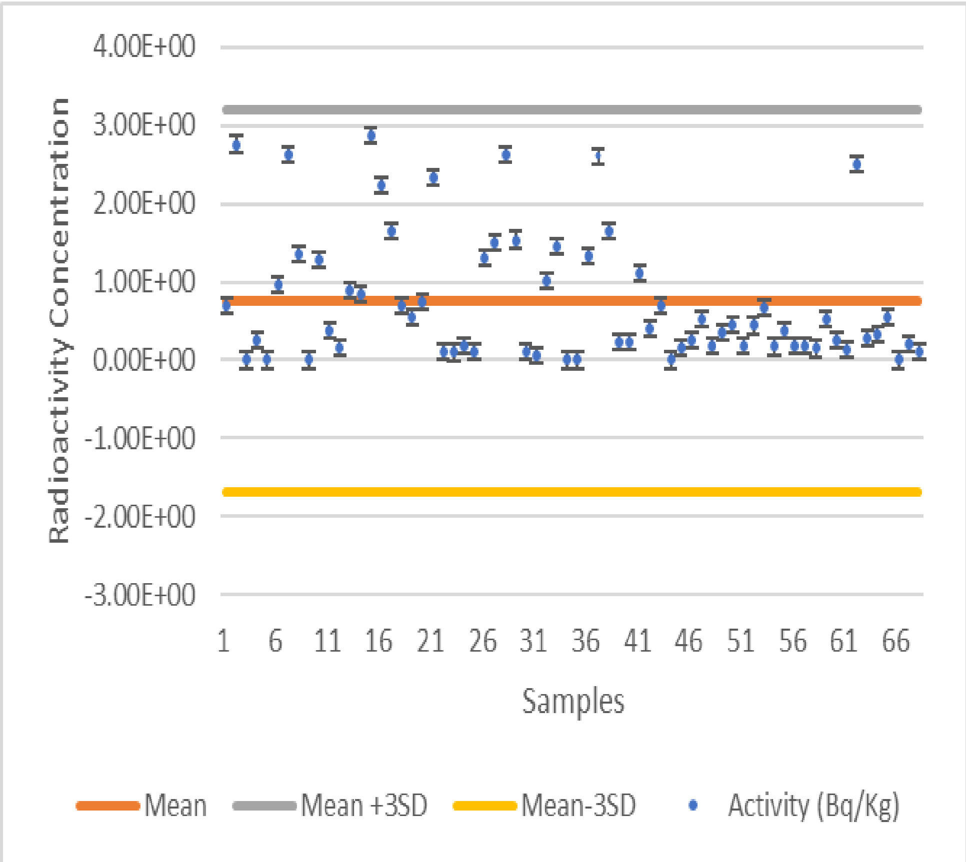


Figure 20: The specific activity concentrations of ^{137}Cs

3.3 The Mean Concentration of Minerals and Trace Metals of the UAE Agricultural Soil

The determination of the presence of 22 minerals from 100 soil samples is illustrated in Table 9.

Table 9: Concentrations of the minerals and heavy metals of the UAE agricultural soil samples using ICP-OES (n=99)

Element	Total Mean Concentration (ppm)	Minimum Concentration (ppm)	25th Percentile	50th Percentile (Median)	75th Percentile	Maximum Concentration (ppm)
Al	8,539.7	3,217.5	4,651.2	6,364.5	9,706.9	34,912.6
As	2.17	<0.0009	2.42	3.39	3.39	7.33
B	47.68	13.2	29.7	38.7	51.7	971.6
Ca	86,264.5	23,661.0	46,613.3	81,820.6	94,064.5	163,189.0
Cd	1.35	0.46	0.80	1.48	3.13	4.84
Co	10.30	1.71	3.08	5.79	16.36	55.50
Cr	111.20	20.89	35.66	61.42	114.62	1,140.82
Cu	14.32	3.14	6.38	8.75	14.67	1,222.50
Fe	9,839.80	3,002.9	4,396.0	6,595.7	13,819.8	31,489.0
K	2,026.80	864.4	1,313.1	1,670.5	2,344.6	6,425.6
Mg	26,688.30	3,032.2	8,716.8	13,939.9	30,147.8	145,394.0
Mn	237.40	66.5	143.9	193.0	307.9	629.6
Mo	0.02	<0.018	<0.018	<0.018	<0.018	<0.018
Na	470.40	207.2	487.6	867.9	1,523.4	9,314.9
Ni	160.90	8.4	26.3	73.5	171.3	1,010.9
P	450.60	56.5	197.6	326.3	539.9	3,507.2
Pb	4.25	< 0.01	2.65	3.47	4.43	25.19
S	2,393.50	129.8	364.9	511.2	1278.8	26,812.8
Si	795.68	241.4	618.1	764.5	971.4	1,488.9
Sr	593.70	149.3	395.6	501.8	629.7	1,540.8
V	20.90	9.7	14.6	18.8	25.6	52.2
Zn	24.90	5.67	11.3	19.1	31.0	218.1

3.4 GIS Mapping

Agricultural soil samples activity results for the radionuclides of interest and massive elements were geographically mapped according to the location and the magnitude of the activity. The Geographic Information System (GIS) was used to produce state-of-the-art radiological-maps and the elemental fingerprint- maps for identifying both sampling locations and the radioactivity concentration for the selected research radioisotopes and elements. The Maps are included in the Appendix.

Chapter 4: Discussion

4.1 Highlights on Possible Solutions and Future Perspectives

Since climate change implications have no geographical boundaries, national, regional and cross-regional collaboration and coordination, in particular through conducting integrated research projects, are necessary to achieve the sustainable development, and to safeguarding food security for all developing nations (Hermwille et al., 2015; Ajaj et al., 2015).

Indeed, it is crucial to divide the food production system into main food production sectors and to decide the significant roles and responsibilities of each sector on facing climate change, while ensuring the sustainable development and food security. The primary food production sectors could be summarized as four key sectors, including decision-makers, researchers, and scientists, farmers, and households. Undoubtedly, specifying clear duties for each area would provide an integrated overview of the necessary framework, as illustrated in Figure 21.

As a result, this will guarantee a sustainable food production system locally and globally (Shahin et al., 2015a).

- Decision Makers

Policy makers are mainly responsible for developing legislation and policies that can significantly reduce climate change implications, as required for Paris agreement implementation. Also, policymakers are responsible for managing and assessing the agricultural systems in conjunction with climate change impacts on the agricultural productivity. The decision makers sector has the most substantial weight, compare to the other food production sectors, regarding the power and economic impacts of their decisions, at the national and international levels, to cope with climate change (Shahin et al., 2015a).

Also, decision makers play a fundamental role in developing sustainable agricultural systems and strategic plans, which mainly aim to securely increase the agricultural crop productivity and efficiency, while maintaining and conserving the natural ecosystem.

Besides, decision makers review and adopt the best international practices related to reducing the factors that contribute to climate change and global warming. This could be done through establishing restricted permissible levels for the industrial activities to emit GHG, and particularly the CO_2 emissions. Also, implementation of the Environmental Impact Assessment Studies (EIA) has to be more restricted and periodically inspected. Furthermore, advancements in carbon recycling and capturing are recommended to reduce the implications of climate change. Moreover, the establishment of energy efficient systems play a significant role in reducing the amounts of burning fossil fuels, and consequently in reducing the CO_2 emissions.

Development of the Unified Water Sector Strategy and Implementation Plan for the Gulf Corporation Council of the Arab Member States (2015-2035), conducted on 10th of March 2015 in Dubai, has clearly stated its vision, which is "By 2050 the GCC countries have achieved sustainable, efficient, equitable and secure water sector contributing and emphasized to their sustainable socio-economic development". It has significantly mentioned that climate change and global warming is a real threat to the water resources in the GCC countries, including the UAE. Climate change was stated as the top five cross-cutting issues, which are facing all the GCC countries. That is why it has to be considered in the GCC water strategic plans and conservation approaches.

Besides, it has been emphasized that water governance be highly required; to have full integral control on the limited water resources (Shahin and Salem, 2013).

It is worth to be mentioned that, the water use in a country like the UAE, has to be based on priority use, such as food production purposes and medicinal and therapeutic purposes (Shahin and Salem, 2014a; Shahin and Salem 2015b). On the other hand, forage cultivation, which is the cheapest form of crops, has to be avoided. It is economically efficient to import such crops along the other crops, which consume high amounts of water, from other countries, that are rich in precipitation patterns, instead of cultivating them through using a costly water supply (EAD, 2009).

The establishment of Barakah, which will employ the nuclear power to generate electricity, is a significant step toward minimizing the UAE carbon footprint. Barakah is sited in the western region of Abu Dhabi, and it is expected to be functional in 2017. This initiative supposed to minimize the pressure on burning fossil fuels and thus on carbon emissions through generating energy for green purposes (Asif, 2016).

- Researchers and Scientists

Researchers and scientists are the second sectors, which works beside the decision makers, and conduct research projects seeking solutions to the emerging problems (e.g., crop tolerance to emerging pests and diseases). Such research projects must have an integrated point of view, involving the governmental organizations and the non-governmental ones (NGOs), and working in parallel and coordination with the national and the international scope. Also, researchers are responsible for figuring out the crops that are sensitive to climate change, to minimize dependency on such cultivation. On the other hand, they are responsible for recommending plants that can tolerate weather modifications. Particular interest has to be given to projects that are seeking and predicting for crops, which can withstand both environmental extremes, including very high temperatures (Shahin et al., 2015a).

Indeed, the international and local organizations are moving toward investing more efforts and budgets in supporting the research related to global warming, climate change, and food security issues. One of the great examples that, the international atomic energy agency (IAEA) announced in 2015 is many project proposals were related to diet and agriculture. It is has invited all interested institutions to submit research proposals for such hot topics. It worth mentioning that, the IAEA research topics include; land management for climate-smart agriculture, food irradiation applications through using novel radiation technologies and mutation induction for better adaptation to climate change.

In the UAE, the UAE University (UAEU) is much interested in supporting projects related to the influence of global warming and climate change on the agricultural productivity and food security. Specific studies related to the effect of UV-B radiation are currently established, such as, examining the effect of UV-B on dates palm (Phoenix dactylifera), which produce the date fruit, that is one of the top crops in the country. Besides, another study is currently under preparation and conducting level, related to exploring the influence of UV-B radiation on some potential UAE's native plant species.

Enormous efforts and research collaborations have to be established; to investigate all the possible future scenarios related to influence of high UV-B radiation on the top national agricultural commodities. This is very essential; to recommend cultivating the adapted varieties, that can best cope with the challenges of climate change and global warming (Ajaj et al., 2015a, 2015b; Ajaj and Salem 2015).

It is worth mentioning that, a leading research is currently conducted in the UAE, to create the first UAE map for agricultural soil radioactivity. This study is currently in the final stage, and will eventually provide a reference study for the UAE soil radioactivity before Barakah starts generating the nuclear power.

- Farmers

Farmers are another sector in the food system that has a significant duty to follow the best farming practices, in coordination with the researcher's sectors, which guarantee the maximum feasible agricultural productivity to feed the growing populations in conjunction with climate change. Besides, they are responsible for following the adaptation and mitigation practices and policies that are legislated by the decision makers (Shahin et al., 2015a).

In the UAE, the nationality of the farmers is mostly from eastern Asia countries (e.g., India, Pakistan, Bangladesh, etc). There are major differences between the environmental conditions of the different producers' countries and the UAE environmental conditions. Thus, the farmers should be enrolled in training and awareness programs, to make them familiar with the UAE renewable resources, especially the concerns related to freshwater scarcity and the necessity to reduce carbon and greenhouse gasses.

- Households

The last sector consists of the houses and the regular community members, which are following laws, decided by the policy makers, on climate change adaptation and carbon emission mitigation practices (Shahin et al., 2015a).

As a part of the UAE society, reduce food loss and wastage is an important issue. Individuals should work on maintaining and reshaping their lifestyles, moving towards green daily habits; to reduce the unnecessary food consumptions and losses.

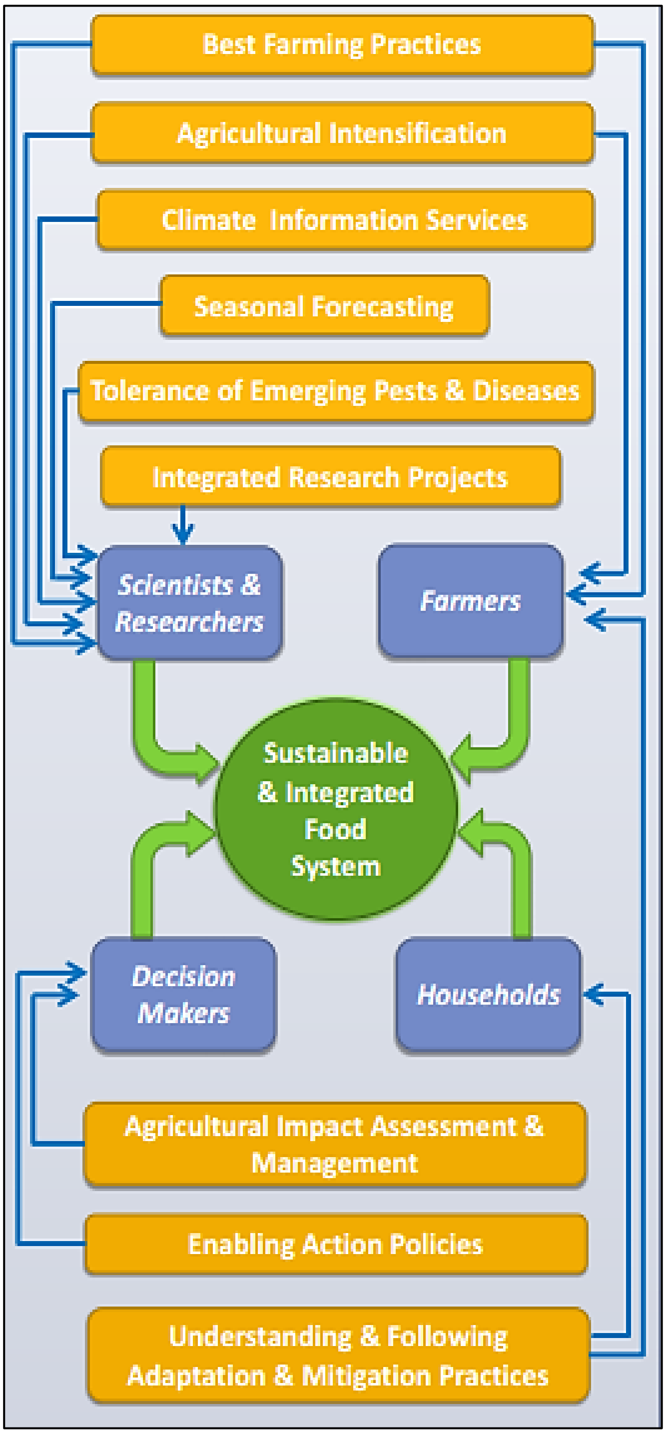


Figure 21: Roles and responsibilities in the food production system

4.2 The Primordial and Anthropogenic Radionuclides Concentrations of the Agricultural Soil of the UAE and the Radiological Parameters

The average activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K in the study location calculated using Equation 1 are 15.34 ± 2.80, 4.18 ± 1.4 and 310.74 ± 63.90

respectively. Thus, the average activity concentrations of the study radionuclides are lower than the global revised average values of 30, 35 and 420 $BqKg^{-1}$, respectively. The average activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K are represented as a radiological map in Figure 22, 23 and 24.

Radium equivalent activity (Ra_{eq}) calculated using Equation 2 is 45.24 ± 5.35 $BqKg^{-1}$ which is much less than the threshold value of 370 $BqKg^{-1}$. The absorbed dose rate (D_r) calculated using Equation 3 is 22.68 ± 1.40 $nGyh^{-1}$ which is lower than the world average value of 60 $nGyh^{-1}$ given by the UNSCEAR (2000). The outdoor annual effective dose rates calculated by Equation 4 is 0.03 $mSvy^{-1}$ which is lower than the world average value for outdoor annual effective dose for normal radiation background regions which is 0.07 $mSvy^{-1}$.The indoor annual effective dose rates is calculated by Equation 5 is 0.19 $mSvy^{-1}$ which is lower than the world average value for outdoor annual effective dose for normal radiation background regions that is 0.34 $mSvy^{-1}$.The total Annual Effective Dose Equivalent (D_{eff}) calculated by Equation 6 is 0.21 $mSvy^{-1}$ which is lower than the 0.41 $mSvy^{-1}$ recommended by the UNSCEAR (2000). The annual absorbed effective dose distribution is represented as a radiological map in Figure 25. The map represents the annual effective dose equivalent distribution from the soil samples in the present study before the operation of Barakah Nuclear Power Plant. The nuclear reactors are planned to operate between 2017 and 2020 (Ketait et al., 2014).

The SPSS Statistics software (2015 version) was used for statistical analysis. The One-Sample T-Test method used to test the hypothesis and the Null hypothesis (Ho) is accepted. Table 12 in the appendix shows the comparison of the activity concentration reported around the world. It is found that the measured activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in this study are less than most of the reported values for most of other countries in the world.

4.3 The Mean Concentration of Minerals and Trace Metals of the UAE Agricultural Soil

The soil is a vital component of life. The healthy agricultural soil is essential for the safeguard of the environment. According to the UAE Ministry of Environment and Water (MOEW) and Environmental Agency – Abu Dhabi (EAD), the soil of the UAE is considered as one of the most challenging soils around the world. It is very fragile, sensitive and very slowly renewable. A healthy soil includes specific amounts of elements, which can guarantee growing healthy crops and the best yields.

4.3.1 Aluminum (Al) Fingerprint

Aluminum (Al) is not a plant nutrient element and can be extremely toxic to plants at elevated concentration levels. For example, it can adversely affect plant root growth and lower the capability of the plant to absorb phosphorous (P). Al sensitivity depends on the plant variety. Some plants can adapt to moderate levels of Al (e.g., blueberries, strawberries) while the others are susceptible (e.g., lettuce, carrots). Al toxicity is a concern when the soil pH is acidic (pH below 5.5), and not a concern in the sodic soils. The reason for this is when the soil pH is acidic the Al solubility, and plant extractability is increased. The reverse is true when the soil is sodic (Spargo et al., 2013).

In the UAE, the Al concentration ranges from 3,218 to 34,913 ppm, with a total mean concentration of 8,540 ppm, as shown in Table 4. The Al fingerprint of the UAE agricultural soil is represented in Figure 26. The Al concentration results from the study significantly varied according to the sample topographic location. The area of the northern Emirates (e.g. Kalba and Khor Fakkan) showed the highest levels (>17,564 ppm). However, since the country has sodic soil (pH >7), especially in the northern Emirates (range from 7.0 to 8.5) (EAD, 2012), the Al availability in soluble form is restricted, and Al toxicity is not a concern.

4.3.2 Arsenic (As) Fingerprint

Arsenic (As) is a potentially toxic element. As is a heavy metal that exists naturally at low levels in the soil. Worldwide, As background levels in soil are measured a 5 mg/Kg, depending on the soil origin. In the environment, As exists in various forms, organically as monomethyl arsenic acid and inorganically as arsenate (Heikens, 2006). According to Dubai Municipality (2003), the land contamination indicator level for As is 50 ppm.

Results of the total mean As (around 2.17 ppm) in the agricultural soils of the UAE showed lower levels compare to the threshold levels (5 ppm) (Tóth et al., 2016). The maximum recorded results were registered in Ramah in Al Ain area. Distribution levels of As in the UAE agricultural soils is illustrated in Figure 27. The results indicate that no As contamination is recorded.

4.3.3 Boron (B) Fingerprint

Boron (B) is a soil micronutrient that may limit plant growth if available in low levels below specified limits. On the other hand, its availability at high concentrations can be toxic (Horneck et al., 2011). B sensitivity depends upon the plant species (Abreu et al., 2005)which is why stating B permissible limits in agricultural soil is a hard task. B deficiency is most likely in arid regions with high sodic nature and low organic matter content. On the other hand, B toxicity is also probably in sandy soils, which are exposed to heavy fertilization (Sillanpää, 1972). According to the results of Sillanpää (1972), work published by Food and Agriculture Organization (FAO), the maximum permissible limits for B are varied from one plant species to another, generally not exceeding concentrations greater than100 ppm.

In the UAE, B screening has shown results that range from 13.2 to 971.6 ppm, with a total mean concentration of 48 ppm. The minimum results were recorded in Abu Dhabi city while the maximum results were registered in the western region of the Abu Dhabi Emirate (e.g., Arada) (Figure 28). In general, B deficiency is not recorded in the sample screened areas. Periodic monitoring of the UAE agricultural soil to check for the excess levels of B is highly recommended, particularly in farms located in the Abu Dhabi Emirate western region, to avoid B toxicity.

4.3.4 Calcium (Ca) Fingerprint

Calcium (Ca) is an essential element for efficient and healthy plant cell membranes and walls. It is an essential secondary macronutrient (required in large quantities) for the active growth and development of the plant (participially for plant roots and fruits) (Spargo et al., 2013; Muazu et al., 2016).

In the UAE agricultural soils, the total mean concentration of Ca was found to be 86,264.5 ppm, with a range of 23,661 to 163,189 ppm. The maximum concentrations were recorded in Abu Dhabi city at the Al Ain Road (Al Samha). As the UAE natural soil is rich in calcium carbonate ($CaCo_3$) (EAD, 2012), these results were expected. No calcium deficiency was recorded in the tested agricultural soils of the UAE (Figure 29).

4.3.5 Cadmium (Cd) Fingerprint

Cadmium (Cd) is a heavy metal that exists naturally in the soil in a concentration between 0.03 to 0.15 ppm. It can be very toxic at concentrations more significant than the threshold reported by (Tóth et al., 2016). According to Dubai municipality standard limits for land, the maximum Cd level is 5 ppm. Human activity is responsible for Cd distribution (Muazu et al., 2016). At high concentrations, Cd causes adverse effects to soil organisms and microbial processes, and thus cause toxic effects to the plants (depending on plant species) and human health (Smith and Riddell-Black, 2007). Like other heavy metals, Cd is a non-bio degradable element that can undergo global ecological cycles. Therefore, Cd must be managed cautiously to avoid it being transferred to the human food chain (Muazu et al., 2016).

The concentration of Cd in the UAE agricultural soils indicates a total mean concentration of 1.35 ppm, with a range of 0.46 to 4.84 ppm. The maximum levels of Cd were detected in the northern Emirates (Ras Al Khaimah-Masafi), with levels exceeding the threshold level of (Figure 29). However, according to Tóth and other scientists (2016), these results are less than the lower guideline value of 10 ppm. Also, the results were found to be below the maximum permissible limits for land contamination as prescribed by Dubai Municipality (2003) at 5 ppm (Samara et al., 2016). Therefore, results show that no Cd contamination was recorded in the tested agricultural soils. It is recommended that Cd monitoring to be initiated to prevent further increases in Cd levels, resulting in soil Cd contamination. It is also recommended that the use of P fertilizer in the UAE agricultural soils to be limited and done under authorized conditions.

4.3.6 Cobalt (Co) Fingerprint

Cobalt (Co) is an essential element required in insignificant amounts for human health. Soil with Co below 0.3 ppm is considered as Co-deficient (Muazu et al., 2016). Co has a mean natural concentration of 8 ppm with a range of 1 to 30. Soil with Co concentrations above a threshold value of 20 ppm may have health hazards. Individual levels can cause harmful health effects while the guideline value is 100 ppm (Tóth et al., 2016).

Co concentration results from this study indicate a total mean concentration at 10.3 ppm, with a range of 1.71 to 55.5 ppm. The maximum Co levels in the UAE were recorded in the northern Emirates (e.g., Ras Al Khaimah-Masafi) (Figure 31). It is recommended that the Co levels of the UAE agricultural soils to be monitored to prevent further accumulation and contamination concerns.

4.3.7 Chromium (Cr) Fingerprint

In Nature, chrome or chromium (Cr) does not occur in an elemental form but occurs only in compounds (Wuana, and Okieimen, 2011). The naturally occurring mean concentration for Cr is 31 ppm with a range of 6 to 170 ppm. The Cr threshold concentration is 100 ppm while the lower guideline value is 200 ppm (Tóth et al., 2016). However, according to Muazu and other scientists (2016), the recommended permissible level of Cr is 150 ppm. Also, the Cr contamination indicator level, as stated by Dubai Municipality (2003), is 250 ppm. The activity of Cr is controlled by pH and organic matter (Mandal et al., 2011). Human activity plays a crucial role in Cr distribution. Cr is a non-bio degradable heavy metal that can be very toxic, even at low concentrations, causing adverse effects on ecology and human health (Muazu et al., 2016).

The study results for the UAE agricultural soil indicate that the total mean concentration of Cr is 111.2 ppm with a range from of 20.89 to 1140.8 ppm. The highest concentration levels were recorded as being in the northern Emirates (e.g. Ras Al Khaimah – Masafi). In general, the total mean Cr concentration is within the threshold value with some exceeding levels at some farms. Thus, periodic monitoring of the UAE agricultural soils is recommended to maintain awareness of any changes in Cr levels to prevent further increases in its concentration (Figure 32).

4.3.8 Copper (Cu) Fingerprint

Copper (Cu) is a micronutrient required in very less amounts for healthy soil and healthy plant growth (Spargo et al., 2013). In plants, Cu is an essential element for seed production, disease resistance, and water control. In humans, Cu assists in blood hemoglobin production (Muazu et al., 2016). Cu deficiency is most likely to occur in sandy soil, with low organic matter and high pH (Spargo et al., 2013). The normal healthy concentration range for Cu is 0.84 to 1.69 ppm. According to the World Health Organization (WHO), the maximum permissible limit for Cu is 20.00 ppm. Above this level, Cu could cause adverse effects to human health and environment. For example, it can cause anemia, digestive system irritation and even liver and kidney damage (Muazu et al., 2016). According to other studies, the maximum permissible levels for Cu in agricultural soils are between 5 to 50 ppm (Llopis et al., 2006) or even up to 100 ppm (Samara et al., 2016).

In the UAE, results of this study indicated that some agricultural soils (e.g., Thubian and Khatem in Abu Dhabi) were below the minimum Cu recommended concentration (<8 ppm) (Llopis et al., 2006). On the other hand, the levels in some regions reached above 44 ppm. Maximum levels (around 110 ppm), were recorded in northern Emirates (e.g., Ras Al Khaimah-Masafi) (Figure 33). Some of the detected Cu concentrations were higher than the permissible levels determined by the WHO standards but found within Dubai Municipality (2003) Land Standards (100 ppm) (Samara et al., 2016). It is highly required to monitor Cu levels to restrict any further increase in its concentrations. Since Cu is highly pH dependent, it is essential to keep the soil pH value to a slightly sodic level to minimize Cu mobility. Improving the soil with organic matter and fly ash can bind significant amounts of Cu and thus can reduce it to the safe levels (Kumpiene et al., 2008).

4.3.9 Iron (Fe) Fingerprint

Iron (Fe) is the third most abundant element in the earth's crust. Its availability in soil depends on the pH values of the soil. As pH increases, the concentration of Fe decreases (Sillanpää, 1972). Fe is not considering as a contaminating element. However, it is considered as an essential component of living organisms as it affects the chemical and physical properties of the soil. It also affects plant nutrition by influencing the abundance of macro and micronutrients (Llopis et al., 2006). Also, Fe is a component of the vital chlorophyll molecule (Sillanpää, 1972). Determining the concentration of Fe in soil is not recommended as it is not being considered an indicator of availability in soil and plants (Llopis et al., 2006; Horneck et al., 2011). It is estimated that the soluble Fe values in the soil can vary from 1 ppm up to more than 1000 ppm (Sillanpää, 1972). The recommended Fe values in the agricultural soil are between 50-120 ppm (Altland, 2006).

