FANR
الهيئة الاتحادية للرقابة النووية
Federal Authority for Nuclear Regulation

الإمارات العربية المتحدة
United Arab Emirates

Radiological Environmental Monitoring

in the United Arab Emirates

ANNUAL REPORT

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Federal Authority for Nuclear Regulation
Abu Dhabi, United Arab Emirates

Vision

To be globally recognised as a Leading Nuclear Regulator

Mission

To protect the public and the environment from the harmful effects of ionising radiation and to ensure the exclusively peaceful use of nuclear energy in an integrated manner with the concerned authorities and according to international best practices, as well as capacity building of Emiratis in the nuclear field and various technical fields.

Core Values

- Safety Culture
- Collaboration
- Transparency
- Independence
- Excellence

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I.

SUMMARY

I. Summary

The Federal Authority for Nuclear Regulation (FANR) was established by federal decree in 2009. Under the Federal Law by Decree No 6 of 2009, Concerning the Peaceful Uses of Nuclear Energy, FANR has the responsibility and authority to monitor radiation in the areas around nuclear facilities. The statutory requirements also stipulate that FANR shall advise relevant government entities on the radiation protection aspects of environmental protection, public health, radioactive waste, water use, consumption of food, and land use.

In order to satisfy its statutory requirements on monitoring radiation and advising government entities on matters related to radiation protection, FANR established a radiological environmental monitoring programme to monitor radiation and radioactive materials throughout the United Arab Emirates. The results of this environmental monitoring programme are included in a series of annual reports.

In accordance with FANR's core values of being a transparent and independent regulator, FANR worked independently and objectively to obtain the data for inclusion in this report. This report aims to engage openly and objectively with the public, government entities in the United Arab Emirates, and the international nuclear community.

In 2019 FANR measured the radioactivity concentration of seventy four (74) samples of soil, water, sediment, fish, air borne and vegetation (i.e. date palm fruit and tomato) samples were collected from different locations in UAE. The samples prepared and analysed according to approved standard operating procedures in FANR's laboratory in Abu Dhabi.

In addition, during 2019, the laboratory collected continuous measurements of gamma dose rates from a network of gamma monitoring stations located throughout the UAE. Furthermore, FANR used Optically Stimulated Luminescence Dosimeters (OSL) to measure gamma dose equivalent at 17 locations across the UAE. Monitoring the atmospheric environment involved sampling the air at three locations including Barakah Nuclear Facility. The particulate filters and charcoal cartridge were analysed for gamma emitting nuclides using gamma spectrometry. The charcoal cartridges were analysed for airborne gaseous radioiodine. All results are summarised in this report (Section III.C).

FANR's radiological environmental monitoring programme (REMP) is divided into two parts. One part of the programme monitors radiation and radioactive material around the Barakah Nuclear Power Plant (NPP) in Al Dhafra region of the Emirate of Abu Dhabi. The second part of the programme monitors radiation and radioactive material in different areas of the UAE that are beyond the influence of the Barakah NPP. The criteria for selecting the different monitoring areas based on particular interest due to the presence of food crops, special public concerns, population centres, recreational value, or other characteristics affecting public dose.

II.

INTRODUCTION TO RADIATION AND EXPOSURE PATHWAYS

II. Introduction to Radiation and Exposure Pathways

Radiation is all around us, all the time. It is found in the food we eat, the water we drink, the ground we walk on, the air we breathe, in the building materials used to construct our homes, and inside the muscles and bones of our bodies[1].

Radiation can be divided into two types: ionising and non-ionising radiation. The main difference between the two types is the amount of energy they carry. Ionising radiation such as gamma rays and X-rays carries more energy than non-ionising radiation such as visible light and electromagnetic fields[2]. Ionising radiation has enough energy to cause damage to cells and might affect the various biological processes in living organisms based on the received doses. As a result, protective measures are included in Federal Law by Decree No 6 of 2009, Concerning the Peaceful Uses of Nuclear Energy. For regulatory purposes, exposure to ionising radiation is often divided into two categories: natural and man-made radioactivity exposures.

Exposures to natural radiation come from various sources e.g. cosmic radiation from outer space, terrestrial radiation generated naturally from the earth's components, and internal radiation generated from natural elements such as the potassium and carbon inside our bodies1. In every second of every day, all people receive exposure from natural radioactivity. For the average member of the population, natural radioactivity is responsible for the majority of the exposure received by the population.

People also receive exposure from ionising radiation generated from man-made sources such as medical treatments (e.g. X-ray imaging and cancer therapy), fallout from nuclear weapons, nuclear incidents and accidents , and other industrial sources (e.g. self-powered exit signs, smoke detectors, and rifle scopes), which also includes the routine, low-level releases of radioactivity from nuclear power plants[3].

We can see from the previously mentioned examples that radioactivity that produces ionising radiation is used in different fields from medicine and education to industries and power production. Accordingly, it is vital to regulate these activities and the use of radioactive materials through a robust regulatory regime to ensure the safety of both the people and the environment. One of the FANR mandates is ensuring the protection of the public, the workers and the environment through implementation of robust regulatory regime to all nuclear/radiological related activities in the country.

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FANR's Radiation Safety Department is dedicated to ensure protecting the health and safety of the public and radiation workers against any potential hazard from ionising radiation used by medical, industrial and nuclear facilities during normal operation or in case of emergency.