In the UAE agricultural soil, the mean concentration of total Fe metal is approximately 9,840 ppm, with a maximum concentration reaching 31,490 ppm in the northern Emirates (e.g., Ras Al Khaimah-Masafi). The results of the present study for

Fe in soil significantly varied from one location to another (Figure 34). According to Fe limits stated by Altland (2016), the results of the Fe values in the present study are above the permissible levels in many agricultural soils. Thus, periodic monitoring for Fe in soil is recommended. Also, the application of Fe amendment techniques is required in the contaminated areas.

4.3.10 Potassium (K) Fingerprint

Potassium (K) is a significant soil macronutrient. It is necessary for plant root growth and essential for drought, heat and disease tolerance (Sillanpää, 1972). K is considered a prime cation, which requires significant management consideration. If the values of K exceed acceptable levels, this could result in enriching the K levels in the forage, and this could affect animal health. On the other hand, low values of K could have an impact on plant growth negatively (Horneck et al., 2011). The levels of K in soil may be divided into four categories (Low <150 ppm, Medium 150 - 250 ppm, High 250 - 800 ppm, and Excessive >800 ppm). In general, acceptable K values range from 160 to 220 ppm (Altland, 2006; Horneck et al., 2011).

The results of the present study analysis of the UAE agricultural soils indicates that total mean concentration for K is 2,026.8 ppm, with a range of 864.4 to 6,425.6 ppm. The maximum levels were recorded in Wadi Sha'am in Ras Al Khaimah (Figure 35). In general, screened areas did not show K deficiency. However, it is recommended to do the periodic checking of the UAE agricultural soils to avoid K over fertilization.

4.3.11 Magnesium (Mg) Fingerprint

Magnesium (Mg) is a secondary plant macronutrient. Mg plays an essential role in phosphorous (P) in plant metabolism and photosynthesis (Spargo et al., 2013).

Mg levels in soil may be divided into three categories (Low <60 ppm, Medium 60 to 300 ppm, and High >300 ppm). In general, the acceptable Mg values range from 1 to 1.6 ppm (Altland, 2006; Horneck et al., 2011). Mg levels can be increased through the application of liming or Epsom salts (magnesium sulfate ($MgSO_4$)) (Spargo et al., 2013).

In the UAE soils, the results of the present study indicated that the overall means concentration for Mg to be approximately 26,688 ppm, with a range of 3,032 to 145,394 ppm. Furthermore, the results showed minimum results were recorded in the western region of the Abu Dhabi Emirate, while the highest results were registered in the northern Emirates (e.g., Ras Al Khaimah – Masafi) (Figure 36). Study results identified no Mg deficiency among the screened samples. However, the study results indicated elevated levels of Mg above the recommended limits. The same could be a result of Mg over fertilization. Thus, it is recommended to add Epsom salts to the UAE agricultural soils and to conduct periodic Mg monitoring of these soils.

4.3.12 Manganese (Mn) Fingerprint

The origin of Manganese (Mn) comes from the decomposition of ferromagnesian rocks. Moreover, It is crucial in photosynthesis (Sillanpää, 1972). It is an essential trace element for both plant growth (Altland, 2006; Llopis et al., 2006) and photosynthesis (Sillanpää, 1972). It is not mobile in soil; thus, it should be incorporated in the soil before planting activities. The availability of Mn depends on the pH level in the soil, the oxidation-reduction circumstances and the soil's organic matter (Sillanpää, 1972; Altland, 2006). The pH values control Mn deficiencies. If the soil pH value exceeds 8, then a deficiency of Mn would exist (Horneck et al., 2011). Tests for Mn differ with crop and soil type. Acceptable values vary from 1 to 5 ppm

(Sillanpää, 1972). High-quality plants need Mn range of 20 to 40 ppm (Altland, 2006). Effects of toxicity were reported when the Mn concentration was high. (Sillanpää, 1972). According to Dubai Municipality standards (2003), Mn levels above 700 ppm is an indicator of the soil Mn contamination.

In the present study, in the UAE agricultural soils, the overall mean concentration for Mn was 237.4 ppm, with a range of 66.5 to 629.6 ppm. The maximum levels were recorded in northern Emirates (e.g., Dibba Al Fujairah) (Figure 37). The Study results of the present study indicate no Mn deficiency or toxicity in the UAE agricultural soils.

4.3.13 Molybdenum (Mo) Fingerprint

Molybdenum (Mo) is present in the earth's crust in a small amount (2.3 ppm) (Sillanpää, 1972). This micronutrient is considered too low in values to be tested or evaluated in the soil. The probability of deficiencies is infrequent and varies from one plant species to another (Horneck et al., 2011). The availability of Mo is controlled by the soil pH value of the soil. As the pH value increases the concentration of Mo increases. Mo is required in small amounts in soil and plants. Any additional amount could cause toxicity to animals feeding on forage crops. It is estimated that the Mo values in soil usually vary between 0.2 to 5 ppm, averaging at approximately 2 ppm (Sillanpää, 1972; Horneck et al., 2011).

The results of the present study of the UAE agricultural soils screened samples indicated a too small range of Mo concentration for evaluation (<0.018 ppm), with a mean concentration of 0.02 ppm. The results also indicated that the total Mo concentrations below of the UAE agricultural soils were below the recommended levels. Thus, it is recommended to lower the use of phosphate fertilizers to increase the Mo uptake in the UAE sodic soils.

4.3.14 Sodium (Na) Fingerprint

Sodium (Na) is a naturally occurring cation that could be enriched by irrigation water with high sodium content (Horneck et al., 2011). Na is not essential for plant growth as it is not considered a plant nutrient and could affect the soil's health. Some factors are controlling Na concentration, such as soil type and structure, soil penetrability and plant growth. The concentration of Na may be determined by evaluating the exchangeable sodium percentage (ESP) –the percent of the CEC occupied by Na. Na is not toxic. However, it could affect the quality of the soil structure (Clancy, 2010). If the ESP exceeds 10 percent (Horneck et al., 2011) or the sodium base saturation exceeds five percent (Clancy, 2010), then this should be investigated. Arid regions have saline soils and therefore are rich in sodium. There are three categories of soil regarding the sodium concentration (Low<640 ppm, Medium 640-1,600 ppm, High >1,600 ppm) (Horneck et al., 2011). The most appropriate way to maintain the level of Na in soil is to enhance the level of the soluble soil calcium. The management of Na is a critical issue, and it is crucial to understand the reason for sodium accumulation in any soil type. The best way to eliminate such accumulations is by irrigation water treatment (Clancy, 2010).

The present study of the analysis of the UAE agricultural soil indicates that the total mean concentration of Na is 470.4 ppm, with a range between 207.2 to 9,314.9 ppm. Maximum Na concentration from the study was recorded in Abu Dhabi city - Al Ain Road (Ramah) (see Figure 38). Some recorded results were above the high limits (1,600 ppm) as stated by Horneck and other scientists (2011). This means that some

UAE farms are facing a hard time with soil salinity. It is highly recommended to leach the soil periodically. Also, irrigation scheduling and managing crop water requirement are crucially needed. It is essential to focus on cultivating halophyte species (salt-tolerant plants, such as, date palm) that can tolerate high salinity levels.

4.3.15 Nickel (Ni) Fingerprint

Nickel (Ni), like most heavy metals, [Nickel (Ni)] can come from a natural or anthropogenic source (e.g., industrial activities). In healthy soils, Ni is needed in small amounts only. However, above certain levels, it may cause harmful effects to the human immune and reproductive systems. The threshold value for Ni is 50 ppm while the lower and the higher guideline levels are 100 ppm and 150 ppm, respectively (Tóth et al., 2016).

The results of the present study of the UAE agricultural soils indicate that the total Ni mean concentration is 160.9 ppm, which is above the threshold value of 50 ppm. With many agricultural soils, being even above the higher guideline levels. The northern Emirates have the highest recorded levels, and maximum levels were registered in Ras Al Khaimah (e.g., Masafi), reaching around 1000 ppm (Figure 39). The study results of the present research suggest the need to improve Ni contaminated soils by controlling the contamination source via lime application (Wuana and Okieimen, 2011). Also, it is crucial to conduct periodic screening to make sure that Ni levels are within the permissible ranges.

4.3.16 Phosphorous (P) Fingerprint

Phosphorous (P) is a primary macronutrient. It is relatively immobile in soil (Horneck et al., 2011). High-quality plants need P in the soil at levels in the range of

50 to 100 ppm (Altland, 2006). Required amounts of P vary depending on crop varieties. For example, optimum P levels for corn range from 11 to 20 ppm, while for potatoes the optimum range is from 81 to 110 ppm (Pierzynski et al., 1993).

The results of the present study of the UAE agricultural soils indicated that for P the total mean concentration was 450.6 ppm, with a range of 56.5 to 3,507.2 ppm. The elevated levels were found at Al Bidiya in Khor Fakkan (Figure 40). In general, recorded P levels showed no P deficiency, with some recorded levels higher than optimum levels, particularly in the northern Emirates. The high P recorded results may be due to activities of over fertilization. Thus, P monitoring tests should be periodically done to make sure that P levels are within the permissible limits, and to avoid excessive application of P fertilizer.

4.3.17 Lead (Pb) Fingerprint

Lead (Pb) is a biologically toxic heavy metal. Naturally, Pb is available in soil at low levels and may be enriched by human activities (European Commission, 2013; Su, 2014). The overuse of fertilizers, pesticides, and the introduction of industrial solid wastes are enriching the Pb concentration in the soil (Su, 2014). High levels of Pb may cause adverse effects to plant morphology, growth, and productivity (Muazu et al., 2016). Pb accumulation in the soil causes ecological problems and may even destroy agricultural soils (Rahman et al., 2012). Pb has dangerous health effects as it accumulates in bones and may damage many body systems and organs (European Commission, 2013; Su, 2014). Some studies have shown that exposure to lead in the early stages of children's growth affects their intelligence negatively (European Commission, 2013). According to Muazu and other scientists (2016), the WHO has established permissible levels for Pb in the soil in the range between 0.05 to 0.1 ppm.

However, according to Dubai Municipality standards for land contamination (2003), Pb concentrations above 200 ppm is an indicator of land contamination.

The results of the present study of the UAE agricultural soils indicate that total mean concentration for Pb to be 4.25 ppm, and a range that varies from less than 0.01 ppm up to approximately 25 ppm (Figure 41). The maximum Pb levels in the present study were recorded in the northern Emirates, such as Khor Fakkan- Al Bidiya. Based on the permissible levels of WHO, the results of the present research registered in the UAE exceed WHO permissible levels. However, based on Dubai's standards for land contamination, the recorded results are below the permissible levels. It is recommended that periodic soil testing be conducted to ensure that Pb concentrations are kept below permissible limits. Soil remediation through the application of bioremediation techniques can be a safe, natural technique for Pb contamination soil recovery.

4.3.18 Sulfur (S) Fingerprint

Sulfur (S) is a naturally occurring non-metallic element. It is essential for agriculture and considered to be a secondary plant nutrient. Sulfur reacts in the soil in a way that is similar to nitrogen (Schulte, 1981; Lucheta & Lambais, 2012). Sources of Sulfur are natural gas, oil, metal, sulfides and volcanic deposits (Lucheta & Lambais, 2012). Plants absorb S in the sulfur-sulfate form (Horneck et al., 2011). Soil contains 200-600 lb/ac of total sulfur (Schulte, 1981). The agronomic practice of harvesting and leaching reduce sulfur concentration in the soil (Schulte, 1981; Lucheta & Lambais, 2012). Sandy soil needs more sulfur compared to other soil types as the sulfate is leached out leached (Schulte, 1981). There is four Sulfate-sulfur soil test categories (Deficient <2 ppm, Low 2-5 ppm, Medium 5-20 ppm, and High >20 ppm) (Horneck et al., 2011).

The results of the present study indicate that for the UAE agricultural soils, the total mean concentration of S was 2,393.5 ppm, with a range between 129.8 up 26,812.8 ppm. Further, the study results indicated that there is a significant variation between the S results recorded in different UAE regions. The maximum study result was found in the Al Ain-Ramah area, while the northern Emirates indicated the minimum S results (Figure 42). The concentration of Sulfur from over-fertilization activities on some UAE farms could be responsible for the significant variation in the study results. According to the limits stated by Horneck and other researchers (2011), all the study results for the soils of the screened farms exceeded the S permissible limits. Therefore, it is recommended to lower S fertilizers applications to adequate levels, with periodic testing to make sure S availability stays within recommended limits.

4.3.19 Silicon (Si) Fingerprint

Silicon (Si) is a secondary element (Sillanpää, 1972) needed for the healthy growth of many plants (e.g., rice, wheat, and cucumber). It is captivated by plants in the form of silicic acid and then transported to the shoot to eventually polymerize as silica gets on the surface of the stems and the leaves. Si is the only element that does not lead to severe injuries in the presence of excess amounts. Its role in plants is more likely mechanical rather than physiological, and its effect is more noticeable as biotic and abiotic stress factors (Ma et al., 2001).

In the UAE, the present study of its agricultural soils indicated an overall mean concentration to be 795.68 ppm, with a range of 241.4 to 1,488.9 ppm. The maximum recorded result in the present study was found in Al Ain - Dubai (Road) - Al Faqa (Figure 43). The results showed that no concerns related to Si deficiency or toxicity were observed in the UAE agricultural soils.

4.3.20 Strontium (Sr) Fingerprint

Strontium (Sr) is known to be an alkaline earth element. In general, arid regions are characterized by high strontium concentrations comparing to non-arid regions. Sr has a pervasive distribution pattern and is mostly associated with large quantities of calcium (Bowen and Dymond, 1955; Aubert and Pinta, 1980).

The present study of the UAE agricultural soils indicated that the total mean concentration of Sr to be 593.7 ppm, with a range of 149.3 to 1,540.8 ppm. The maximum study result was recorded in Abu Dhabi- Al Ain Road (Al Samha) (Figure 45). According to Aubert and Pinta (1980), the permissible range for Sr was within permissible limits.

4.3.21 Vanadium (V) Fingerprint

Vanadium (V) is a massive trace element. It is needed in small amounts by some plant species. V commonly exists in high concentrations in phosphate fertilizers and accumulates in plant roots (Mermut et al., 1996). V is believed to precipitate as calcium vanadate in the roots. V toxicity is not common in plants (Hooda, 2010). Similar to other heavy metals, when V exists in concentrations higher than optimal limits, it can lead to harmful human health effects (e.g., organ damage, bone damage, neurological problems, and cancer) (Samara et al., 2016). V is relatively immobile in soils and thus has low environmental risk potential (Hooda, 2010).

For the UAE agricultural soils, the present study results indicate that V overall mean concentration is 20.9 ppm, with a range of 9.7 to 52.2 ppm. The highest V study result was recorded in We hail (located in western region) (Figure 46). Further, the study results indicated that there are no V deficiency or toxicity concerns for the UAE agricultural soils.

4.3.22 Zinc (Zn) Fingerprint

Zinc is one of the most common elements. It is readily available in the Earth's crust. It occurs naturally, and its concentration is enriched by human activities (ATSDR, 1994). The total Zn concentration in soil is measured to be about 10 – 300 ppm (Sillanpää, 1972). Zn saltly is essential as a fertilizer (Sillanpää, 1972) and it in is used in small amounts as a micronutrient (Atsdr, 1994). Zn is more likely found in the acid soils than sodic soils, where the pH varies from 6 to 7. It is increasingly found in wet and cool weather more than dry and warm climate conditions. Zn deficiency occurs mostly in sandy soils due to soil erosion. Soil erosion is considered the main reason for Zn deficiency. Zn toxicity occurs if the soil is acidified to increase other nutrient elements or when there is a continuous fertilization process applied over a prolonged period with high Zn concentration (Sillanpää, 1972).

The present study analysis of the UAE agricultural soils indicates that the overall mean concentration of Zn to be 24.9 ppm, with a range of 5.67 to 218.1 ppm. The maximum study result was found in Khor Fakkan - Al Bidiya. In general, the northern Emirates indicated higher Zn results when compared to other areas (Figure 47). According to Dubai standard limits, the maximum permissible concentration of Zn is 500 ppm. Although, the present study results were within the permissible limits.

On the other hand, it is recommended that the UAE agricultural soils in some areas should be tested periodically to ensure that Zn levels remain at the safe levels.

Chapter 5: Conclusion

In the UAE, the food production sector, which is already facing many environmental and climatological stress factors, would face further critical challenges with the impacts of climate change and global warming. The productivity of many crops could be adversely affected by the implications of climate change. Especially, with the sharp population growth, the expansion in the urbanization and the industrial activities, will all add more stresses in the food production sector. To best cope with such emerging challenges, it is significant to act quickly in adapting and mitigating climate change and global warming implications. Honestly, research plays a fundamental role in investigating the UAE indigenous crop varieties that can tolerate and adapt climate change effects. Besides, each of the food production system components has to play a significant role in the execution of climate change adaptation and mitigation actions. This will only functionally work through bridging the interaction gaps at locally, regionally and cross-regional levels. Finally, climate change has no boundaries, and its implications could reach everywhere and can affect the global food security. Consequently, national and international cooperation plans and strategies, at the UAE, GCC and the global level, are crucially needed; to control the implications of this phenomenon, secure enough food for the humanity and lastly provide a sustainable earth for the next generations.

The present study was performed to measure the natural radioisotopic levels in UAE agricultural soils for selected radionuclides. The study provides the first baseline reference database for natural radioisotope concentrations in the UAE. Radioactive secular equilibrium was demonstrated for specific activities of ^{226}R, ^{232}Th, and ^{40}K to estimate their accompanying radiological risk factors. In general, the distribution of selected primordial radioisotopes in this study sample location is uniform. The activity levels in the UAE agricultural soils due to naturally occurring radionuclides are lower than the mean universal values. The absorbed dose rate was below the corresponding worldwide average. The values of radium equivalent activity, internal and external hazard indexes show that there is no health risk from the UAE agricultural soil. Radiological hazard indices showed that the soils of the UAE study location presented no radiation risk.

Most properly, the ^{137}Cs exists in soil naturally only in trace amounts following the spontaneous fission of ^{238}U. Thus, UAE agriculture has low natural radioactivity and is thus safe for the population. The values of all radiation parameters studied are within permissible limits of international standards and recommendations. It is advisable to test the quantities of chemical fertilizers on continues basis to ensure the radioactivity concentration contents. The regular testing of the used fertilizers will provide essential information in the monitoring for any environmental contamination. For future perspectives of this work, a baseline for radioisotopic concentration and transfer factors for various plants in the UAE is advisable. A detailed study of the concentration of radionuclides in plants besides the radioactive materials uptake in the plants will be the basis for the baseline. The evaluation of radionuclide transfer factors from the agricultural soils to plants will be used to estimate the radiological dose to the UAE population.

The present study analysis of the UAE agricultural soils indicated that total overall mean concentrations for various elements with ranges of availability (in ppm) are as follow; Al: 8,539.7 (3,217.5 to 34,912.6), As: 2.17 (<0.0009 to 7.33), B: 47.68 (13.2 to 971.6), Ca: 86,264.5 (23,661.0 to 163,189.0), Cd: 1.35 (0.46 to 4.84), Co: 10.30 (1.71 to 55.5), Cr: 111.20 (20.89 to 1,140.82), Cu: 14.32 (3.14 to 1,222.50), Fe:

9,839.80 (3,002.9 to 31,489.0), K: 2,026.80 (864.4 to 6,425.6), Mg: 26,688.30 (3,032.2 to 145,394.0), Mn: 237.40 (66.5 to 629.6), Mo: 0.02 (<0.018) ,Na: 470.40 (207.2 to 9,314.9), Ni:160.90 (8.4 to 1,010.9), P: 450.60 (56.5 to 3,507.2), Pb: 4.25 (< 0.01 to 25.19), S: 2,393.50 (129.8 to 26,812.8), Si: 795.68 (241.4 to 1,488.9), Sr: 593.70 (149.3 to 1,540.8), V: 20.90 (9.7 to 52.2) and Zn: 24.90 (5.67 to 218.1).

The results of the present study were found to be within permissible levels for As, Ca, Mn, Sr and V. A deficiency of Mo was recorded for some farms. Also, amounts of Z were found to be below permissible limits in some areas. On the other hand, excessive amounts were found at some farms were recorded for Al, Fe, K, Mg, Na, Ni, P, S, and Si. The activities of over-fertilization may be responsible for such cases, particularly in the region of the northern Emirates. Thus, it is recommended to do periodic soil testing and to apply fertilizers accordingly.

Chapter 6: Recommendations and Future Research

The radionuclides transfer from agricultural soil to plants and estimate the radiological dose to the UAE public. As it is very crucial to have information about radioactive materials uptake in these plants. The transfer of radionuclides from irrigation water to soil- plant system for different vegetables and fruits depending on the type of the irrigation system. The specific periodic testing for the total concentration of Co and Cr is recommended since soil pH plays a vital role in elements availability and mobility. Future studies relating to the effect of pH on elements and their concentration should be considered by decision-makers.

The different status according to different standards was found for the following elements Cd, Cu, and Pb. The study results were found to be within permissible the limits according to the Dubai Land standards but were found to be above the permissible limits according to other international standards. Therefore, it is recommended to do the periodic testing to ensure that concentrations do not increase further. Finally, it is crucial to calculate the permissible limits for each element as reference limits.

References

Abiama, P. E., Ateba, P. O., Ben-Bolie, G. H., Ekobena, F. H. P., and El Khoukhi, T. 2010. High background radiation investigated by gamma spectrometry of the soil in the southwestern region of Cameroon. Journal of Environmental Radioactivity, 101: 739-743.

Ademola, A. K., Bello, A. K., and Adejumobi, A. C. 2014. Determination of natural radioactivity and hazard in soil samples in and around gold mining area in Itagunmodi, south-western, Nigeria. Journal of Radiation Research and Applied Sciences, 7: 249-255.

Ajaj, R. M., and Salem M. A. 2015. Estimating the potential negative effects of elevated ultraviolet-B (UV-B) radiation on global agricultural sustainability: Status, challenges, and recommendations. The annual meeting of the American society of agronomy (ASA). ACCESS Digital Library.

Ajaj, R. M., Shahin S. M., and Salem, M. A. 2015a. The challenges of climate change and food security in the United Arab Emirates (UAE): a Critical review of the Influence of UV-B radiation with future research perspectives. In: proceedings of the third international conference on global warming: food security. Publisher RAK Environment Protection and Development Authority, United Arab Emirates. P 33.

Ajaj, R. M., Shahin S. M., and Salem, M. A. 2015b. Climate change and food security: The effects of long-term elevated solar ultraviolet–B (UV-B) radiation on the agricultural sustainability in the United Arab Emirates (UAE). In: proceedings of the annual research and innovation conference. Publisher United Arab Emirates University (UAEU), United Arab Emirates. P 238.

Akhtar, N., Tufail, M., Ashraf, M., and Iqbal, M. M. 2005. Measurement of environmental radioactivity for estimation of radiation exposure from saline soil of Lahore, Pakistan. Radiation Measurements, 39: 11-14.

Al-Jaseem, Q. K., Almasoud, F. I., Ababneh, A. M., and Al-Hobaib, A. S. (2016). Radiological assessment of water treatment processes in a water treatment plant in Saudi Arabia: Water and sludge radium content, radon air concentrations and dose rates. Science of The Total Environment, 563: 1030-1036.

AlFarra, H. J., and Abu-Hijleh, B. 2012. The potential role of nuclear energy in mitigating CO_2 emissions in the United Arab Emirates. Energy Policy. 42: 272-285.

Almayahi, B. A., Tajuddin, A. A., and Jaafar, M. S. 2012. Effect of the natural radioactivity concentrations and 226 Ra/238 U disequilibrium on cancer diseases in Penang, Malaysia. Radiation Physics and Chemistry, 81: 1547-1558.

Al-Sulaiti, H., Regan, P. H., Bradley, D. A., Malain, D., Santawamaitre, T., Habib, A., ... & Al-Dosari, M. 2010. A preliminary report on the determination of natural radioactivity levels of the State of Qatar using high-resolution gamma-ray spectrometry. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 619: 427-431.

ANSI N42.14, 2002. American National Standard,"Calibration and Use of Germanium Spectrometers for the Measurment of Gamma-Ray Emission Rates of Radionuclides:, American Standards Institute, New York, NY 10036.

Asif, M. (2016). Growth and sustainability trends in the buildings sector in the GCC region with particular reference to the KSA and UAE. Renewable and Sustainable Energy Reviews, 55: 1267-1273.

Bajoga, A. D., Alazemi, N., Regan, P. H., and Bradley, D. A. 2015. Radioactive investigation of NORM samples from Southern Kuwait soil using high-resolution gamma-ray spectroscopy. Radiation Physics and Chemistry, 116: 305-311.

Bala, P., Mehra, R., and Ramola, R. C. 2014. Distribution of natural radioactivity in soil samples and radiological hazards in building material of Una, Himachal Pradesh. Journal of Geochemical Exploration, 142: 11-15.

Barnes, P. W., Jordan, P. W., Gold, W. G., Flint, S. D., & Caldwell, M. M. (1988). Competition, morphology and canopy structure in wheat (*Triticum aestivum L.*) and wild oat (*Avena fatua L.*) exposed to enhanced ultraviolet-B radiation. Functional Ecology, 319-330.

Boukhenfouf, W., and Boucenna, A. 2011. The radioactivity measurements in soils and fertilizers using gamma spectrometry technique. Journal of Environmental Radioactivity, 102: 336-339.

Chivers, D. H. 2008. Pulse shape parameterization and signal decomposition for high sensitivity Compton imaging using high-purity germanium double-sided strip detectors. ProQuest.

Debertin, K. and Helmer, R. G. 1988. Gamma and X-ray Spectrometry with Semiconductor Detectors Amsterdam: North Holland Publishing Co..

Dhawal, S. J., Phadatare, M. R., Kulkarni, G. S., and Pawar, S. H. 2014. Gamma radiation levels in the villages of South Konkan, Maharashtra, India. Environmental Earth Sciences, 72: 511-523.

Ding, Z., Duan, X., Ge, Q., and Zhang, Z. 2009. Control of atmospheric CO_2 concentrations by 2050: A calculation on the emission rights of different countries. Science in China Series D: Earth Sciences. 52: 1447-1469.

EAD (Environmental Agency of Abu Dhabi). 2009. Abu Dhabi water resources master plan, Abu Dhabi, UAE.

El-Samad, O., Baydoun, R., Nsouli, B., and Darwish, T. 2013. Determination of natural and artificial radioactivity in soil at North Lebanon province. Journal of Environmental Radioactivity, 125: 36-39.

Environmental Agency of Abu Dhabi (EAD). 2012. EAD Corporate Strategy 2011 – 2015.

Erdtman,. and Soyka, W. The Gamma Rays of the Radionuclides, Tables for Applied Gamma-Ray Spectrometry, Topical Presentation in Nuclear Chemistry, Volume 7, Verlag Chemie, Weinheim, New York, 1979.

Erdtmann,. and Soyka, W. The Gamma Rays of the Radionuclides, GmbH, F-6940 Winheim, New York; Verlag Chemie, 1979.

EPA. 2012. Stratospheric Ozone - AIRTrends 1995 Summary. Retrieved from the Unietd States Environmental Protection Agency - EPA: http://www.epa.gov/airtrends/aqtrnd95/stratoz.html

Fagerberg, W.R. and Bornman, J. F. 2005. Modification of leaf cytology and anatomy in Brassica napus grown under above ambient levels of supplemental UV-B radiation. Photochem. Photobiol. Sci. 4: 275–279.

FAO (Food and Agriculture Organization of the United Nations). 2006. World agriculture: Towards 2030/2050, Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). 2009. The state of food security in the world, Rome, Italy.

Gaafar, I., El-Shershaby, A., Zeidan, I., and El-Ahll, L. S. 2016. Natural radioactivity and radiation hazard assessment of phosphate mining, Quseir-Safaga area, Central Eastern Desert, Egypt. NRIAG Journal of Astronomy and Geophysics, 5: 160-172.

Grafton, R. Q., J. Williams and Q. Jiang. 2015. Food and water gaps to 2050: Preliminary results from the global food and water system (GFWS) platform. Food Security. 7: 209-220.

Grene, R. 2002. Oxidative stress and acclimation mechanisms in plants. *Arabidopsis* Book 1: e0036.

Guidotti, L., Carini, F., Rossi, R., Gatti, M., Cenci, R. M., and Beone, G. M. 2015. Gamma-spectrometric measurement of radioactivity in agricultural soils of the Lombardia region, northern Italy. Journal of Environmental Radioactivity, 142: 36-44.

Hamidalddin, S. H. 2014. Determination of agriculture soil primordial radionuclide concentrations in Um Hablayn, north Jeddah west of Saudi Arabia. International Journal of Current Microbiology Applied Sciences, 3: 623-633.

Hectors, K., Prinsen, E., Coen, W. D., Jansen, M. A. K. M. A. K., and Guisez, Y. 2007. Arabidopsis thaliana plants acclimated to low dose rates of ultraviolet B radiation show specific changes in morphology and gene expression in the absence of stress symptoms. New Phytologist, 175: 255-270.

Hermwille, L., W. Obergassel, H. E. Ott and C. Beuermann. 2015. UNFCCC before and after Paris: What's necessary for an effective climate regime? Climate Policy, pp. 1-21.

International Commission On Radiological Protection (ICRP). 1993. Limits for intake of radionuclides by workers, ICRP publication 65, Ann ICRP., Vol. 23. Pergamoon Press, Oxford (No.2).

Jahan, F., and Quddusi, K. S. K. A. 2014. Climate Change and Bangladesh: Geographical and Socio-economic Impacts. Dhaulagiri Journal of Sociology and Anthropology, 7: 113-132.

Jankovic, M., Nikolic, J., Pantelic, G., Rajacic, M., Sarap, N., and Todorovic, D. 2013. Radioactivity in Chemical Fertilizers. In Majer, M. (Ed.). Proceedings of 9th Symposium of the Croatian Radiation Protection Association, (p. 578). Croatia.

Jansen, A. K., Hideg É., and Lidon, F. 2012. UV-B radiation: When does the stressor cause stress? Emirates Journal of Food and Agriculture, 24:6.

Jeevarenuka, K., Pillai, G. S., Hameed, P. S., and Mathiyarasu, R. 2014. Evaluation of natural gamma radiation and absorbed gamma dose in soil and rocks of Perambalur district (Tamil Nadu, India). Journal of Radioanalytical and Nuclear Chemistry, 302: 245-252.

Julkunen-Tiitto, R., Häggman, H. Aphalo, P. J., Lavola, A., Tegelberg, R., and Veteli, T. 2005. Growth and defense in deciduous trees and shrubs under UV-B, Environmental Pollution, 137: 404−414.

Karahan, G., and Bayulken, A. 2000. Assessment of gamma dose rates around Istanbul (Turkey). Journal of Environmental Radioactivity, 47: 213-221.3w

Ketait, R., Khatib, S. E., and Mezher, T. 2014. Formulation of an Integrated Energy Strategy for Abu Dhabi based on a Holistic Optimization of the Country's Energy Resources. Energy Procedia, 61: 862-869.

Khan, H. M., Ismail, M., Khan, K., and Akhter, P. 2011. Measurement of radionuclides and gamma-ray dose rate in soil and transfer of radionuclides from soil to vegetation, vegetable of some northern area of Pakistan using γ-ray spectrometry. Water, Air, & Soil Pollution, 219: 129-142.

Knoll, Radiation Detection and Measurement, 3rd edition, New York: Wiley & Sons, Inc. 1999.

Kocher, D. R. 1981. Radioactive Decay Data Tables,, Ed., Report No. DOE/Tic-11026.

Kuzemko, C., Lockwood, M., Mitchell, C., and Hoggett, R. 2016. Governing for sustainable energy system change: Politics, contexts and contingency. Energy Research and Social Science. 12: 96-105.

Lidon, F. J. C., Teixeira, M., and Ramalho, J. C. 2012. Decay of the Chloroplast Pool of Ascorbate Switches on the Oxidative Burst in UV-B-Irradiated Rice. J. Agron. Crop Sci. 198:130–144.

Lu, X., Zhao, C., Chen, C., and Liu, W. 2012. Radioactivity level of soil around Baqiao coal-fired power plant in China. Radiation Physics and Chemistry, 81: 1827-1832.

Matthew C. A., Hoffmann, G. L., McKenzie, R. L., Kemp P. D., and Osborne, M. A. 1996. Growth of ryegrass and white clover under canopies with contrasting transmission of ultraviolet-B radiation. Proc. Ann. Conf. Agron. Soc. New Zealand, 26: 23–30.

Mehra, R., Badhan, K., Sonkawade, R. G., Kansal, S., and Singh, S. 2010. Analysis of terrestrial natural radionuclides in soil samples and assessment of average effective dose.

Mewis, I., Schreiner, M., Nguyen, C. N., Krumbein, A., Ulrichs, C., Lohse M., and Zrenner. R. 2012. UV-B irradiation changes specifically the secondary metabolite profile in broccoli sprouts: induced signaling overlaps with defense response to biotic stressors. Plant and Cell Physiology, 53: 1546-1560.

Ministry of Environment and Water (MEW). 2005. Agriculture information center, Dubai, UAE

Ministry of Information and Culture. 2010. UAE yearbook, Abu Dhabi, UAE.

Mohammed, A. O., and Shahin, S. M. 2011. Impact of soil magnetic properties on moisture content prediction using TDR. Geotechnical Testing Journal, 34: 273-278.

Mohery, M., Baz, S., Kelany, A. M., and Abdallah, A. M. 2014. Environmental radiation levels in soil and sediment samples collected from floating water from a land runway resulting from heavy rains in the Jeddah region, KSA. Radiation Physics and Chemistry, 97: 16-24.

Murad, A., Al-Nuaimi H. and Al-Hammadi, M. 2007. Comprehensive assessment of water resources in the United Arab Emirates (UAE), Water Resources Management, 21: 1449-1463.

Ormord, D. P., and Hale, B. A. 1995. Physiological response of plants and crops to ultraviolet-B radiation stress. In: M. Pessarakli (Ed.). Handbook of plant and crop physiology. Marcel Dekker Inc. N.Y, 761-770.

Proposal by the President. 2015. Adoption of the Paris Agreement. Framework convention on climate change. United Nations.

Radhi, H. 2009. Evaluating the potential impact of global warming on the UAE residential buildings–a contribution to reduce the CO_2 emissions. Building and Environment, 44: 2451-2462.

Rani, A., Mittal, S., Mehra, R., and Ramola, R. C. 2015. Assessment of natural radionuclides in the soil samples from Marwar region of Rajasthan, India. Applied Radiation and Isotopes, 101: 122-126.

Ravisankar, R., Chandrasekaran, A., Vijayagopal, P., Venkatraman, B., Senthilkumar, G., Eswaran, P., and Rajalakshmi, A. 2012. Natural radioactivity in soil samples of Yelagiri Hills, Tamil Nadu, India and the associated radiation hazards. Radiation Physics and Chemistry, 81: 1789-1795.

Ravisankar, R., Sivakumar, S., Chandrasekaran, A., Jebakumar, J. P. P., Vijayalakshmi, I., Vijayagopal, P., and Venkatraman, B. 2015. Spatial distribution of gamma radioactivity levels and radiological hazard indices in the East Coastal sediments of Tamilnadu, India with statistical approach. Radiation Physics and Chemistry, 103, 89-98.

Rhodes, C. J. 2016. The 2015 Paris climate change conference: COP21. Science progress, 99: 97-104.

Ryde, S. J. S. 1995. Practical gamma-ray spectrometry G. Gilmore and JD Hemingway published by John Wiley & Sons, Chichester, 1995 ISBN 0-471-95150-1 price£ 60.00; 314 pp. Rapid Communications in Mass Spectrometry, 9: 1225-1225.

Sakschewski, B., von Bloh, W., Huber, V., Müller, C., and Bondeau, A. 2014. Feeding 10 billion people under climate change: How large is the production gap of current agricultural systems?Ecological Modeling, 288: 103-111.

Saleh, H., Shayeb, M. A. 2014. Natural radioactivity distribution of southern part of Jordan (Ma′ an) Soil. Annals of Nuclear Energy, 65: 184-189.

Saleh, M. A., Ramli, A. T., Alajerami, Y., and Aliyu, A. S. 2013. Assessment of environmental 226 Ra, 232 Th and 40 K concentrations in the region of elevated radiation background in Segamat District, Johor, Malaysia. Journal of Environmental Radioactivity, 124: 130-140.

Salem, M. A., Kakani V. G., and Reddy, K. R. 2004. Temperature effects on in vitro pollen germination and pollen tube growth of soybean genotypes. Annual meetings of the Southern Branch of the American Society of Agronomy.

Salem, M. A., Kakani, V. G., Koti, S., and Reddy, K. R. 2007. Pollen-based screening of soybean genotypes for high temperatures. Crop Science, 47: 219-231.

Senthilkumar, B., Dhavamani, V., Ramkumar, S., and Philominathan, P. 2010. Measurement of gamma radiation levels in soil samples from Thanjavur using γ-ray spectrometry and estimation of population exposure. Journal of Medical Physics, 35: 48.

Shahid, S. A. 2007. Soils of Abu Dhabi, book chapter published in the "Physical Geography Sector Paper", Abu Dhabi Global Environment Data Initiative (AGEDI). Environment Agency, Abu Dhabi, United Arab Emirates.

Shahin S. M., and Salem, M. A. 2015a. The three main reasons to focus on essential oil bearing plant species in the United Arab Emirates (UAE). The first UAE graduate students research conference, Abu Dhabi, United Arab Emirates.

Shahin, S. M., and Salem, M. A. 2015b. The challenges of water scarcity and the future of food security in the United Arab Emirates (UAE). Horizon Research, Natural Resources and Conservation. 3: 1, 1-6. Doi: 10.13189/nrc.2015.030101. ISSN: 2331-6365. ISSN: 2331-6373.

Shahin, S. M., and Salem, M. A. 2013. Water governance through regulations and responsibilities in the United Arab Emirates (UAE). The international water summit, Abu Dhabi, United Arab Emirates.

Shahin, S. M., and Salem, M. A. 2014a. Extracting therapeutic grade essential oils from the lamiaceae plant family in the United Arab Emirates (UAE):

Highlights on great possibilities and severe difficulties. International Journal of Biology, Veterinary, Agricultural and Food Engineering. 8: 1223-1228.

Shahin, S. M., and Salem, M. A. 2014b. The five key solutions to rescue the landscaping sector in the United Arab Emirates (UAE). Discovery Publication. 25(88): 41-47. ISSN 2278-5469. EISSN 2278-5450.

Shahin, S. M., and Salem, M. A. 2014c. Four reasons will convince the landscape decision makers to go for indigenous plants in the United Arab Emirates (UAE). International Journal of Recent Development in Engineering and Technology. 3: 1-8.

Shahin, S. M., and Salem, M. A. 2014d. The lifeline rescuers of tomorrow's landscaping in the United Arab Emirates (UAE): All the hope rests on the indigenous plants. In: proceedings of Second International Conference on Modern Trends in Science, Engineering and Technology. Dubai. Publisher Zelus International, United Arab Emirates. ISBN 978-93-83303-81-6.

Shahin, S. M., and Salem, M. A. 2014e. Food security in the United Arab Emirates (UAE): The great competition between the agricultural and forestry sector on irrigation resources. In: proceedings of international research conference on science, health and medicine. Dubai. Publisher Mudranik Technologies Pvt. Ltd, United Arab Emirates. ISBN 978-93-83303-90-8.

Shahin, S. M., and Salem, M. A. 2014f. Review future concerns on Irrigation requirements of date palm tree in the United Arab Emirates (UAE): Call for quick actions. In: Proceedings of the fifth international date palm conference, United Arab Emirates. P 255-262. ISBN978-9948-22-868-4.

Shahin, S. M., and Salem, M. A. 2014g. The cost of landscaping beauty in the United Arab Emirates (UAE): Call for quick actions to save the irrigation resources. In: Proceedings of Second International Conference on Modern Trends in Science, Engineering, and Technology. Publisher Zelus International, United Arab Emirates. ISBN 978-93-83303-81-6

Shahin, S. M., Ajaj, R. M., and Salem, M. A. 2015. Climate change and food security: Bridging the interaction gaps for future integrity. In: proceedings of the transitioning cereal systems to adapt to climate change. Minneapolis, USA. P 41.

Sinkaye, M. O., and Emelue, H. U. 2015. Natural radioactivity measurements and evaluation of radiological hazards in sediment of Oguta Lake, South East Nigeria. Journal of Radiation Research and Applied Sciences, 8: 459-469.

Smith, P., and Olesen, J. E. 2010. Synergies between the mitigation of, and adaptation to, climate change in agriculture. Journal of Agricultural Science, 148: 543–552.

Tevini M., and Teramura, A. H. 1989. UV-B Effects on Terres- trial Plants. Photochemistry and Photobiology, 50: 479-487.

Thabayneh, K. M., and Jazzar, M. M. 2012. Natural radioactivity levels and estimation of radiation exposure in environmental soil samples from Tulkarem Province-Palestine. Open Access Journal of Soil Science, 2: 7.

The United Nations Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: Synthesis report.

The United Nations Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Mitigation of Climate Change. The fifth assessment report.

The United Nations. 2011. World populations policies: The demographic profile of the United Arab Emirates.

The World Bank. 2014. World development indicators: data for United Arab Emirates, Washington, USA.

The World Bank. 2016. World development indicators: data for United Arab Emirates, Washington, USA.

Tufail, M., Akhtar, N., and Waqas, M. 2006. Measurement of terrestrial radiation for assessment of gamma dose from cultivated and barren saline soils of Faisalabad in Pakistan. Radiation Measurements, 41: 443-451.

U.S Nuclear Regulatory Commission. 1981. Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) – Effluent Streams and Environment,".

United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR). 1993. Sources and Effects of Ionizing Radiation. UNSCEAR Report, New York.

United Nations. Scientific Committee on the Effects of Atomic Radiation. 2000. Sources and effects of ionizing radiation: sources (Vol. 1). United Nations Publications.

Wang, W., Vinocur B., and Altman, A. 2003. Plant responses to drought, salinity, and extreme temperatures: towards genetic engineering for stress tolerance. Planta, 218, 1–14.

Wang, Y., and Frei, M. 2011. Stressed food–The impact of abiotic environmental stresses on crop quality. Agriculture. Ecosystems and Environment, 141: 271-286.

Wasim, M., Ali, M., and Iqbal, S. 2015. Assessment of the risk associated with the gamma-emitting radionuclides from the soil of two cities in Central Karakorum. Journal of Radioanalytical and Nuclear Chemistry, 303: 985-991.

Worldometers.info. Dover, Delaware, U.S.A. (2 March, 2017).

Yıldız, N., Oto, B., Turhan, Ş., Uğur, F. A., and Gören, E. 2014. Radionuclide determination and radioactivity evaluation of surface soil samples collected along the Erçek Lake basin in eastern Anatolia, Turkey. Journal of Geochemical Exploration, 146: 34-39.

Zlatev, Z. S., Lidon, J. C., and Kaimakanova, M. 2012. Plant physiological responses to UV-B radiation. Emirates Journal of Food and Agriculture, 24:6.

Zuk-Golaszewska, K., Upadhyaya, M. K., and Golaszewski, J. 2003. The effect of UV-B radiation on plant growth and development. Plant Soil and Environment, 49: 135-140.

Appendix

Radiological Maps

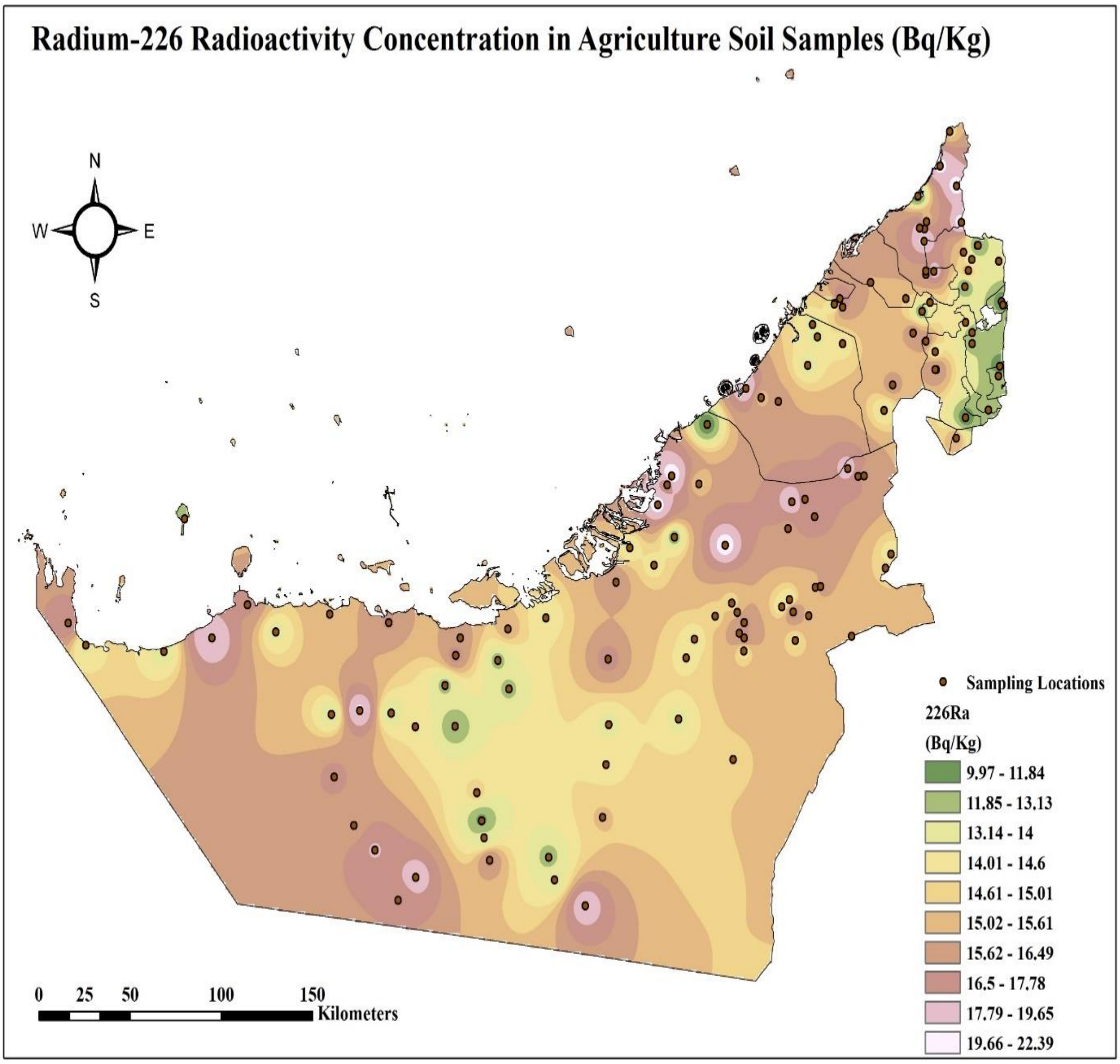


Figure 22: The radiological map of Radium-226 radioactivity concentration in agriculture soil samples (Bq/Kg)

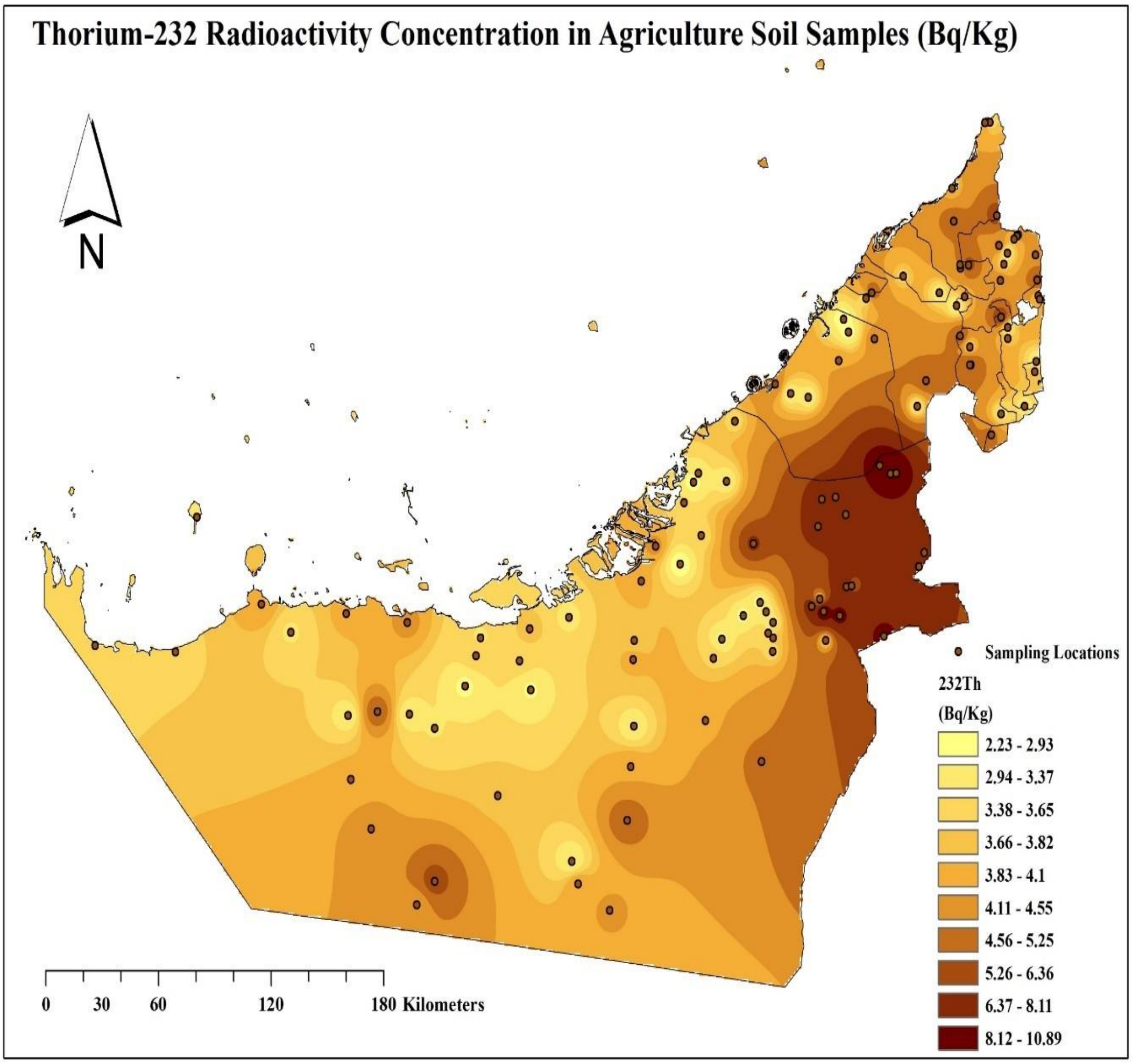


Figure 23: The radiological map of Thorium-232 radioactivity concentration in agriculture soil samples (Bq/Kg)

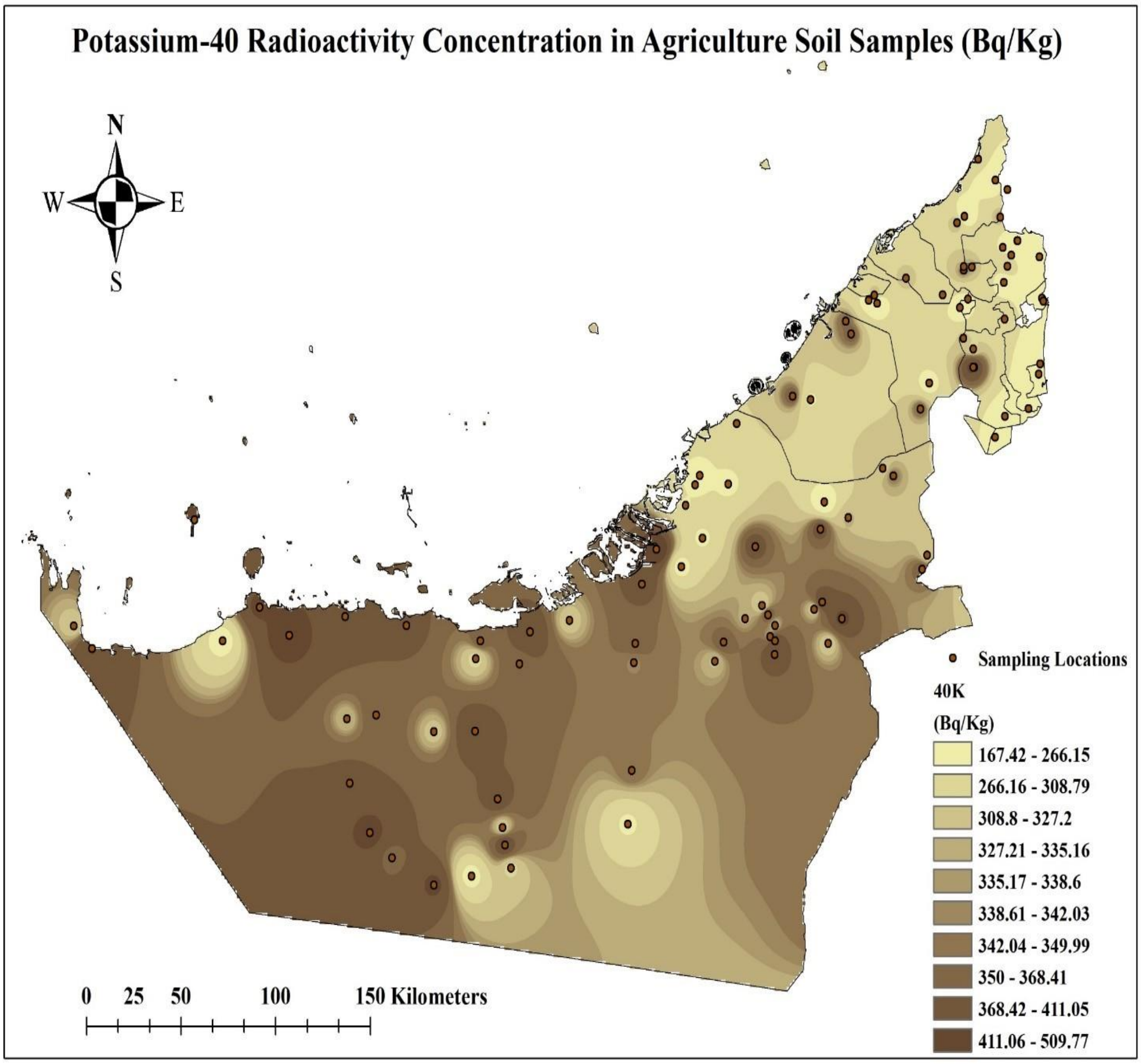


Figure 24: The radiological map of Potassium-40 radioactivity concentration in agriculture soil samples (Bq/Kg)

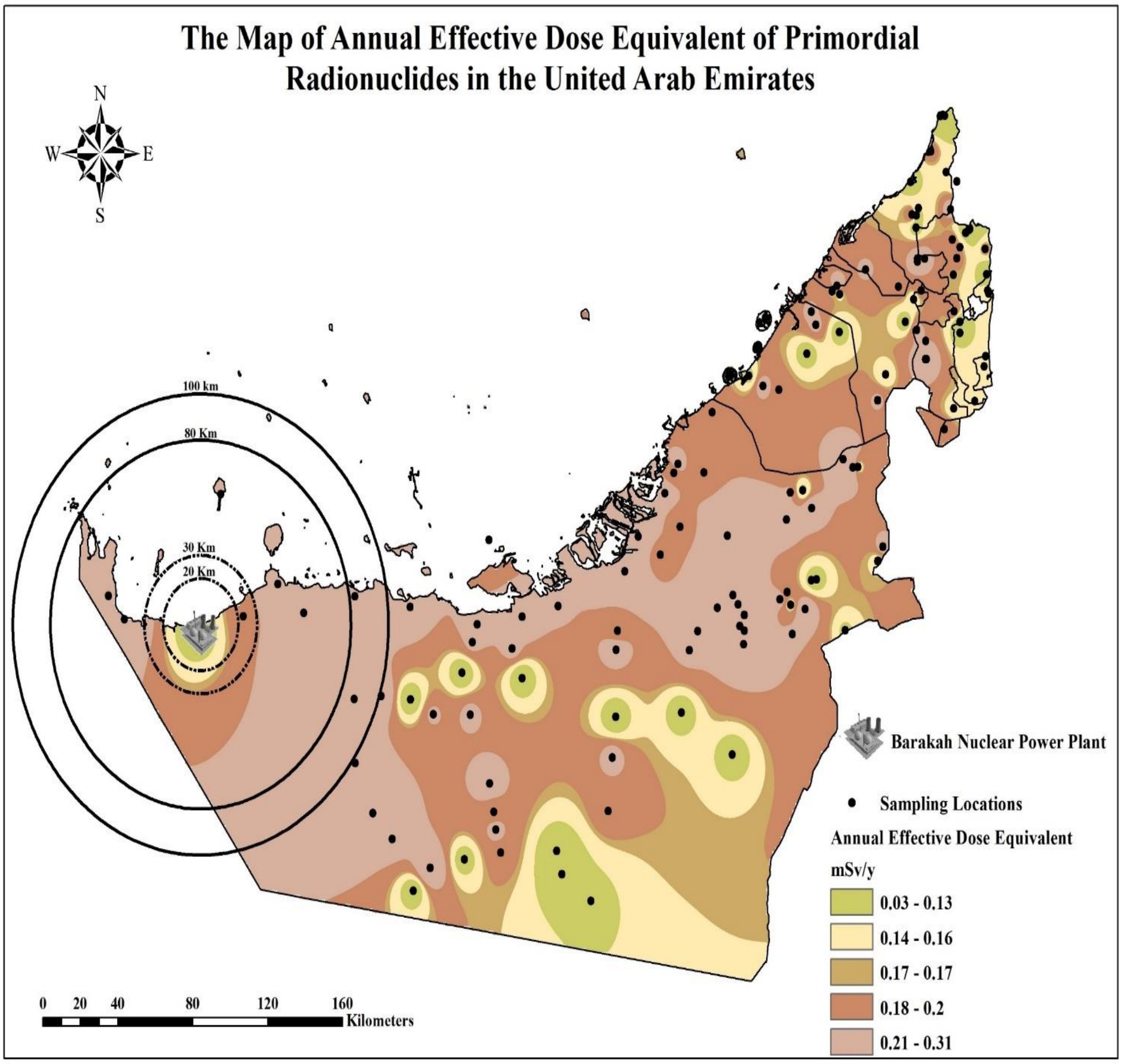


Figure 25: The radiological map of annual effective dose equivalent of primordial radionuclides in the United Arab Emirates

Minerals Maps

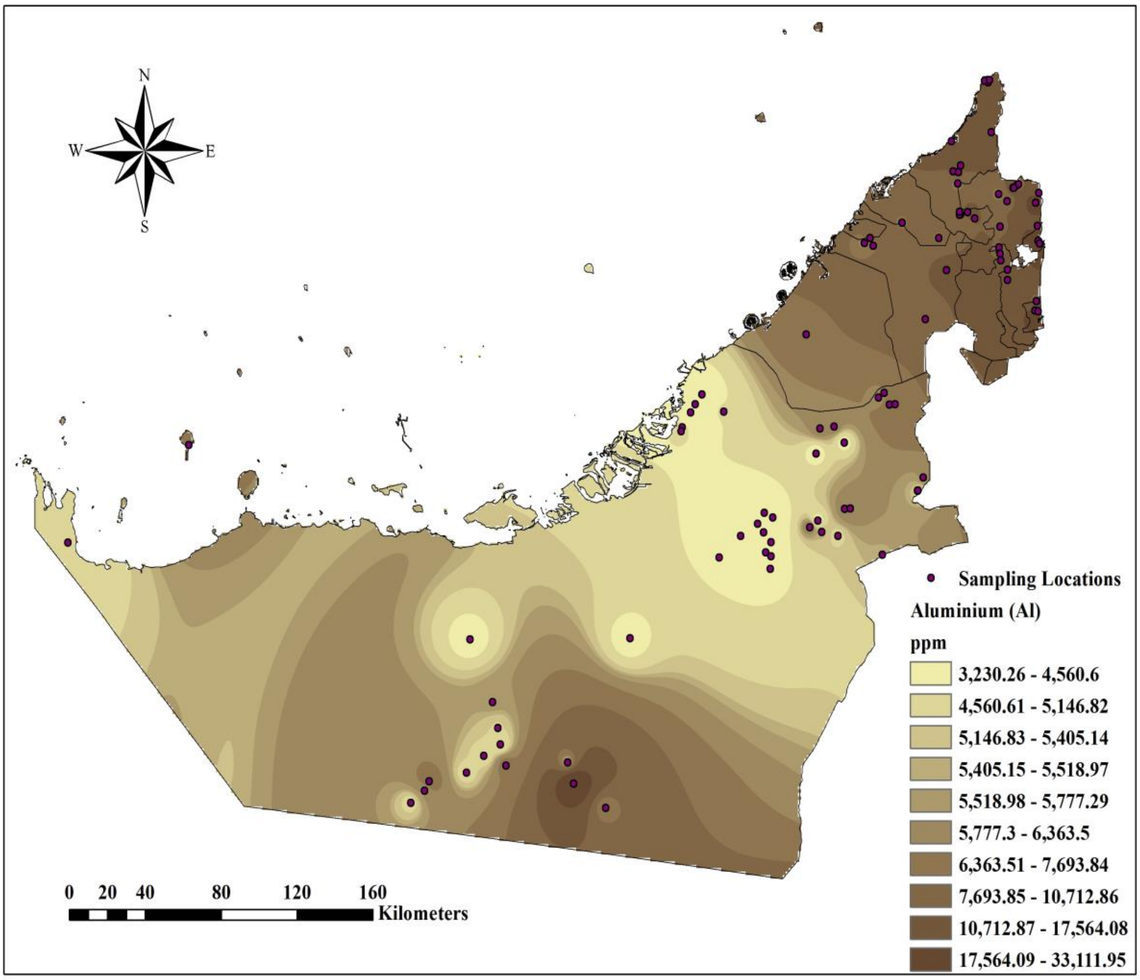


Figure 26: Aluminum (Al) fingerprint of agriculture soils of the United Arab Emirates

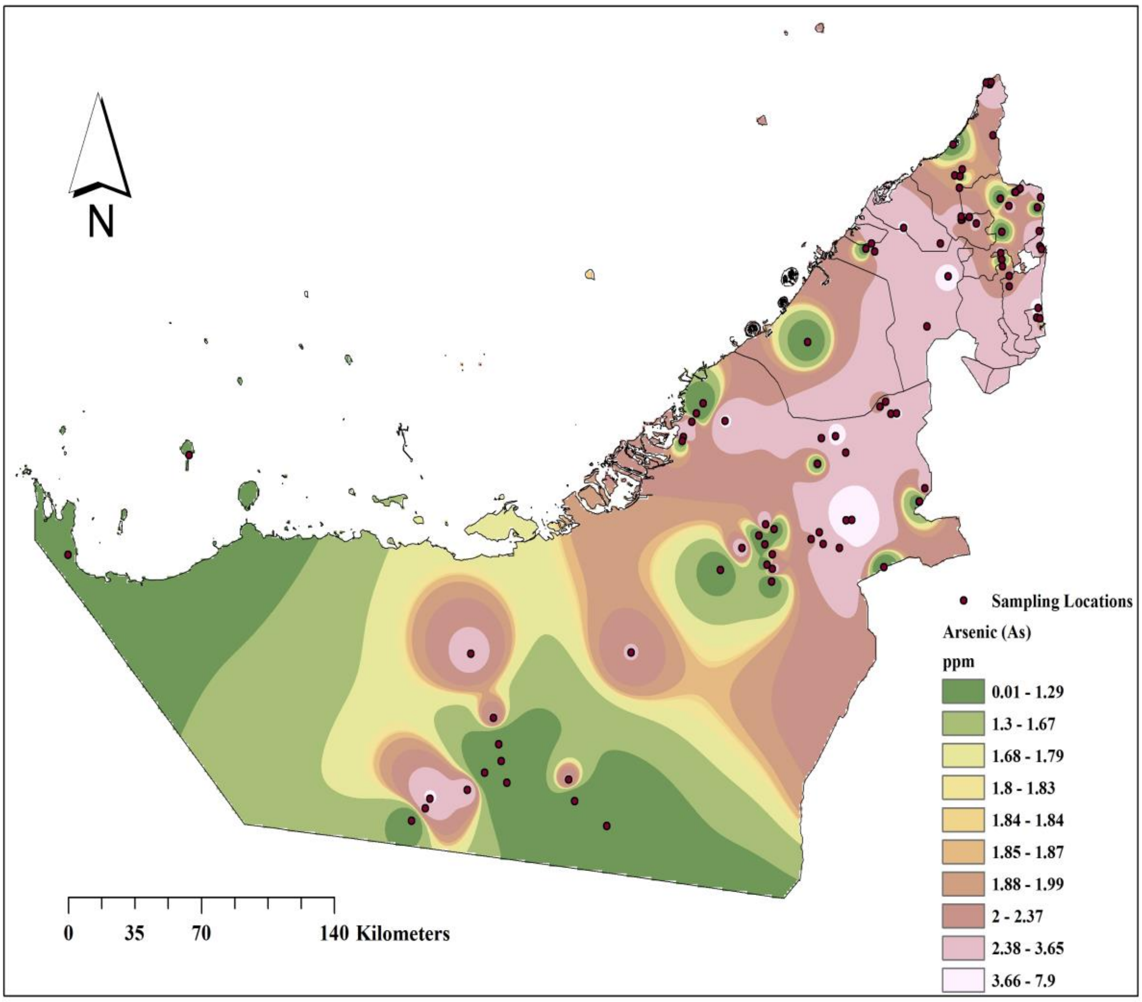


Figure 27: Arsenic (As) fingerprint of agriculture soils of the United Arab Emirates

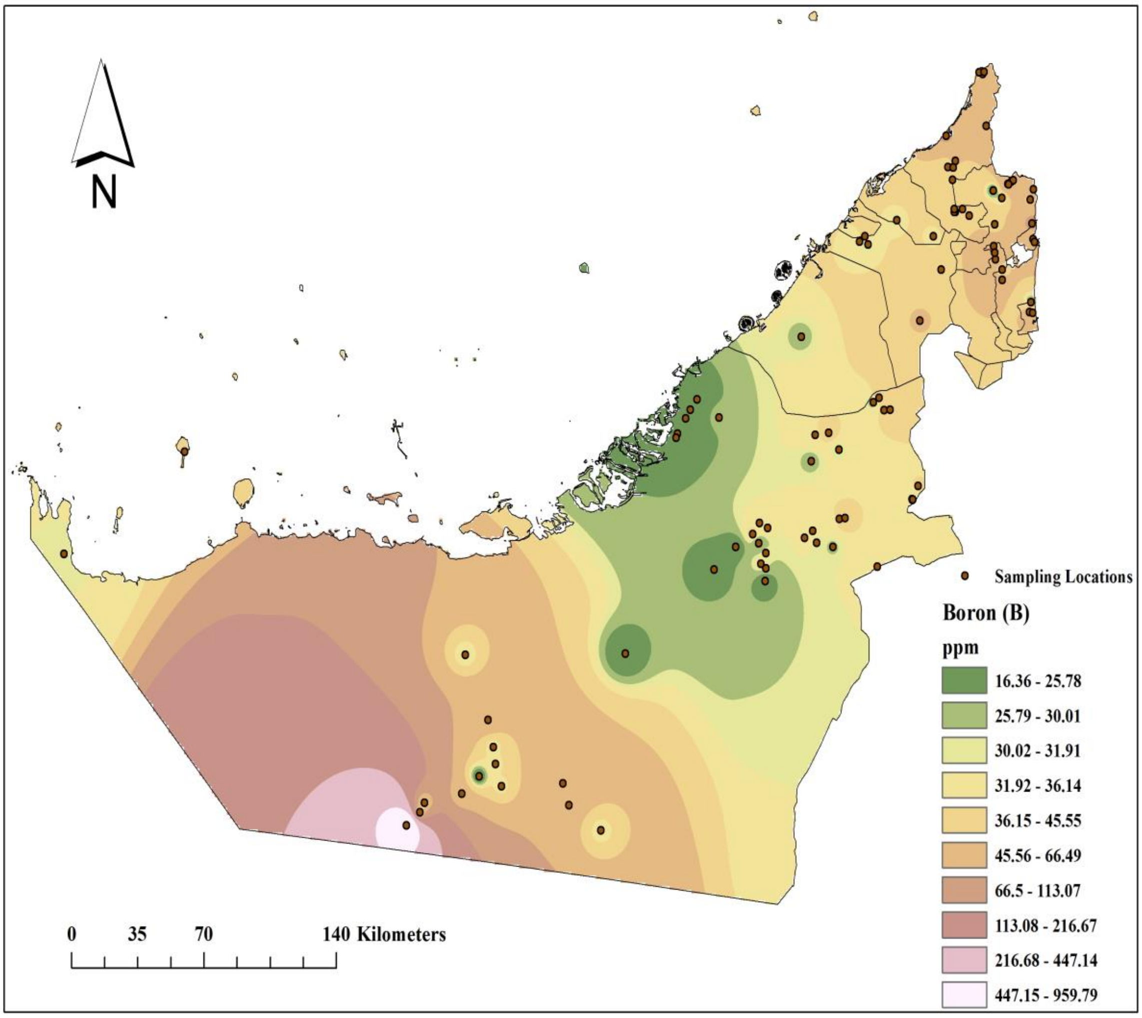


Figure 28: Boron (B) fingerprint of agriculture soils of the United Arab Emirates

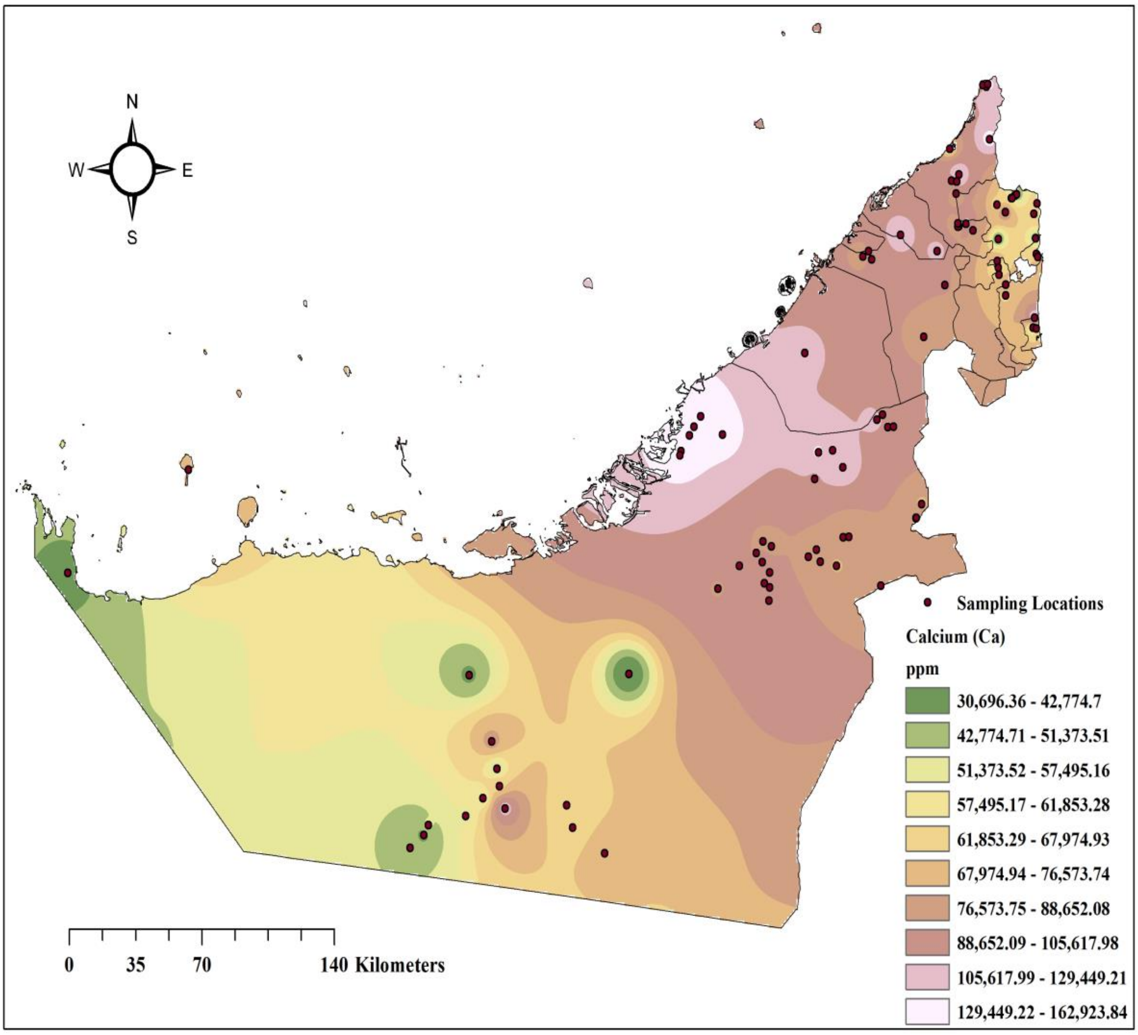


Figure 29: Calcium (Ca) fingerprint of agriculture soils of the United Arab Emirates

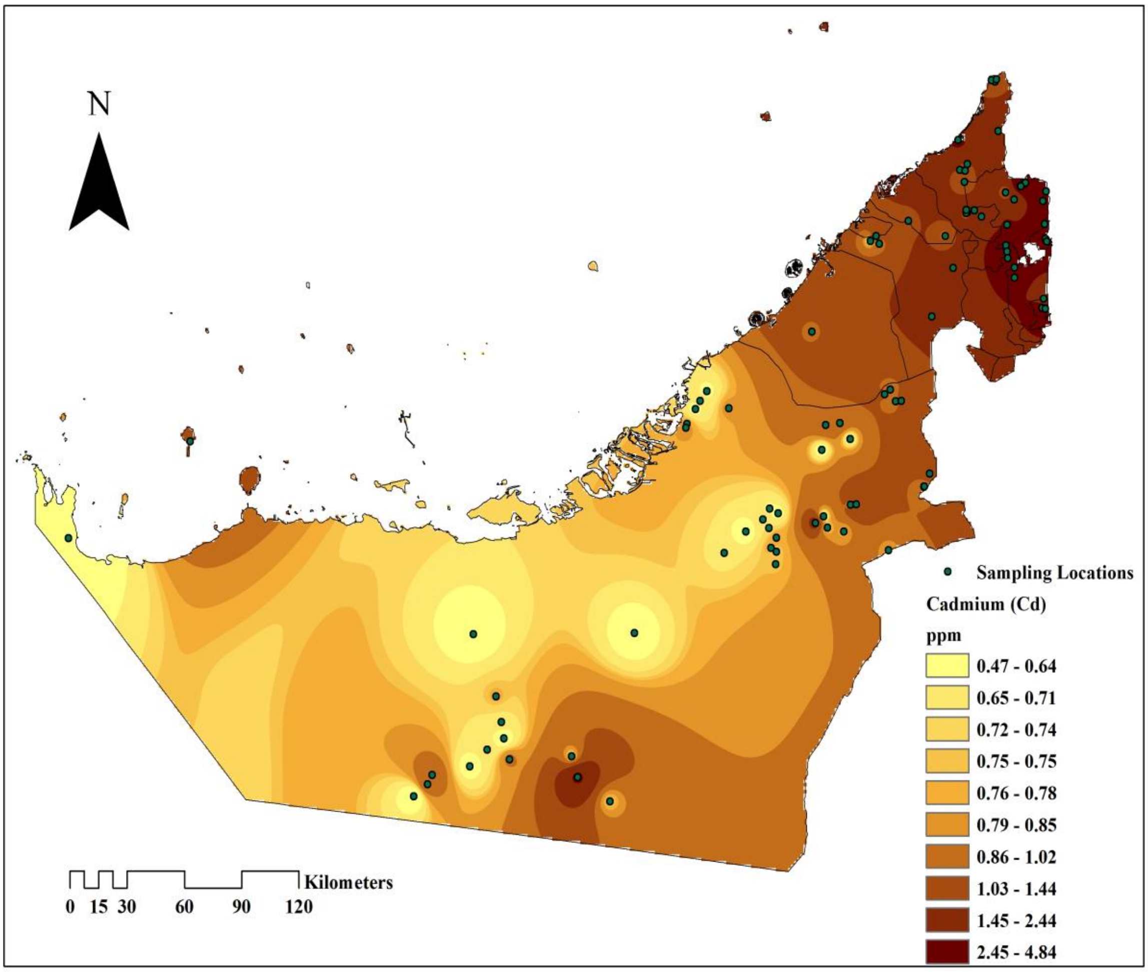


Figure 30: Cadmium (Cd) fingerprint of agriculture soils of the United Arab Emirates

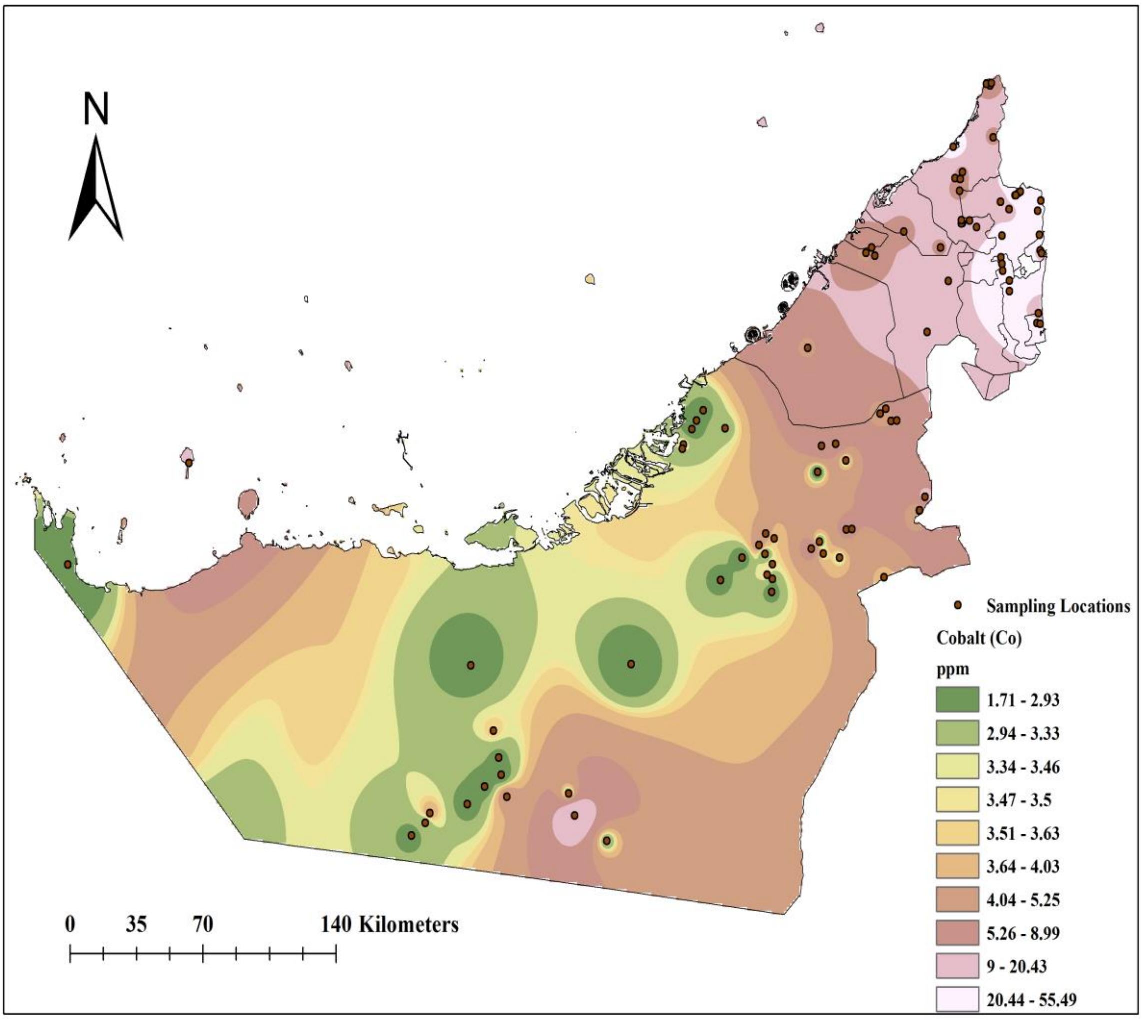


Figure 31: Cobalt (Co) fingerprint of agriculture soils of the United Arab Emirates

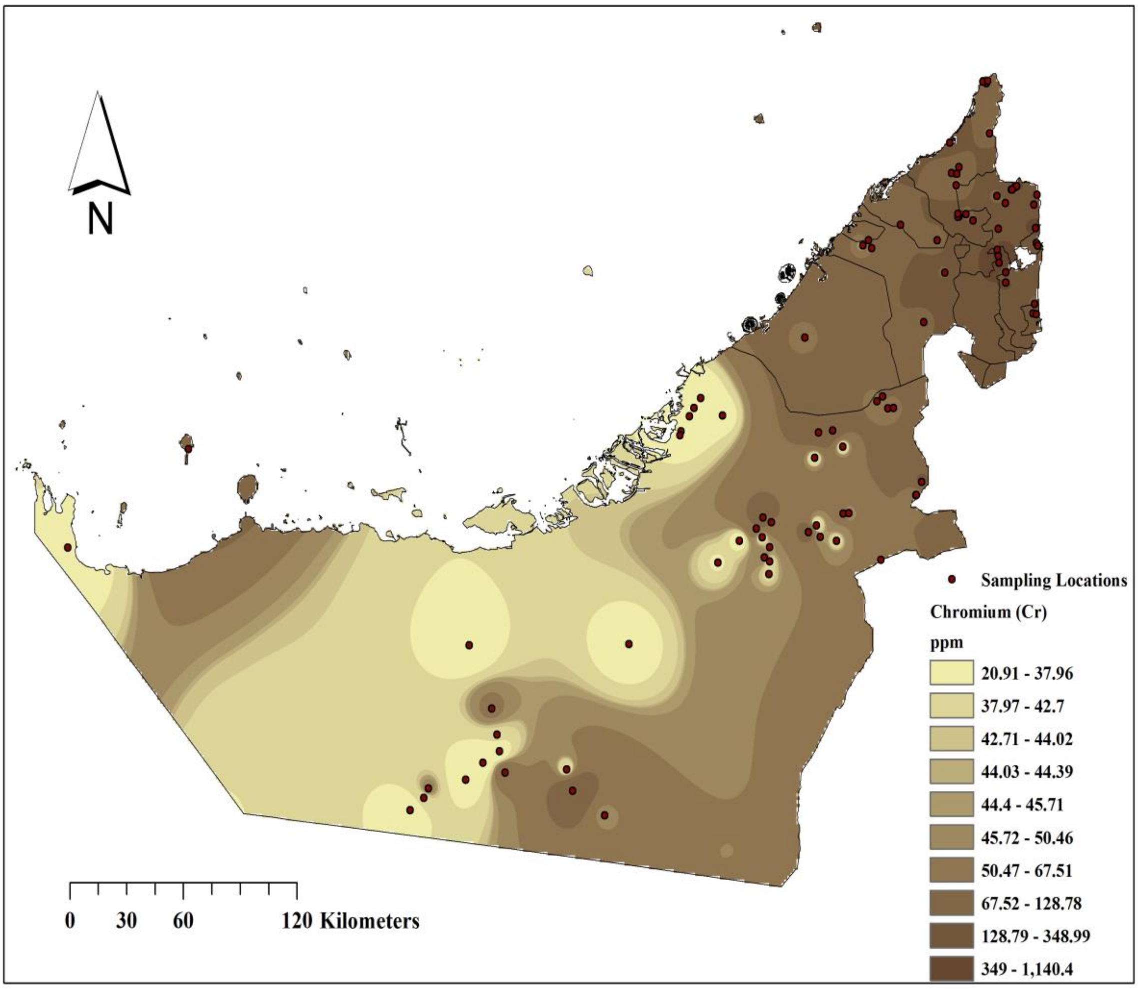


Figure 32: Chromium (Cr) fingerprint of agriculture soils of the United Arab Emirates

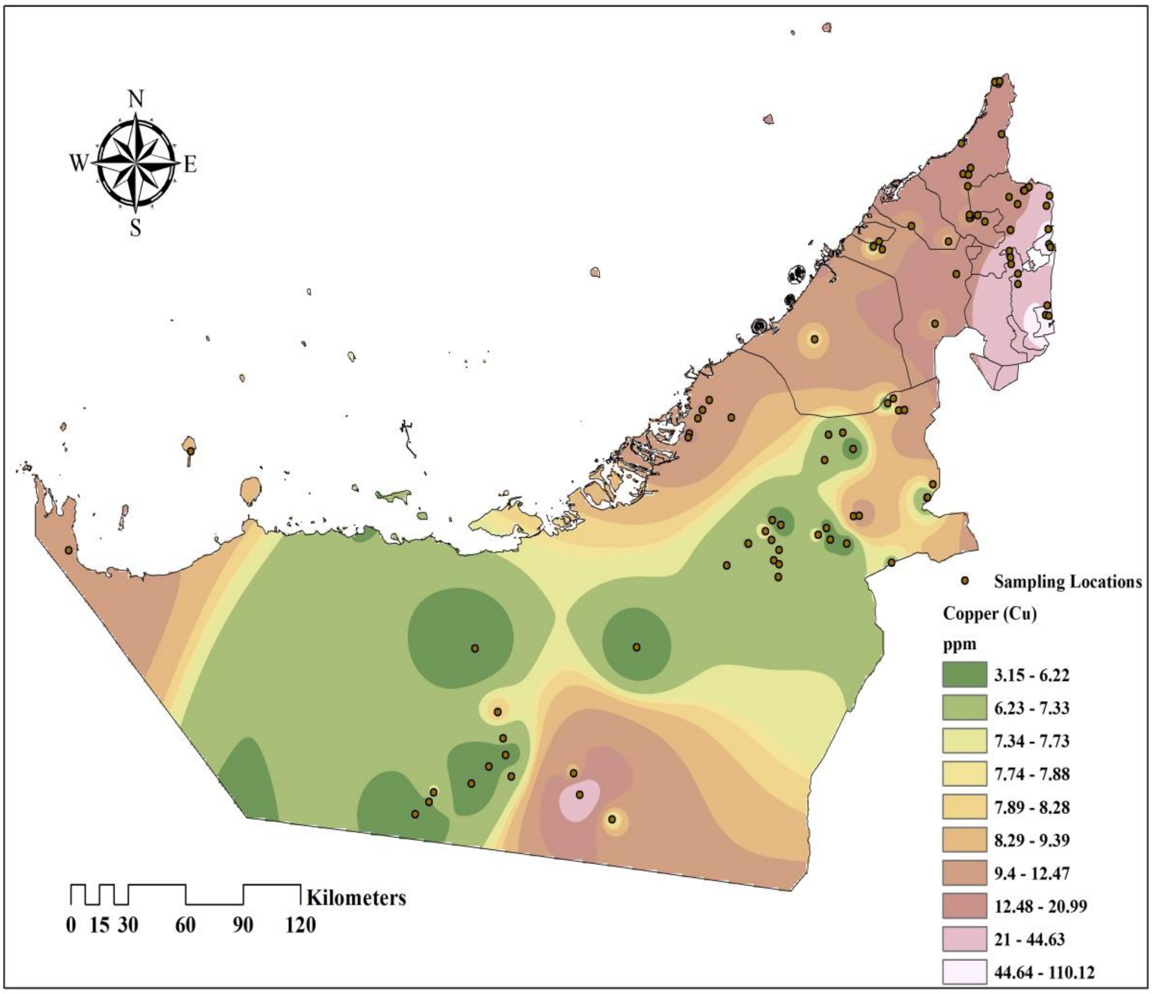


Figure 33: Copper (Cu) fingerprint of agriculture soils of the United Arab Emirate

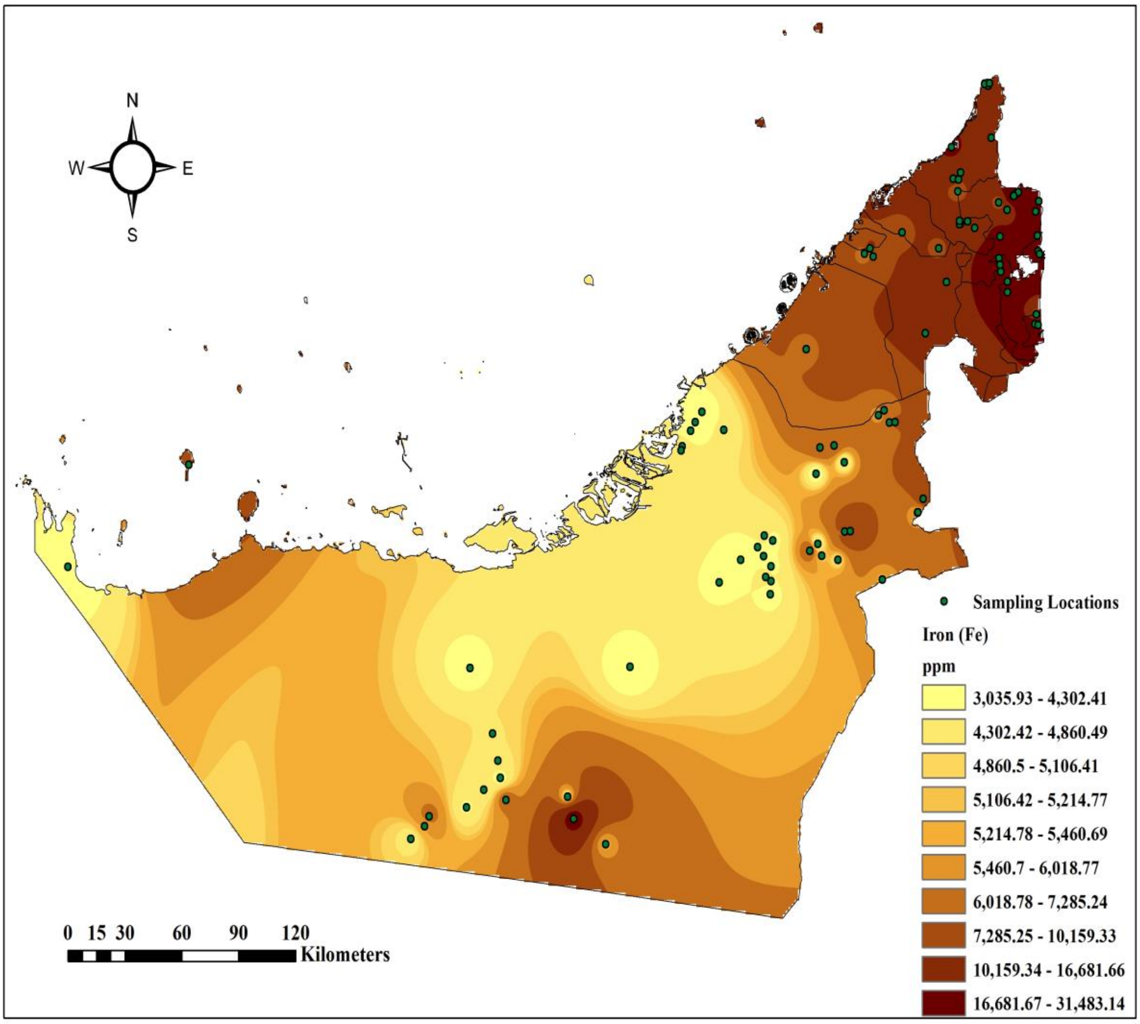


Figure 34: Iron (Fe) fingerprint of agriculture soils of the United Arab Emirates

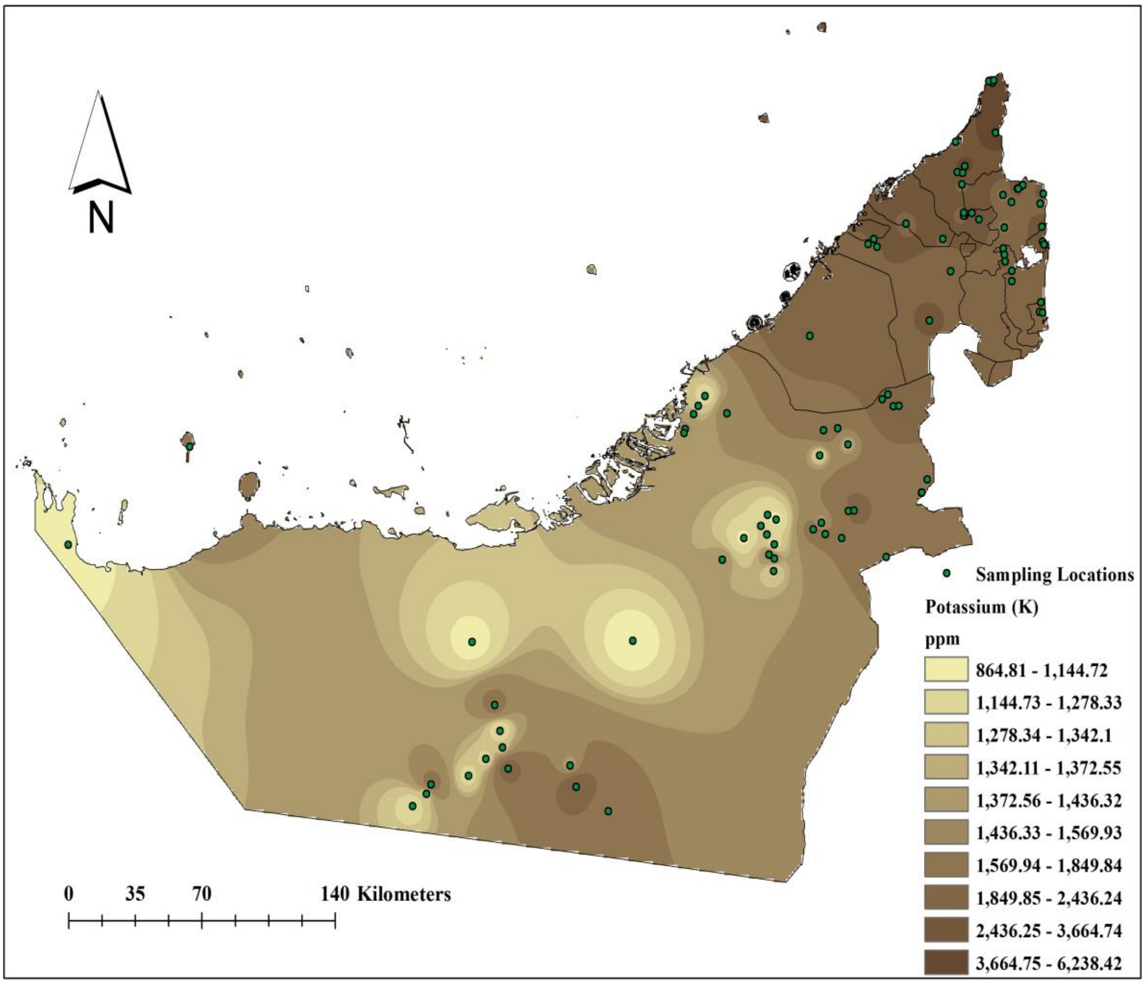


Figure 35: Potassium (K) fingerprint of agriculture soils of the United Arab Emirates

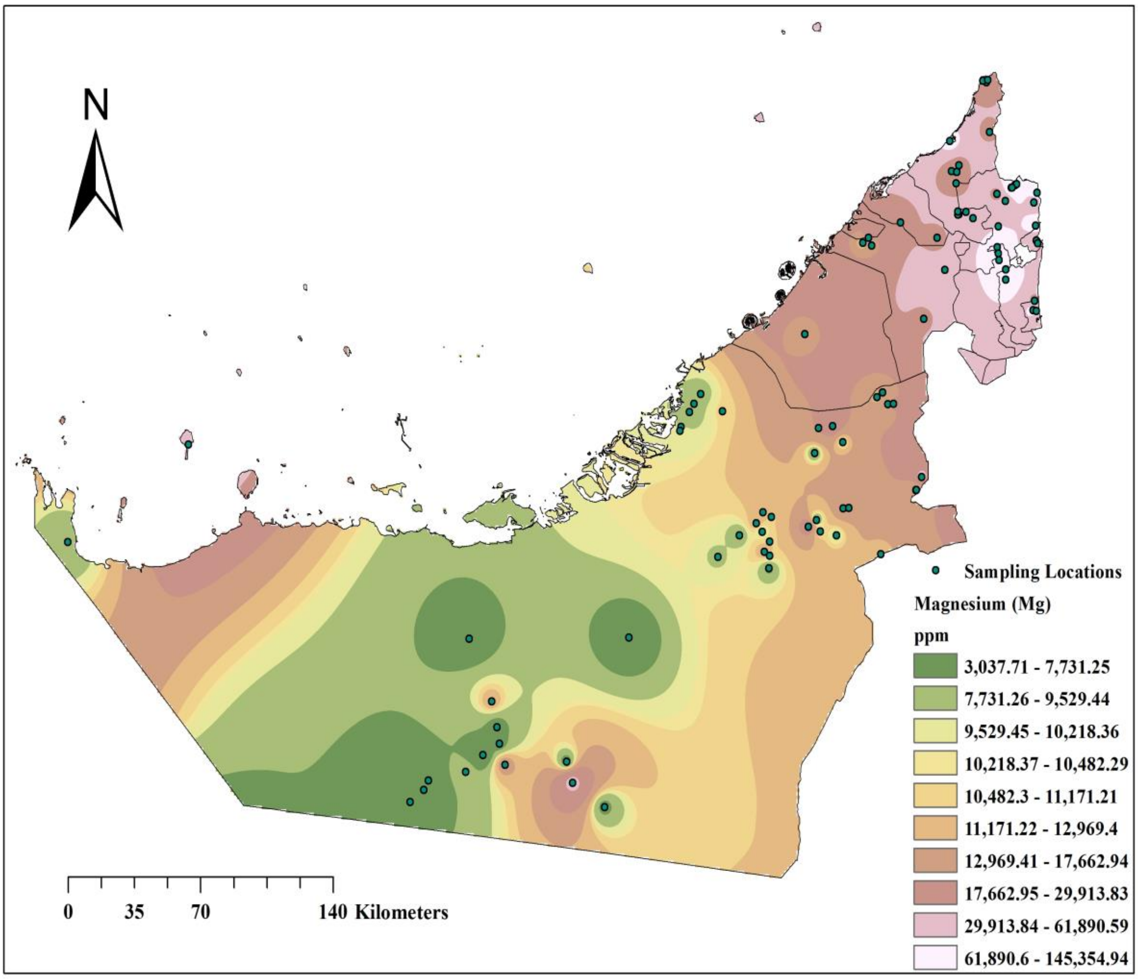


Figure 36: Magnesium (Mg) fingerprint of agriculture soils of the United Arab Emirates

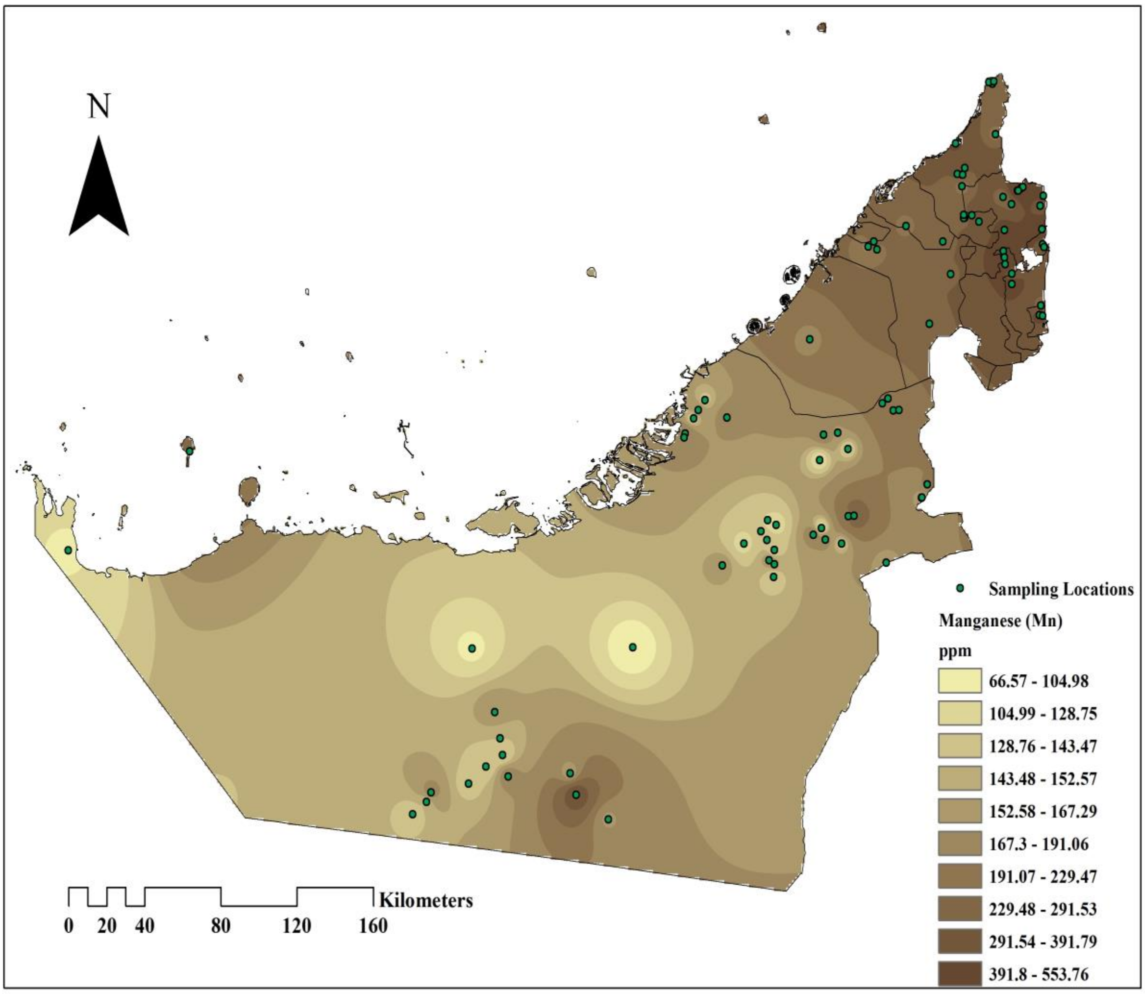


Figure 37: Manganese (Mn) fingerprint of agriculture soils of the United Arab Emirates

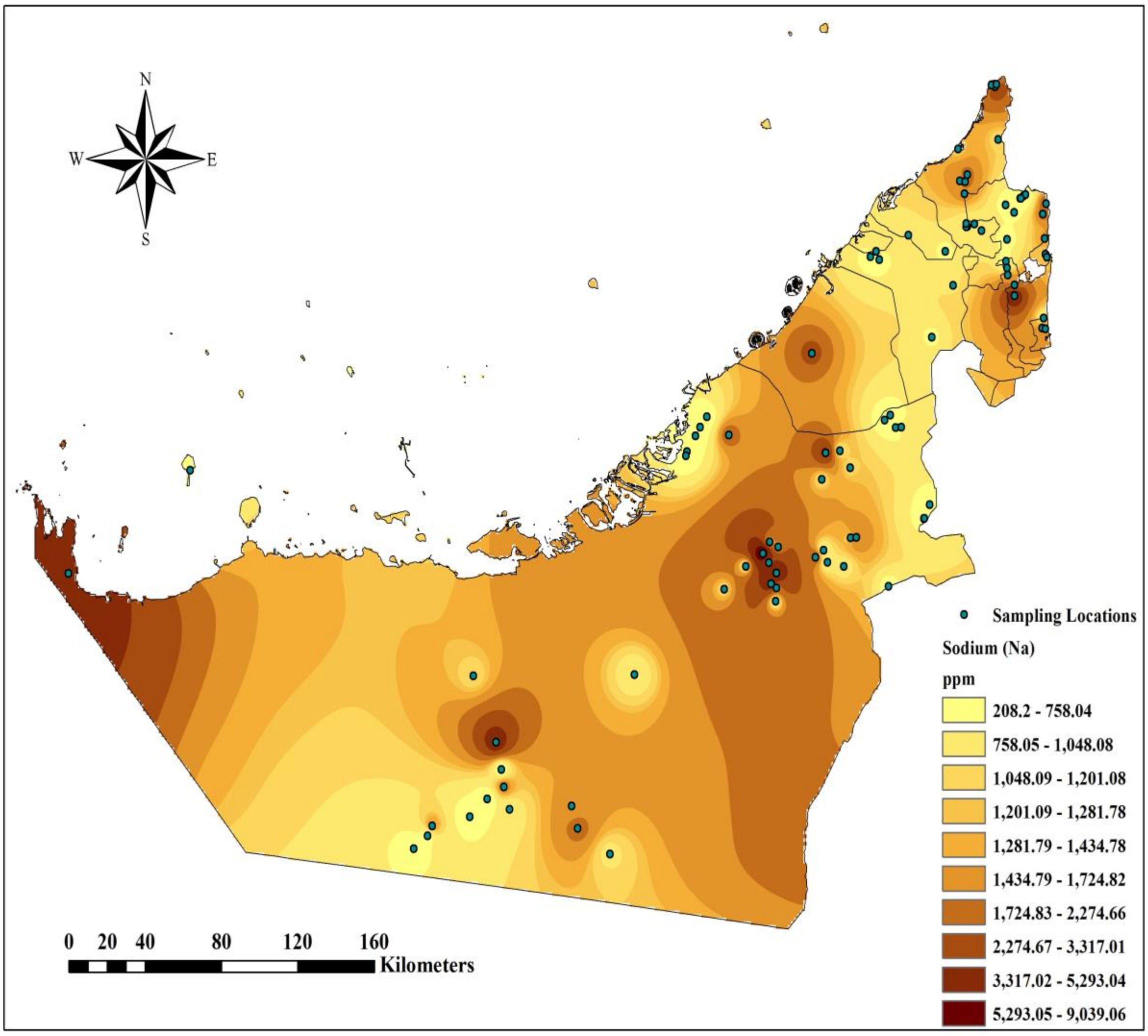


Figure 38: Sodium (Na) fingerprint of agriculture soils of the United Arab Emirates

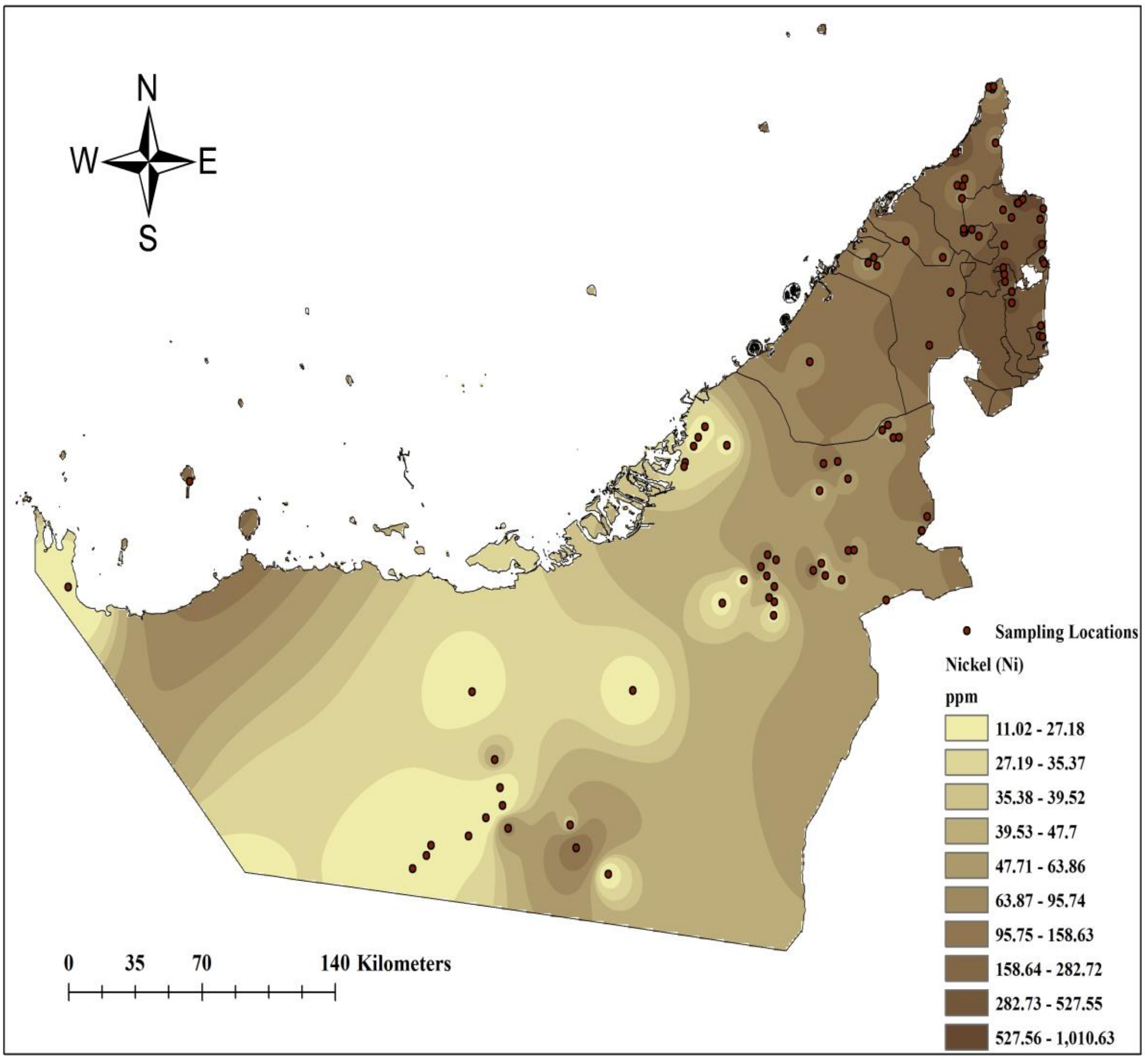


Figure 39: Nickel (Ni) fingerprint of agriculture soils of the United Arab Emirates

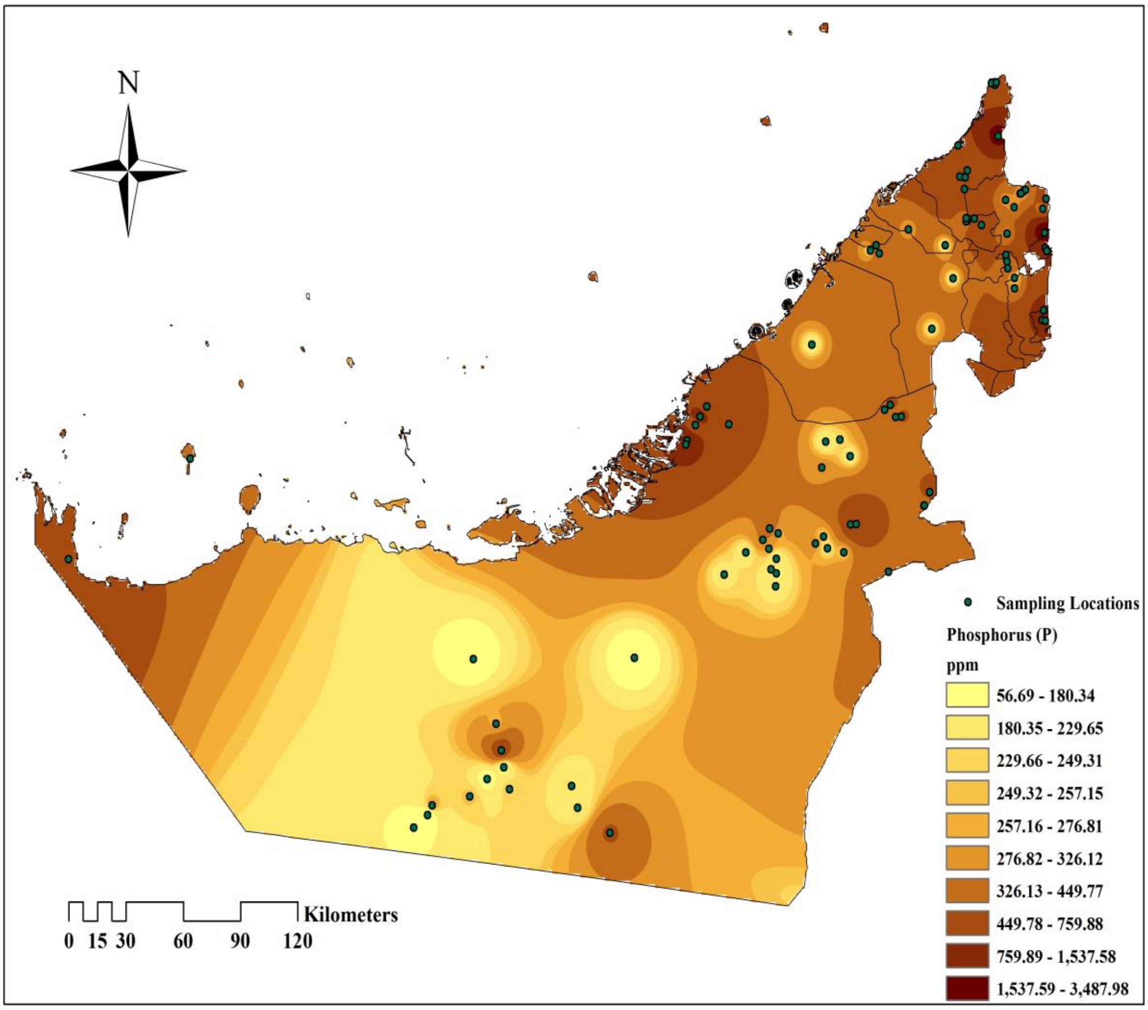


Figure 40: Phosphorus (P) fingerprint of agriculture soils of the United Arab Emirates

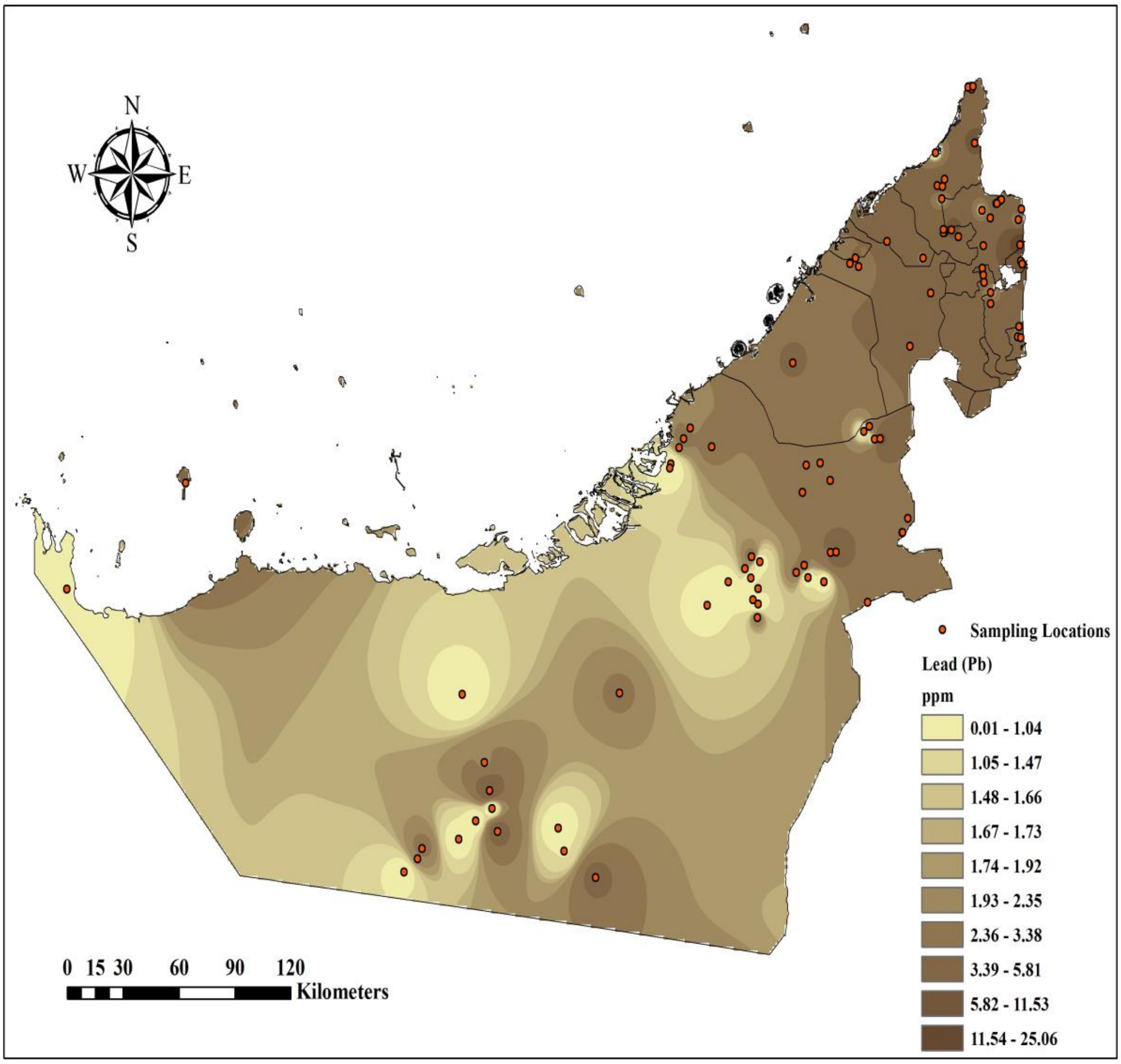


Figure 41: Lead (Pb) fingerprint of agriculture soils of the United Arab Emirates

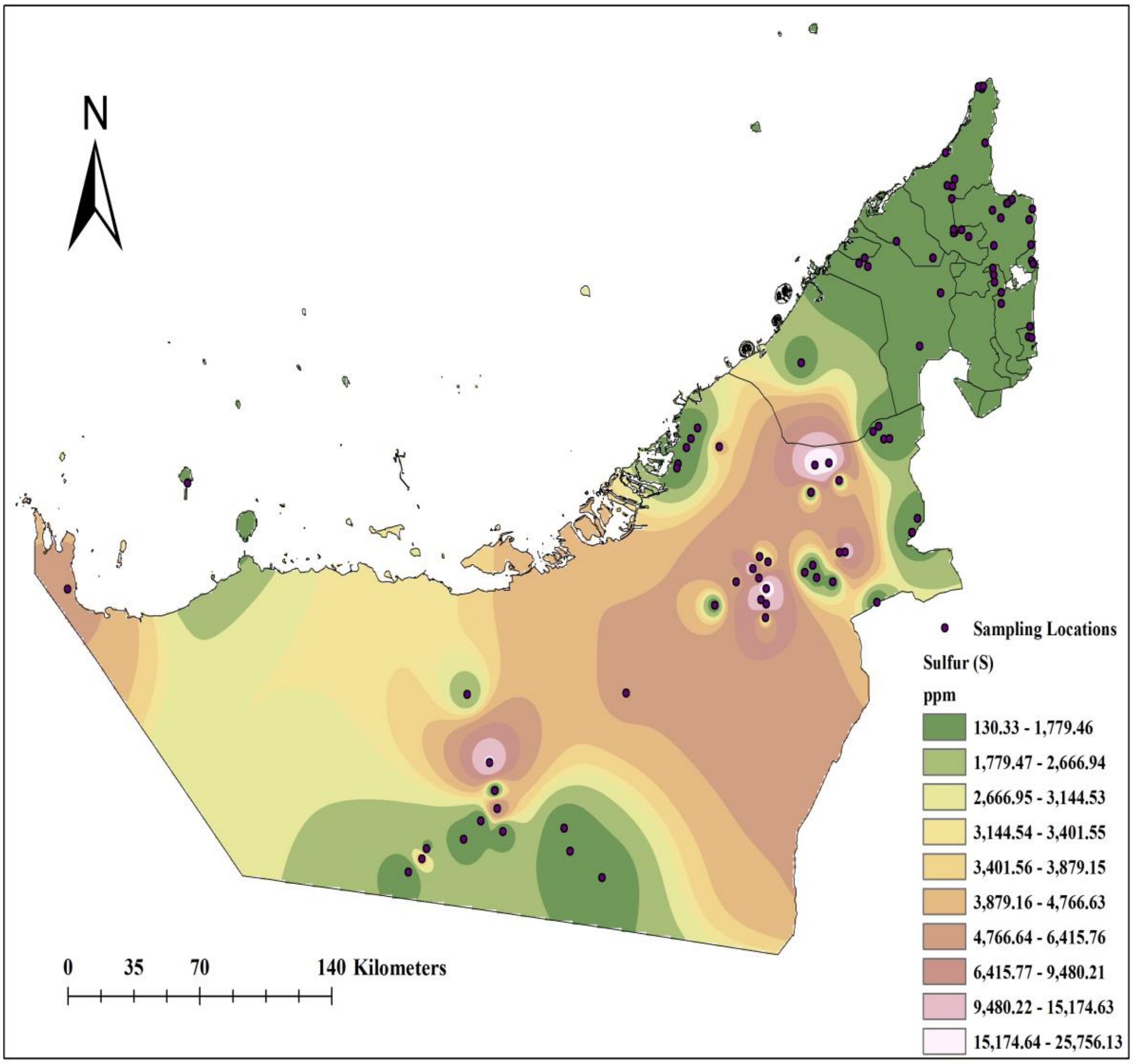


Figure 42: Sulfur (S) fingerprint of agriculture soils of the United Arab Emirates

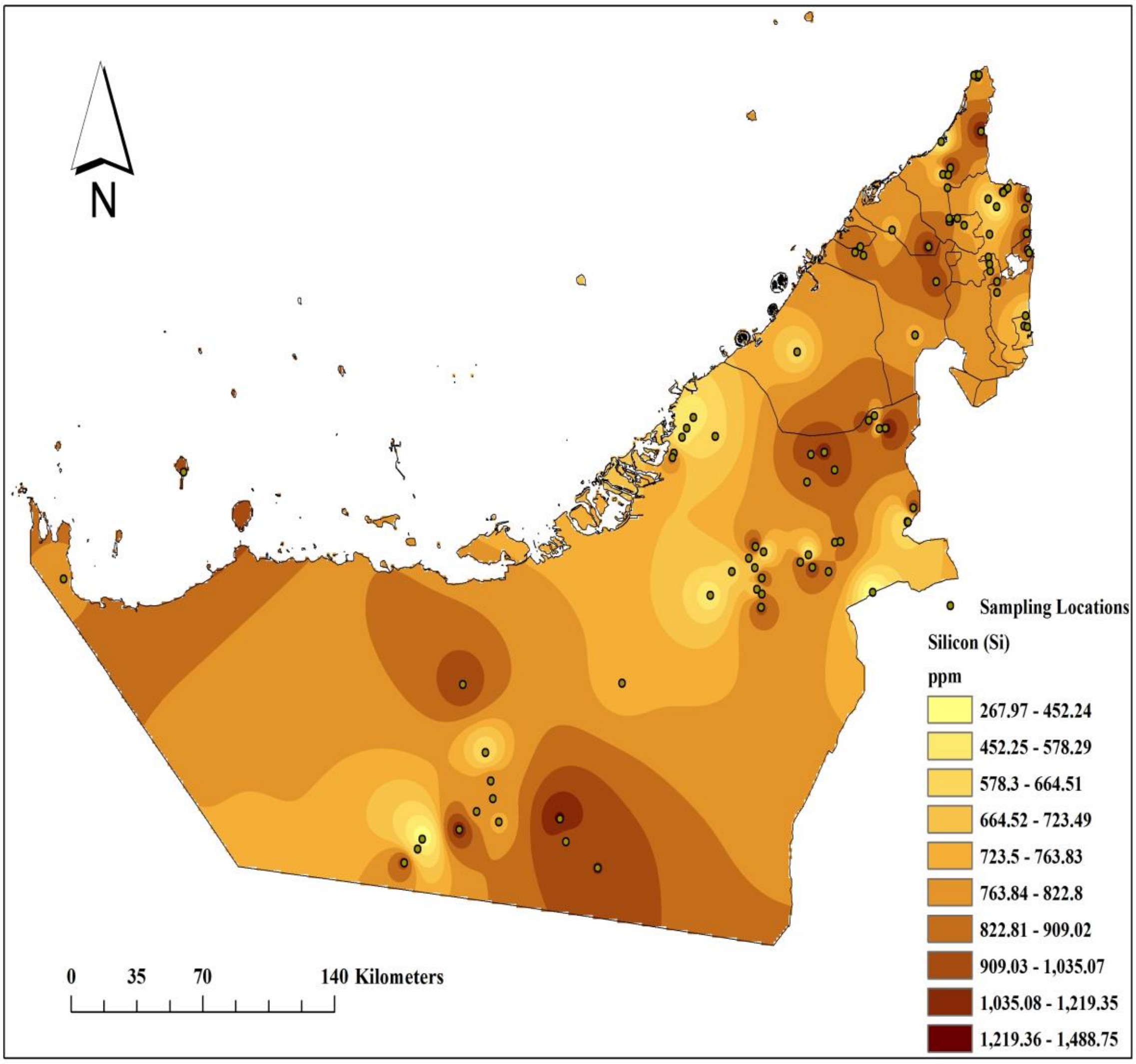


Figure 43: Silicon (Si) fingerprint of agriculture soils of the United Arab Emirates

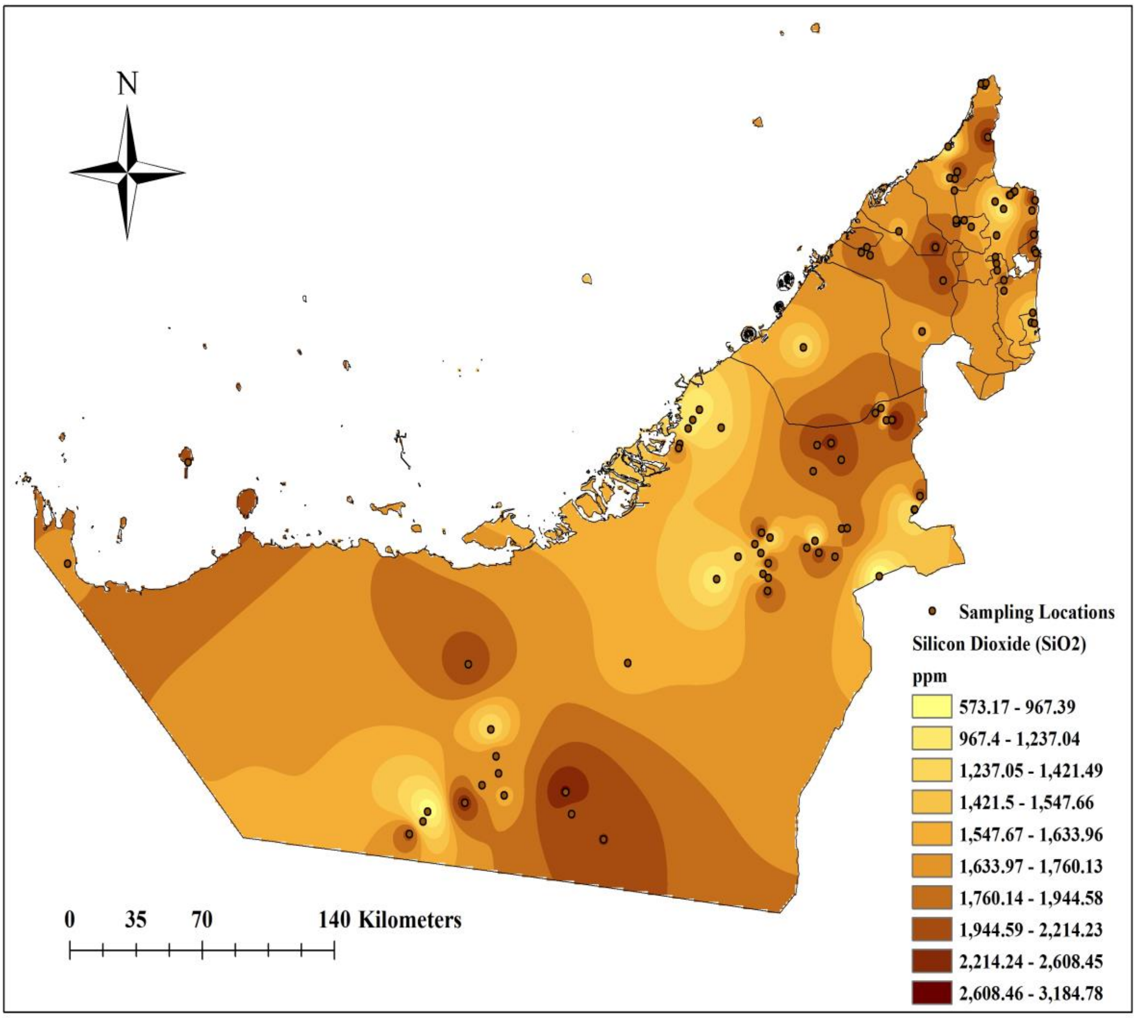


Figure 44: Silicon dioxide (SiO_2) fingerprint of agriculture soils of the United Arab Emirates

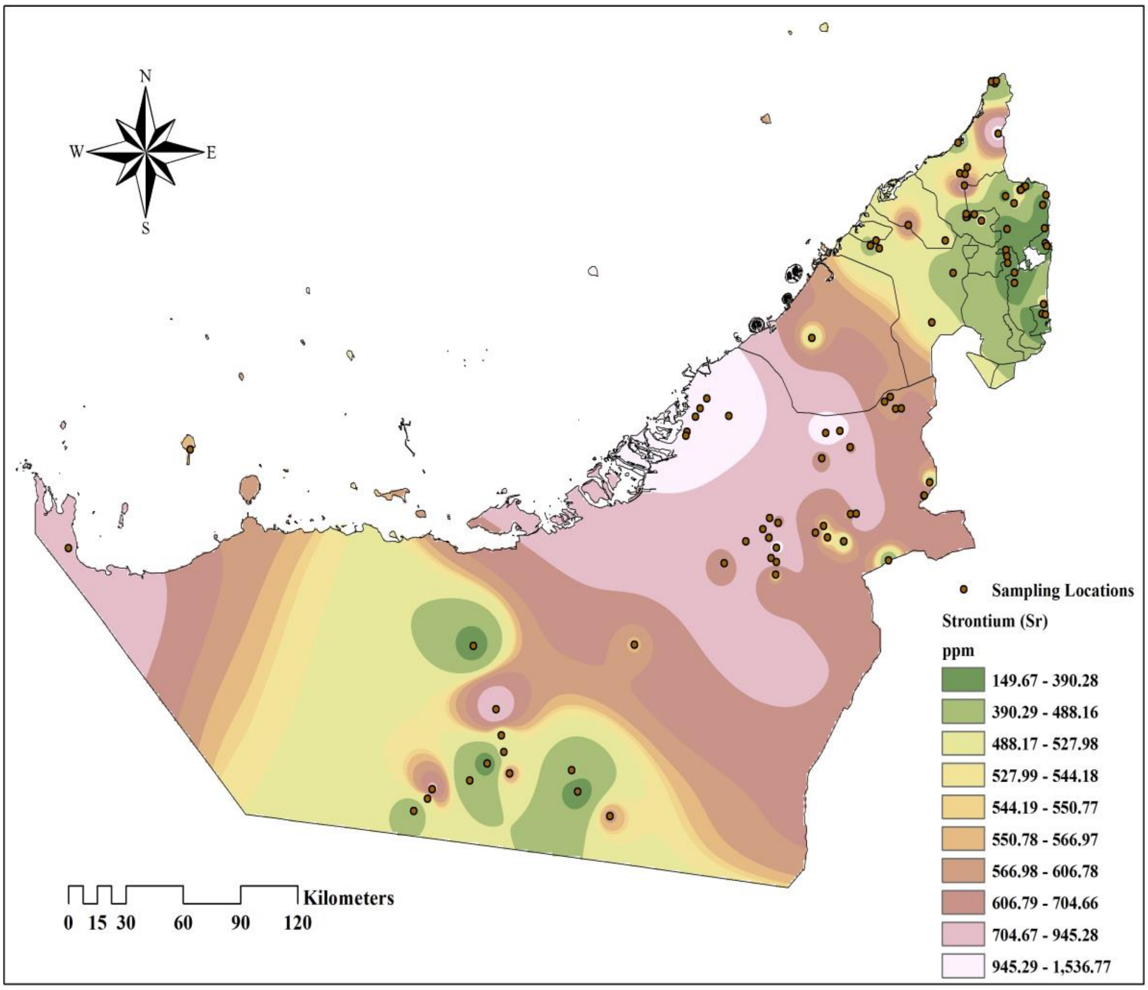


Figure 45: Strontium (Sr) fingerprint of agriculture soils of the United Arab Emirates

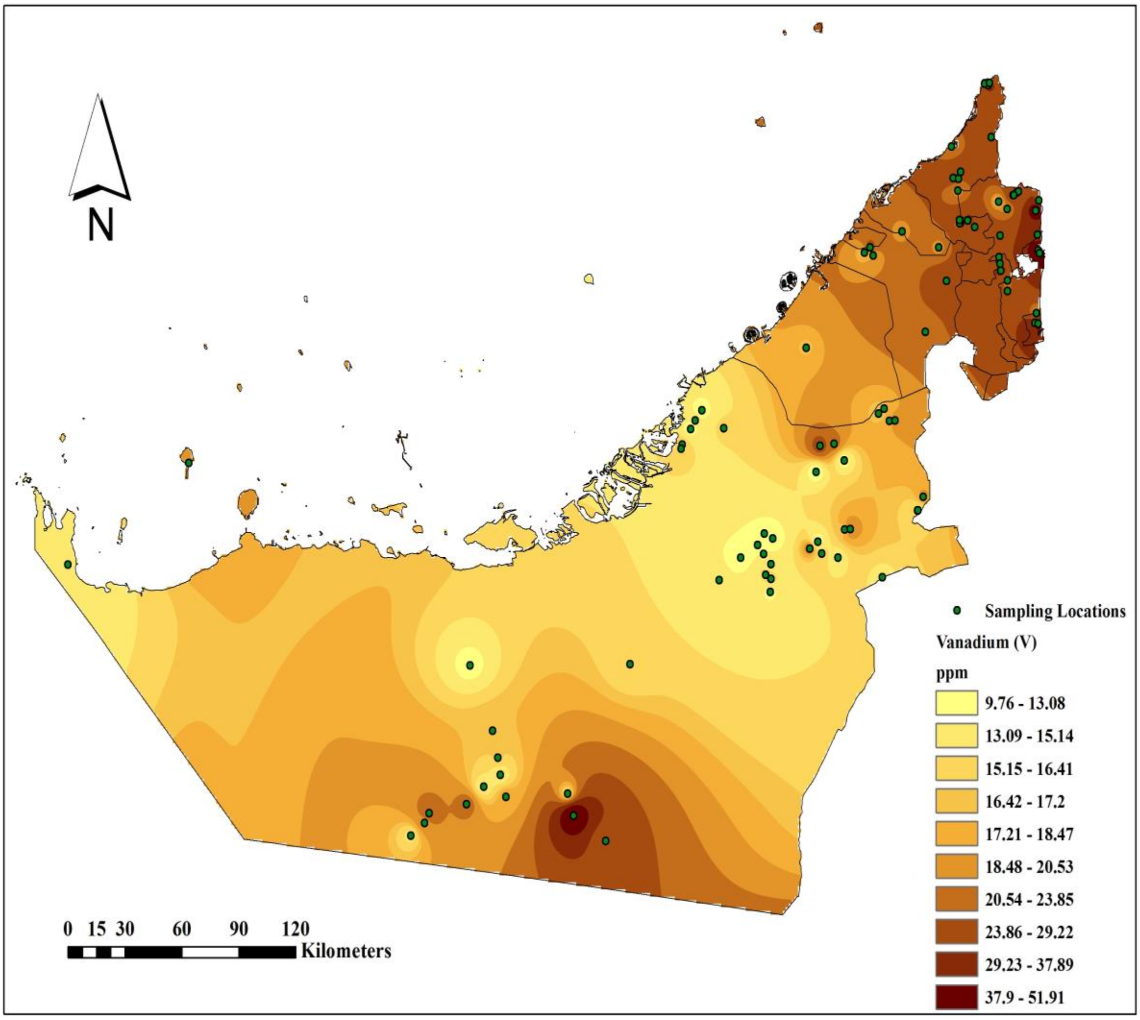


Figure 46: Vanadium (V) fingerprint of agriculture soils of the United Arab Emirates

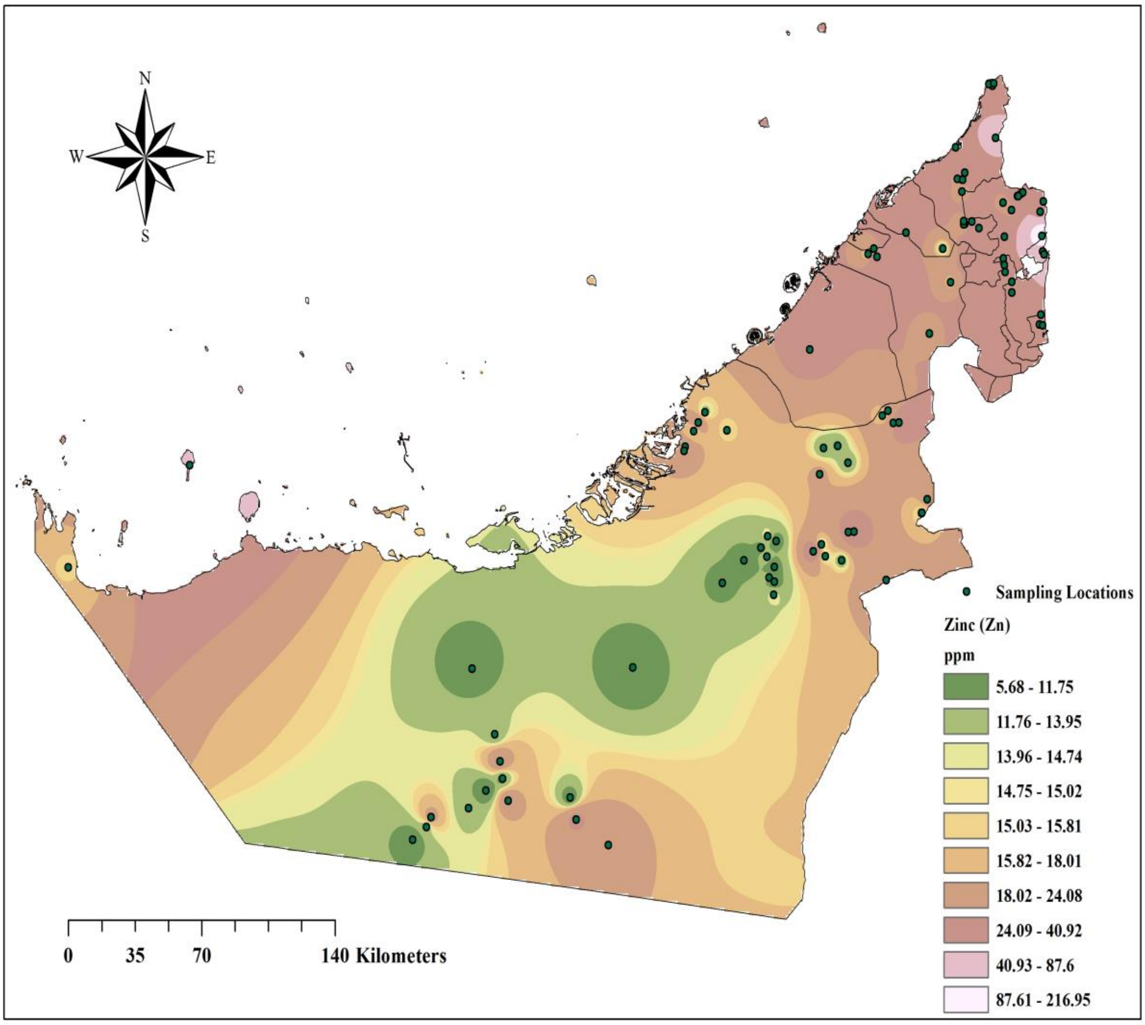


Figure 47: Zinc (Zn) fingerprint of agriculture soils of the United Arab Emirates

Efficiency Curves

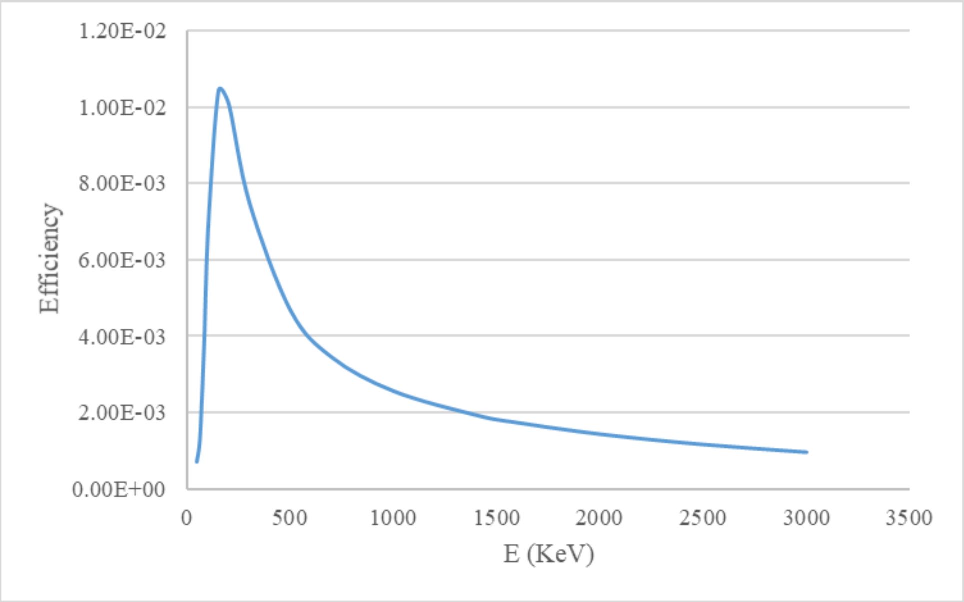


Figure 48: Efficiency calibration curve obtained for the reference geometry (height: 6.7cm, density 1.2gm/cm^3)

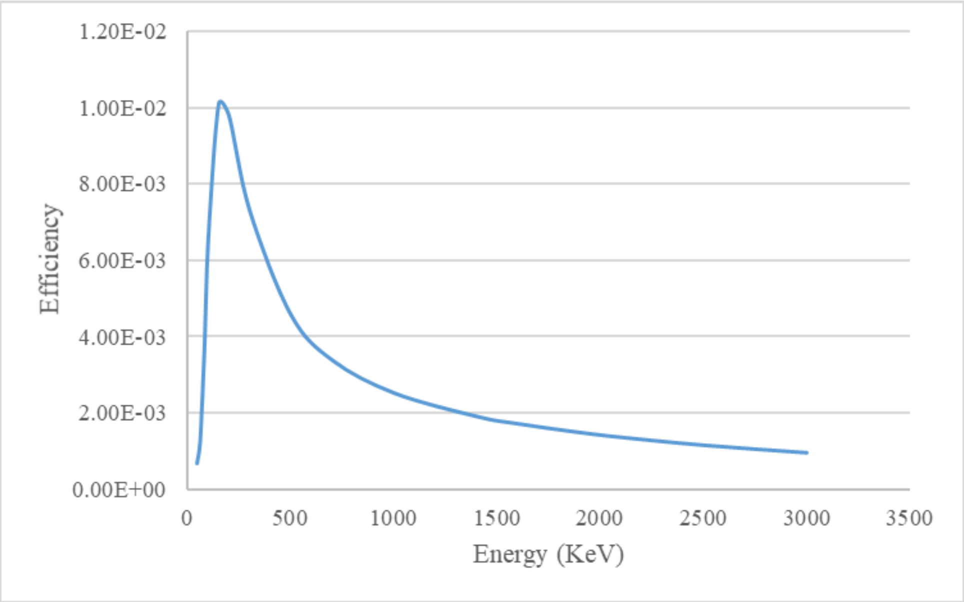


Figure 49: Efficiency calibration curve obtained for the reference geometry (height: 6.7cm, density 1.4 gm/cm^3)

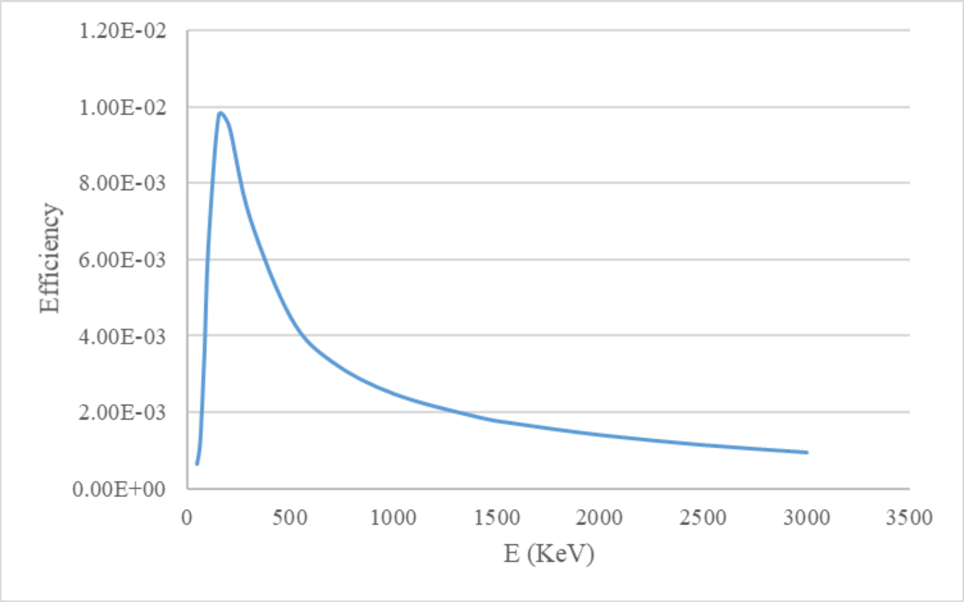


Figure 50: Efficiency calibration curve obtained for the reference geometry (height: 6.7cm, density 1.6 gm/cm^3)

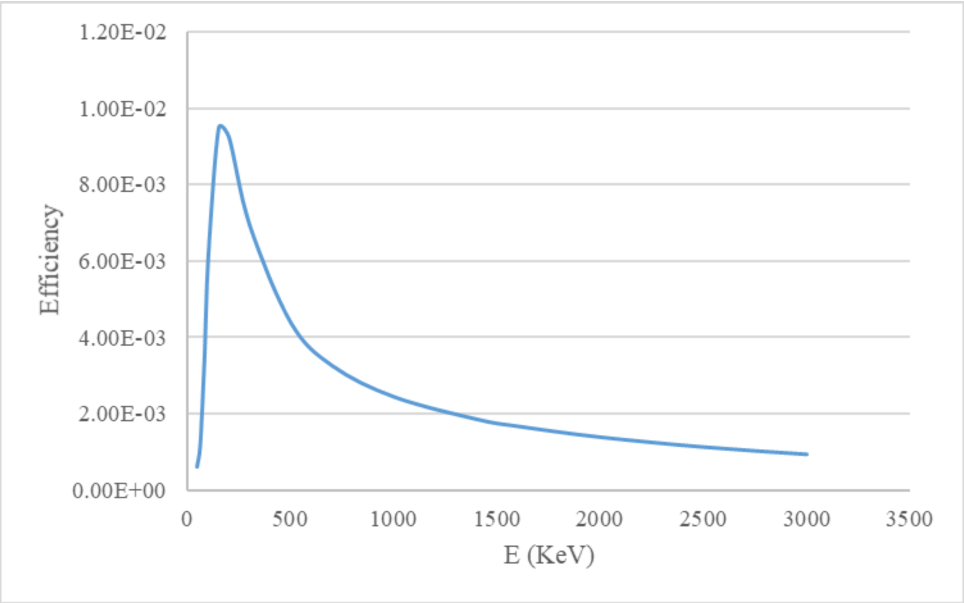


Figure 51: Efficiency calibration curve obtained for the reference geometry (height: 6.7cm, density 1.8 gm/cm^3)

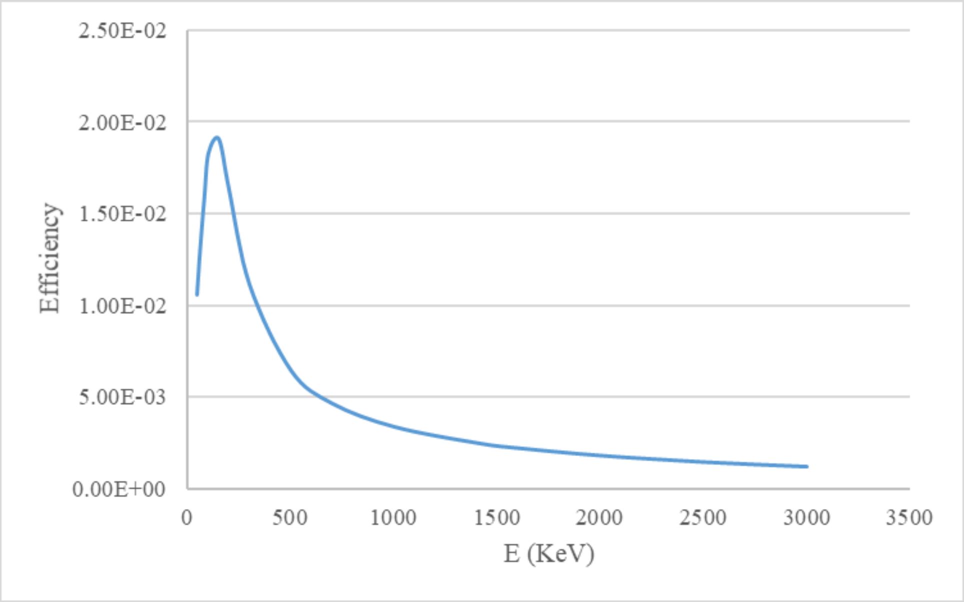


Figure 52: Efficiency calibration curve obtained for the reference geometry (height: 8.4cm, density 1.2 gm/cm^3)

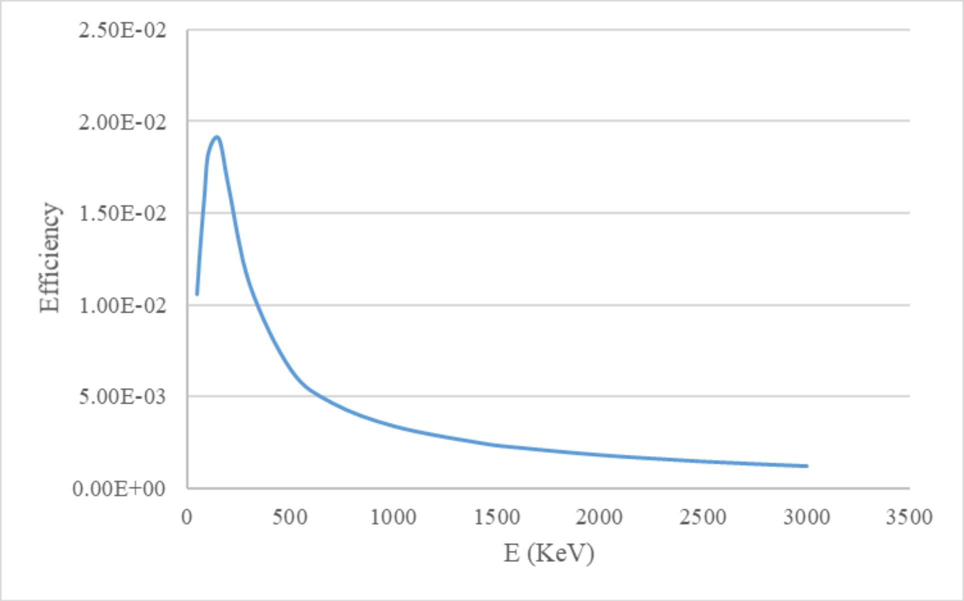


Figure 53: Efficiency calibration curve obtained for the reference geometry (height: 8.4cm, density 1.4 gm/cm^3)

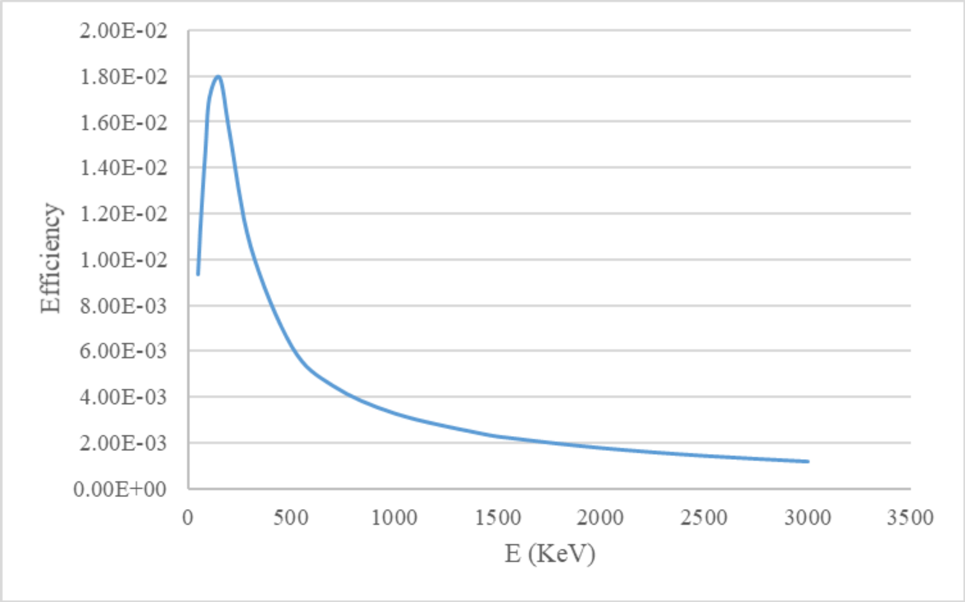


Figure 54: Efficiency calibration curve obtained for the reference geometry (height: 8.4cm, density 1.6 gm/cm^3)

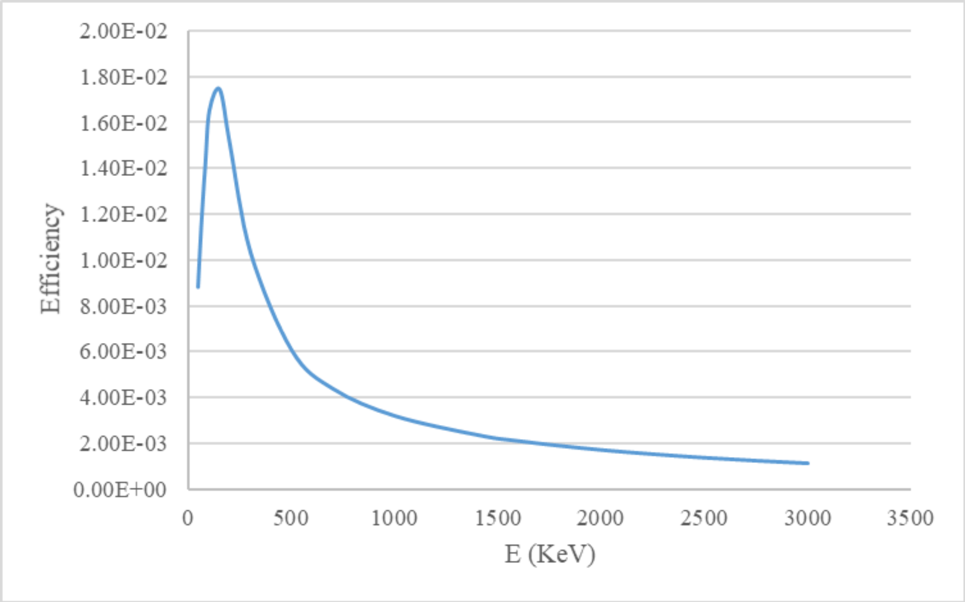


Figure 55: Efficiency calibration curve obtained for the reference geometry (height: 8.4cm, density 1.8 gm/cm^3)

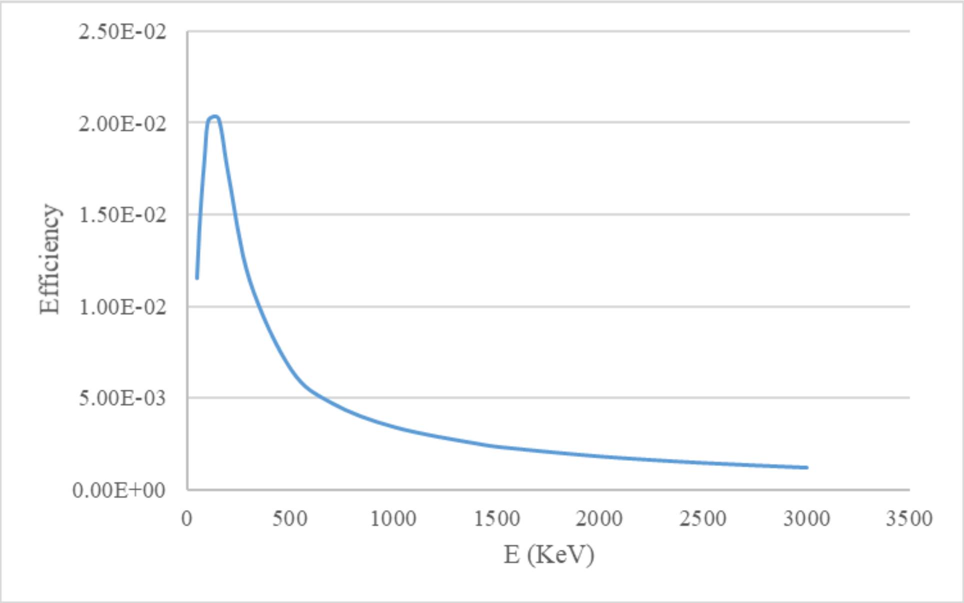


Figure 56: Efficiency calibration curve obtained for the reference geometry (height: 9.5 cm, density 1.2 gm/cm^3)

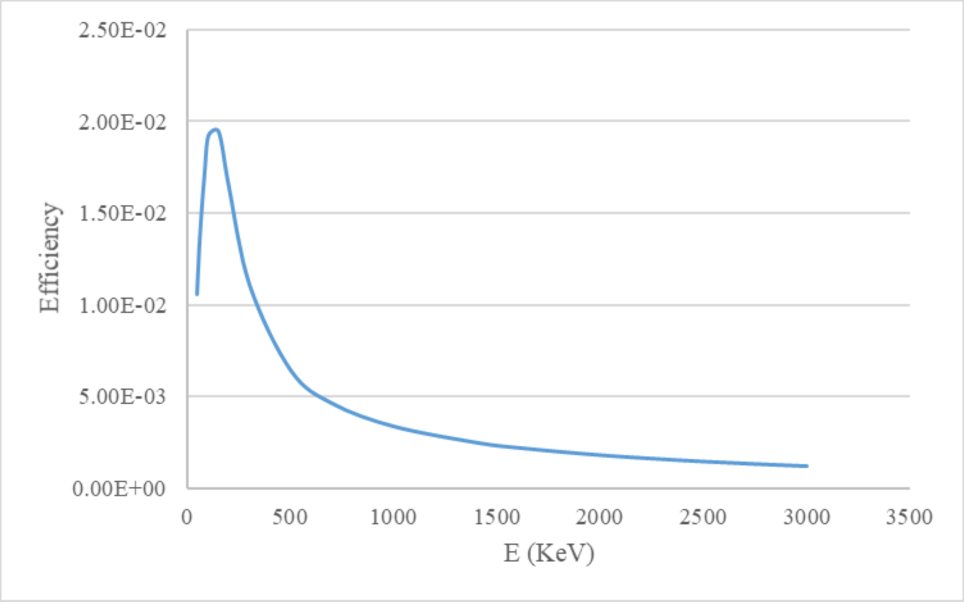


Figure 57: Efficiency calibration curve obtained for the reference geometry (height: 9.5 cm, density 1.4 gm/cm^3)

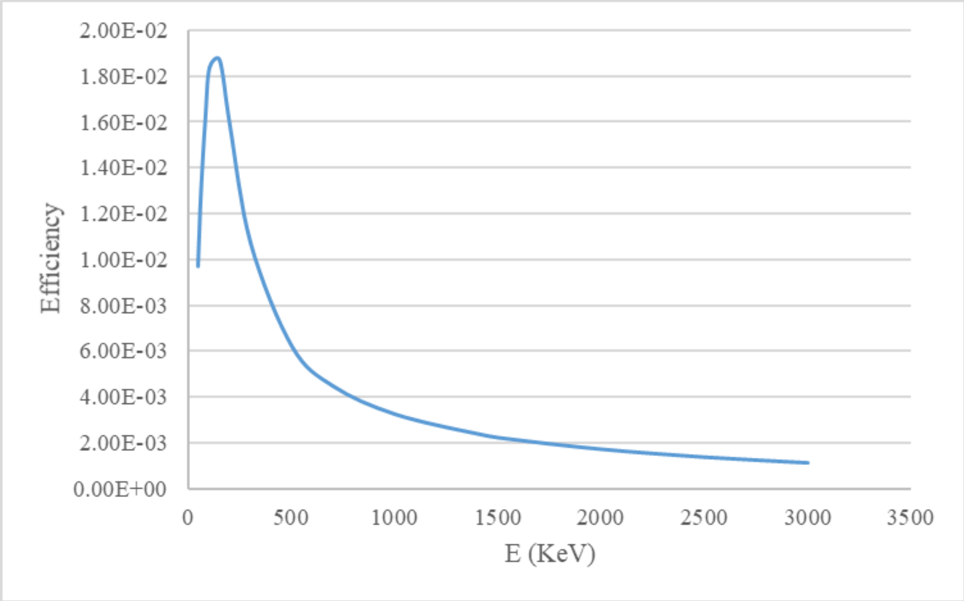


Figure 58: Efficiency calibration curve obtained for the reference geometry (height: 9.5 cm, density 1.6 gm/cm^3)

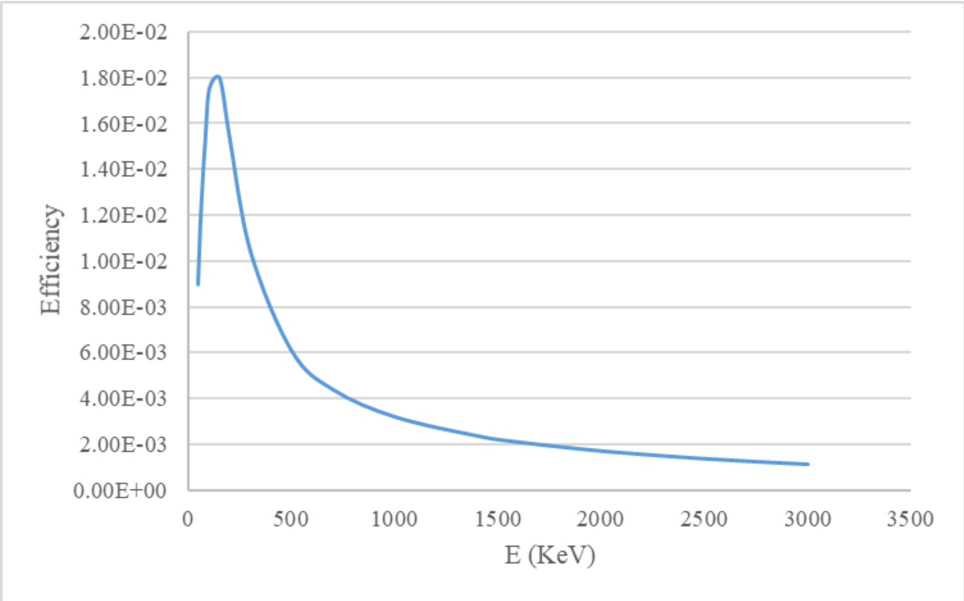


Figure 59: Efficiency calibration curve obtained for the reference geometry (height: 9.5 cm, density 1.8 gm/cm^3)

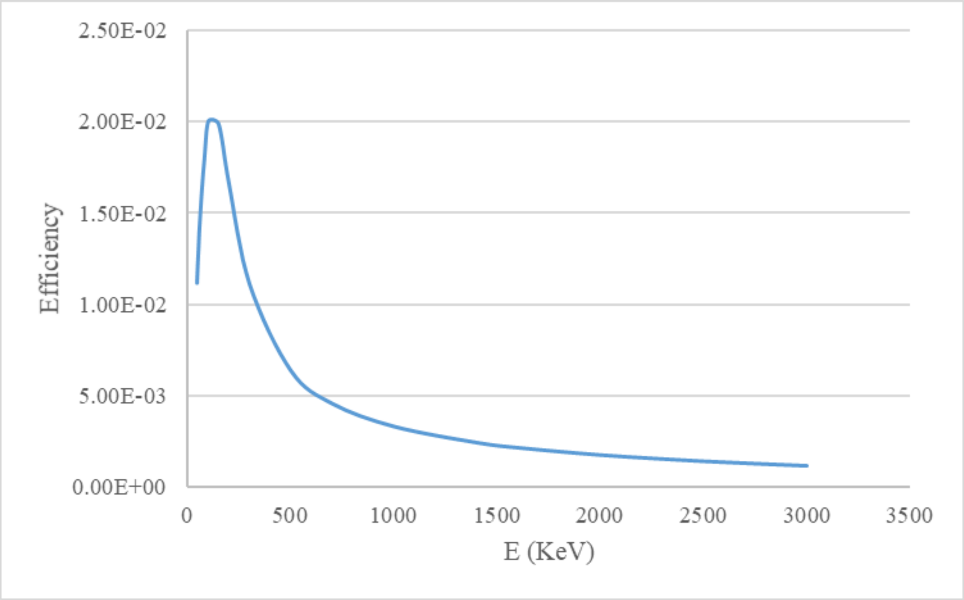


Figure 60: Efficiency calibration curve obtained for the reference geometry (height: 10.5 cm, density 1.2 gm/cm^3)

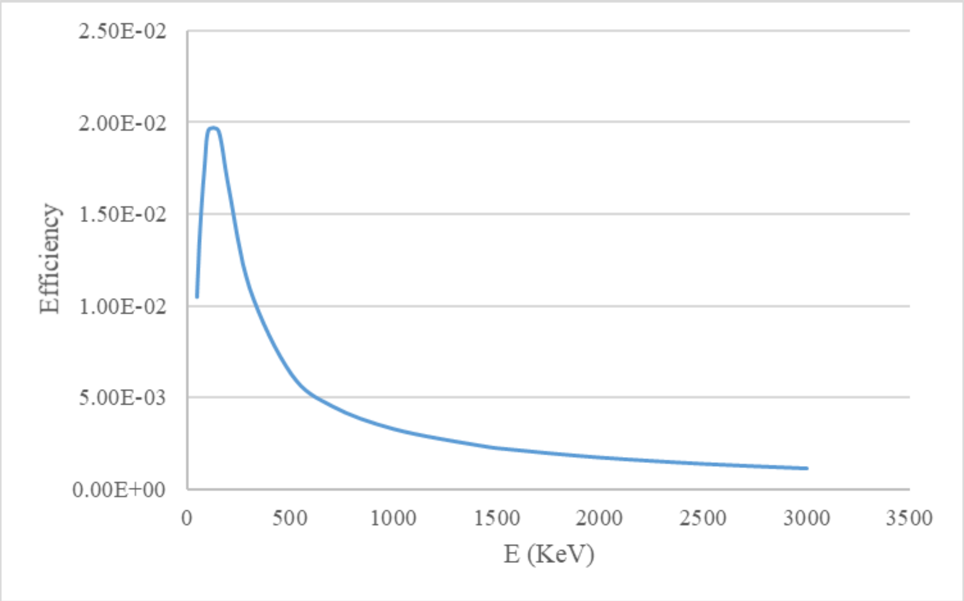


Figure 61: Efficiency calibration curve obtained for the reference geometry (height: 10.5 cm, density 1.4 gm/cm^3)

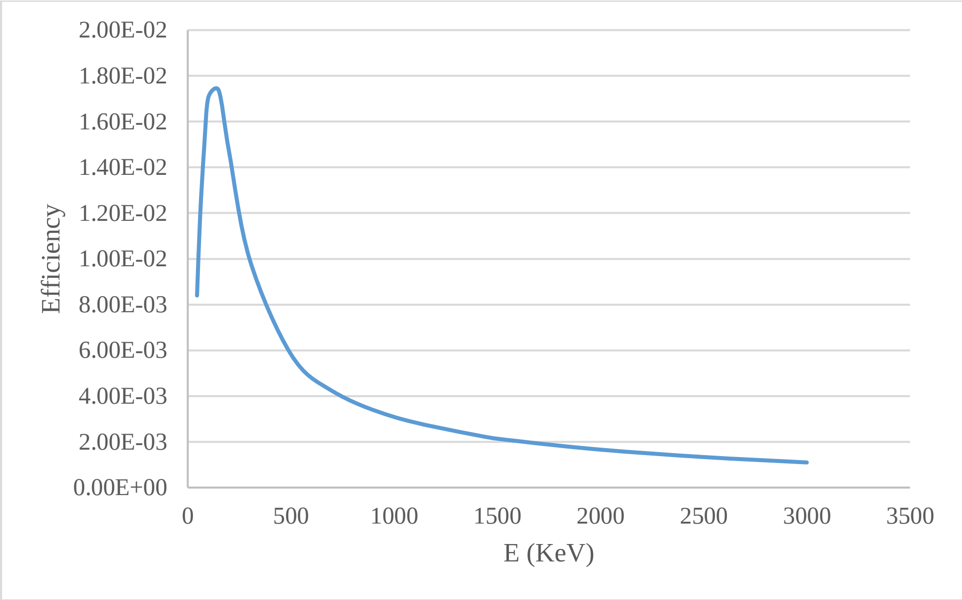


Figure 62: Efficiency calibration curve obtained for the reference geometry (height: 10.5 cm, density 1.6 gm/cm^3)

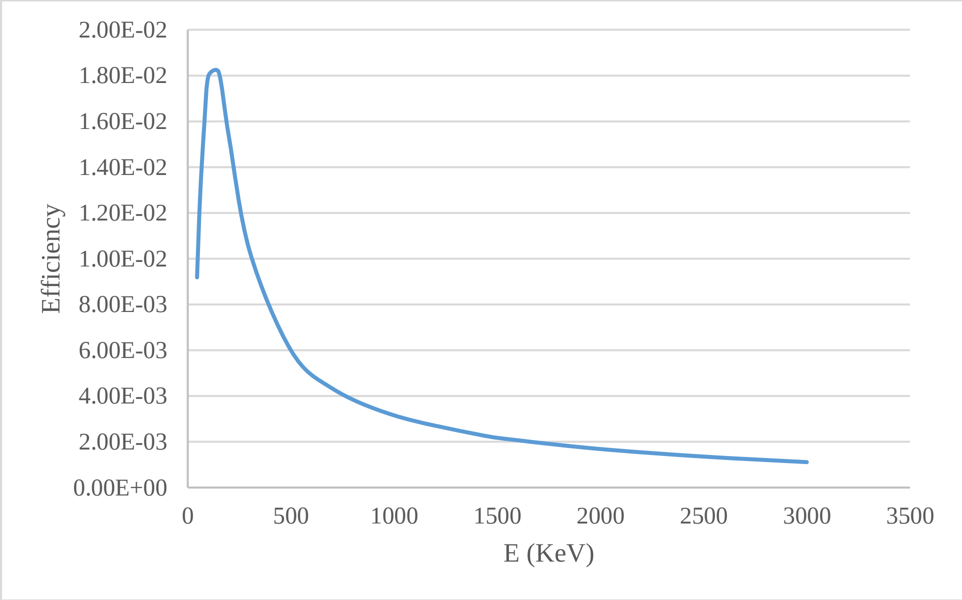


Figure 63: Efficiency calibration curve obtained for the reference geometry (height: 10.5 cm, density 1.8 gm/cm^3)

Source Certificate

ČESKÝ METROLOGICKÝ INSTITUT
INSPEKTORÁT PRO IONIZUJÍCÍ ZÁŘENÍ
Radiová 1, 102 00 Praha 10

CERTIFIKÁT

Cert. No: 9031 - OL - 126/14   Type: MBSS 2   Prod. No: 130214-1425046

Radionuclide	Half life days	Activity kBq	Combined standard uncertainty, %
Am-241	157800	4,331	1,1
Cd-109	462,6	13,62	1,4
Ce-139	137,5	1,314	1,1
Co-57	271,26	1,094	1,1
Co-60	1925,4	2,497	1,1
Cs-137	11019	2,483	1,3
Sn-113	115,1	3,677	2,2
Sr-85	64,78	4,402	1,5
Y-88	106,6	4,916	1,2
Hg-203	46,72	2,242	2,2

Mass: 985,0 g   Density: 0,985 g/cm^3 Volume: 1000 cm^3

Radionuclide inpurities: gamma < 0,1 %

Reference date: 10.3.2014   Homogeneity better than: 1 %

Description:
Radioactive material is homogeneously dispersed in silicone resin. Composition of the matrix: C - 0,324 H - 0,0816 O - 0,216 Si - 0,379 (mass ratio).

Measuring method:
Preparation issues from standard ER solutions whose activities were determined by suitable absolute method. Final control is based on gamma spectrometry on HPGe detector.

Note:
As the criterion of homogeneity standard deviation of the acivity value of 1 cm^3 element was chosen (n=10). The volume is calculated from the mass and the density.

Date of the cetificate issue: 20.2.2014   Validity: 3 years

Customer:
Envinet a.s.
Modřínová 1094
674 01 Třebíč

Český metrologický institut

Ing. Jiří Šuráň, MBA
director

Control: RNDr. Richard Bluďovský, CSc., RNDr. Pavel Dryák, CSc.

Tel.: +420 266 020 497   Fax: +420 266 020 466

Figure 64: Calibration source certificate

Energy Calibration Report

Energy Calibration Report 2/27/2017 3:21:02 PM Page 2

****
***** E N E R G Y C A L I B R A T I O N R E P O R T *****
****

Detector Name: GE1
Sample Title: G114

************* ENERGY CALIBRATION COEFFICIENTS *************

Energy Calibrate Performed on: 2/27/2017 3:20:45 PM
by:
Energy Calibrate Type: POLY

Energy(keV) = -17.079 + 0.339*ch + 0.00E+000*ch^2 + 0.00E+000*ch^3

************* SHAPE CALIBRATION COEFFICIENTS *************

Shape Calibrate Performed on: 2/27/2017 3:20:45 PM
by:

FWHM = 0.278 + 0.035*E^1/2

LOW TAIL = 1.6E+000 + -4.4E-004*E

**************** ENERGY CALIBRATION RESULTS TABLE ****************

Centroid Channel	Centroid error	Energy (keV)
598.65	0.07	186.21
920.48	0.03	295.22
1087.65	0.02	351.93
1846.39	0.05	609.31
2366.61	0.49	785.96
2803.18	0.25	934.06
3352.37	0.16	1120.29
3699.54	0.33	1238.11
4110.79	0.09	1377.67
5250.60	0.16	1764.49
6546.85	0.39	2204.21

********* SHAPE CALIBRATION RESULTS TABLE *********

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
186.21	3.01	0.15	2.14	0.94
295.22	2.41	0.06	6.96	1.00
351.93	2.75	0.03	2.23	0.24
609.31	3.52	0.10	54.40	1.00
785.96	4.25	1.10	9.68	1.00
934.06	3.81	0.63	2.55	3.15
1120.29	4.62	0.37	2.87	1.20
1238.11	4.59	0.81	3.34	3.53
1377.67	4.41	0.12	1.77	0.18
1764.49	5.70	0.30	5.77	1.00
2204.21	7.10	0.85	10.00	1.00

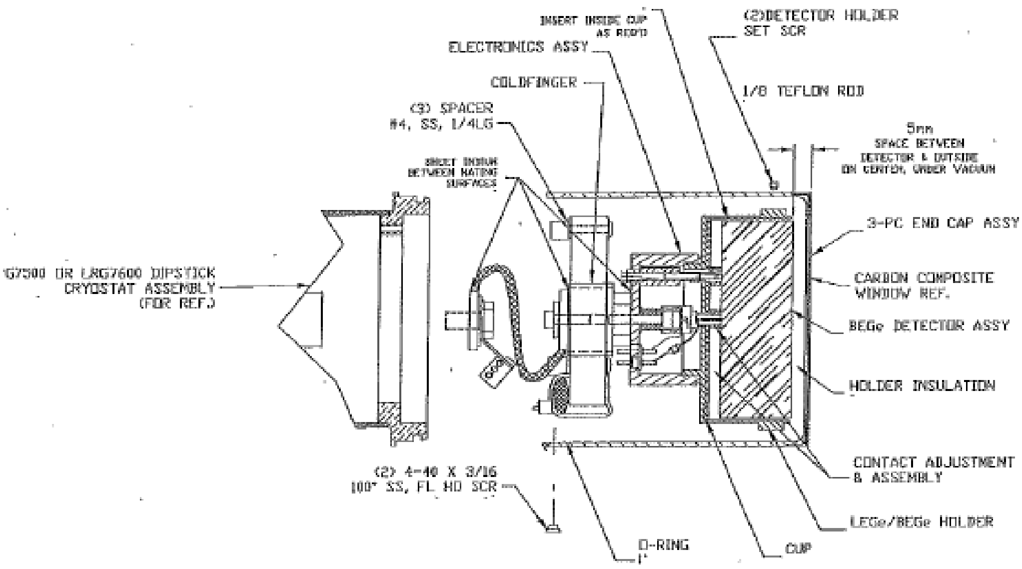
Figure 65: Energy calibration report

Germanium Detector Chamber Typical Cross-sectional View

CANBERRA

Germanium Detector Chamber Typical Cross-Sectional View

Detector Model BE2825
Cryostat Model 7500SL
Detector S/N 8932



Detector Element:

Detector Model	BE2825		
Diameter	60.5	mm	
Thickness	26.1	mm	
Groove ID	14.5	mm	
Groove OD	23.0	mm	
Groove Depth	1.5	mm	(typ 1mm)
Front Dead Layer	0.3×10^{-3}	mm	(typ .3 X 10E-3mm)
Side Dead Layer	0.5	mm	(typ .5mm)
Back Dead Layer	0.5	mm	(typ .5mm)
Front Corner Radius	1.0	mm	(typ 1mm)

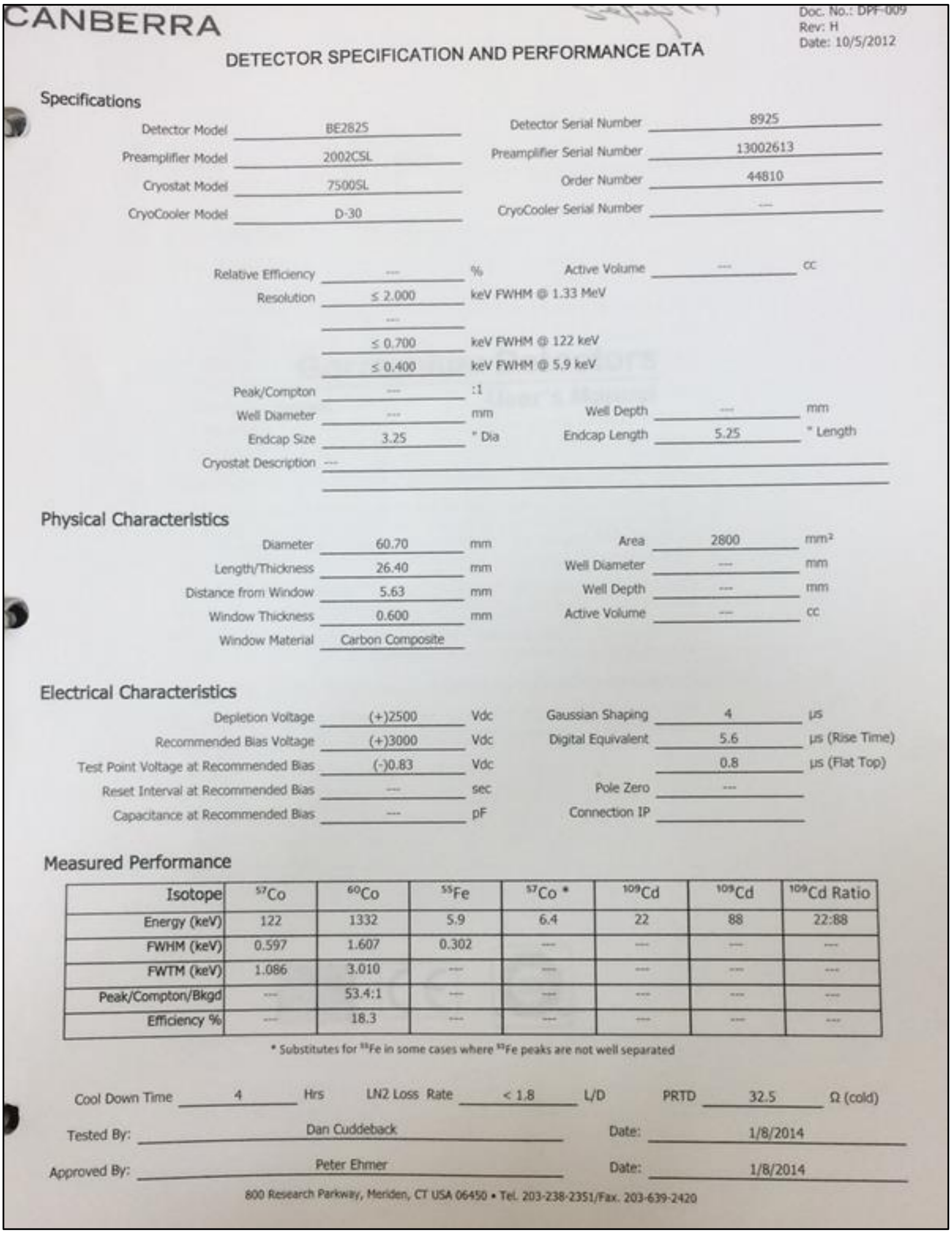
Detector description or drawing number (if special)

Cryostat Window Material: Carbon Composite 0.6mm Thick
Cryostat End Cap Material: Aluminum 1.5mm Thick
Crystal Holder Material: Copper

Canberra Industries, Inc.
800 Research Parkway - Meriden, Connecticut 06450 - Tel. 203-238-2351 - Fax 203-235-1347

Figure 66: Germanium detector chamber typical cross-sectional view

Detector Specifications and Performance Data



CANBERRA

Doc. No.: DPF-009
Rev: H
Date: 10/5/2012

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

Detector Model: BE2825
Detector Serial Number: 8925
Preamplifier Model: 2002CSL
Preamplifier Serial Number: 13002613
Cryostat Model: 7500SL
Order Number: 44810
CryoCooler Model: D-30
CryoCooler Serial Number: ---

Relative Efficiency: --- %
Active Volume: --- cc
Resolution: ≤ 2.000 keV FWHM @ 1.33 MeV

≤ 0.700 keV FWHM @ 122 keV
≤ 0.400 keV FWHM @ 5.9 keV
Peak/Compton: --- :1
Well Diameter: --- mm
Well Depth: --- mm
Endcap Size: 3.25 " Dia
Endcap Length: 5.25 " Length
Cryostat Description: ---

Physical Characteristics

Diameter: 60.70 mm
Area: 2800 mm²
Length/Thickness: 26.40 mm
Well Diameter: --- mm
Distance from Window: 5.63 mm
Well Depth: --- mm
Window Thickness: 0.600 mm
Active Volume: --- cc
Window Material: Carbon Composite

Electrical Characteristics

Depletion Voltage: (+)2500 Vdc
Gaussian Shaping: 4 µs
Recommended Bias Voltage: (+)3000 Vdc
Digital Equivalent: 5.6 µs (Rise Time)
Test Point Voltage at Recommended Bias: (-)0.83 Vdc
0.8 µs (Flat Top)
Reset Interval at Recommended Bias: --- sec
Pole Zero: ---
Capacitance at Recommended Bias: --- pF
Connection IP:

Measured Performance

Isotope	^{57}Co	^{60}Co	^{55}Fe	^{57}Co *	^{109}Cd	^{109}Cd	^{109}Cd Ratio
Energy (keV)	122	1332	5.9	6.4	22	88	22:88
FWHM (keV)	0.597	1.607	0.302	---	---	---	---
FWTM (keV)	1.086	3.010	---	---	---	---	---
Peak/Compton/Bkgd	---	53.4:1	---	---	---	---	---
Efficiency %	---	18.3	---	---	---	---	---

* Substitutes for ^{55}Fe in some cases where ^{55}Fe peaks are not well separated

Cool Down Time: 4 Hrs
LN2 Loss Rate: < 1.8 L/D
PRTD: 32.5 Ω (cold)

Tested By: Dan Cuddeback
Date: 1/8/2014

Approved By: Peter Ehmer
Date: 1/8/2014

800 Research Parkway, Meriden, CT USA 06450 • Tel. 203-238-2351/Fax. 203-639-2420

Figure 67: Detector specifications and performance data

Comparison of natural radioactivity levels in soil for different countries

Table 10: Natural radioactivity levels in soils of different countries

Location	Radioactivity Concentration in Soil (Bq Kg^{-1})			Reference*(s)*
	^{226}Ra	^{232}Th	^{40}K	
	Mean/Range	Mean/Range	Mean/Range	
Algeria	11-25	6-32	56-607	(Ravisankar et al., 2015)
Egypt	5-64	2-96	29-650	(Mehra et al., 2007)(Bajoga et al., 2015)(Agbalagba et al., 2012)(Ravisankar et al., 2012)(Ravisankar et al., 2015)
France	9-62	16-55	120-1,026	(Agbalagba et al., 2012)(Ravisankar et al., 2015)
Ghana	15.00	27.00	157.00	(Bajoga et al., 2015)
Greece	1-240	1-190	12-1,570	(Mehra et al., 2007)(Ravisankar et al., 2015)(Ravisankar et al., 2012)
Hong Kong	20-110	16-200	80-1,100	(Mehra et al., 2007)(Ravisankar et al., 2012)(Ravisankar et al., 2015)
Hungary	14-76	12-96	79-570	(Mehra et al., 2007)(Ravisankar et al., 2015)
India	7-81	14-160	400-1,146.88	(Mehra et al., 2007)(Agbalagba et al., 2012)(Ravisankar et al., 2012)(Ravisankar et al., 2015)(Wasim et al., 2015)
Iran	8-55	5-42	250-980	(Mehra et al., 2007)(Ravisankar et al., 2012)(Bajoga et al., 2015)
Ireland	60.00	26.00	350.00	(Agbalagba et al., 2012)
Italy	42-79	31-48	410-640	(Ravisankar et al., 2015)(Guidorri et al., 2015)
Japan	6-98	15-310	15-990	(Mehra et al., 2007)(Agbalagba et al., 2012)(Ravisankar et al., 2012)(Bajoga et al., 2015)(Wasim et al., 2015)
Jordan	44-49	20-158	158-291	(Saleh & Shayeb, 2014)(Bajoga et al., 2015)

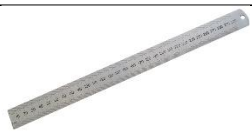
Kazakhstan	35.00	60.00	300.00	(Wasim et al., 2015)
Kenya	28.70	73.30	255.70	(Agbalagba et al., 2012)
Korea	-	-	670.00	(Ravisankar et al., 2012)
Kuwait	13.30	10.00	322.00	(Bajoga et al., 2015)
Lebanon	4-73	5-50	57-554	(El-Samad et al., 2013)
Luxembourg	6-52	7-70	80-1,100	(Mehra et al., 2007)(Ravisankar et al., 2012)
Malaysia	20-94	22-110	125-430	(Mehra et al., 2007)(Agbalagba et al., 2012)(Wasim et al., 2015)(Ravisankar et al., 2015)
Mexico	23.00	19.00	530.00	(Agbalagba et al., 2012)
Morocco	121	65	-	(Boukhenfouf & Boucenna, 2011)
Nigeria	8.00	29.7-34	412-641	(Bajoga et al.,2015)(Agbalagba et al., 2012)
Oman	22-29	10.7-25.2	222.89-535.07	(Ravisankar et al., 2015)(Bajoga et al., 2015)
Pakistan	42.11	43.27	418.27	(Agbalagba et al., 2012)
Poland	5-120	4-77	110-970	(Mehra et al., 2007)(Ravisankar et al., 2012)
Portugal	8-65	22-100	220-1,230	(Mehra et al., 2007)(Ravisankar et al., 2012)(Ravisankar et al., 2015)
Qatar	-	9.4	204	(Al-Sulaiti et al., 2010)
Romania	8-60	11-75	250-1,100	(Mehra et al., 2007)(Ravisankar et al., 2012)
Russian	19-60	30.00	520.00	(Saleh & Shayeb, 2014)
Saudi Arabia	9.30	22.5-37.4	161.82 - 641.1	(Bajoga et al., 2015)(Agbalagba et al., 2012)(Ravisankar et al., 2015)
Spain	6-250	12-210	25-1,650	(Mehra et al., 2007)(Agbalagba et al., 2012)(Ravisankar et al., 2012)
Sudan	28.31	20.12	280.29	(Agbalagba et al., 2012)

Switzerland	10-900	4-70	40-1,000	(Mehra et al., 2007)(Ravisankar et al., 2012)
Syria	23.00	20.00	270.00	(Bajoga et al., 2015)
Thailand	11-78	7-120	7-712	(Mehra et al., 2007)(Wasim et al., 2015)
Turkey	29	33	449	(Saleh & Shayeb, 2014)
United States	4-160	4-190	43.72-700	(Mehra et al., 2007)(Ravisankar et al., 2012)(Agbalagba et al., 2012)(Bajoga et al., 2015)(Jeevarenuka et al., 2011)
United Arab Emirates	**10-22.1**	**2.2-11**	**167.4-510**	**Currant Study**
World Average	35.00	30.00	400.00	(Jeevarenuka et al., 2011)(Agbalagba et al., 2012)(Wasim et al., 2015)(Ravisankar et al., 2015)

Sampling Tools Inventory List

Table 11: Sampling tools inventory list

Sampling Equipment	Purpose of use	Photo
A handheld GPS map	To locate the sampling points.	
Aluminum sieve. size 2 mm.	To eliminate the unwanted particles with mesh size greater than 2 mm.	
Polyethylene sampling bags with two white panels, size 5kg.	To save the soil samples during shipping. Heavy-duty bags.	

Working gloves	For health protection	
Sealing device	For sealing the bags	
Pre-prepared labels – waterproof	For documenting sample's details	
Waterproof marker-pen	For documenting sample's details (5 pieces)	
Field notebook	For documenting sample's details	
Stainless steel Scoop	Sampling tool	
30 cm steel Ruler	To measure the depth	
Stainless steel spoon	Sampling tool	
Stainless steel shovel	Sampling tool	

Stainless steel Collecting pan	Sampling tool	
Dust masks	For health protection	
Waterproof wide tape	To protect the written sample details on the labels from moisture.	
Scale Machine	Measure samples up to 5 Kg	
Cylinder	Measure volume 0.5 L and 1 L	
Aluminum pans	Dry soil samples, with enough size, medium and big sizes	
Water Sample Bottles