[1] See reference (1) in section IV
[2] See reference (2) in section IV
[3] See reference (3) in section IV

FANR's Environmental Laboratory is responsible for measuring radiation levels and radioactivity concentrations of different environmental samples media at different locations in UAE generally and specifically around the Barakah NPP. In order to achieve this mission, FANR's Environmental Laboratory continuously monitor gamma dose rates levels across the UAE and collect different environmental samples that are analysed in this laboratory. In this way, the Environmental Laboratory is measuring the natural radiation in the UAE to establish a radiological baseline in the country prior to the operation of the Barakah NPP. The measurements provided by the Environmental Laboratory are independent assessments that document the levels of radioactivity in the environment at the vicinity of Barakah NPP.

When FANR conducts radiological environmental measurements, two items are particularly considered from regulatory perspective: measuring of radioactivity and exposure. In the UAE, the international (SI) units are used to express the results of radiation measurements. Radioactivity, which can also be referred to as activity, is the number of atoms that undergo radioactive decay in one second. When measuring radioactivity, instruments measure the number of radioactive atoms that decay each second. One disintegration per second is often written as 1 Bq or 1 Becquerel. When an atom undergoes radioactive decay, it emits energy in the form of radiation.

Exposure is the circumstance of being subject to irradiation. A measure of the impacts of exposure is called Dose. While, the effective dose is a measure of dose designed to represent the amount of radiation damage likely to result from the dose. The effective dose is measured using a unit called a Sievert (Sv). When dealing with small exposures such as the exposures commonly associated with natural radioactive materials, the Sv is considered a large unit of measurement, and as a result, the millisievert (mSv) is more commonly used in expressing effective dose. One thousand mSv is one Sievert.

In order to better understand a population's exposure to natural and artificial radiation, The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has estimated the global average annual effective dose for individuals is around 3.0 mSv. The annual dose from natural sources has the largest contribution to public exposure, approximately 2.4 mSv. The remaining exposure is due to artificial radiation sources, is around 0.65 mSv. The most contribution comes from radiation used in medicine, with an individual average annual effective dose of 0.62 mSv. Nuclear Power Plant has the lowest contribution for public exposure as artificial sources with 0.0002 mSv. Please see Figure 1 for more details[4].

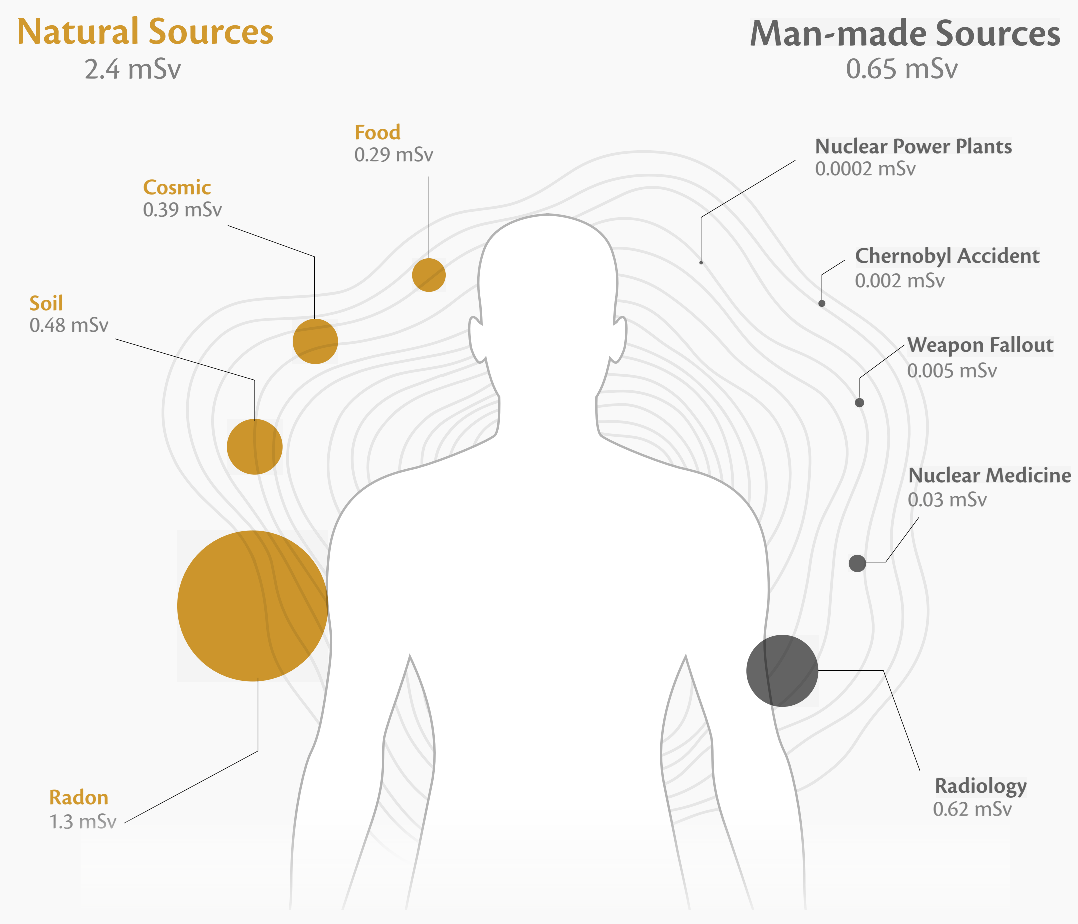
[4] See reference (3) in section IV

Figure 1

World Average Public Exposure By Radiation Sources (Natural And Man-Made).

Reference: UNCEAR[5]

Average Public Exposure by Radiation Sources*



*Rounded estimates of the effective dose to a person in a year (world average).

[5] See reference (3) in section IV

III.

THE RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAMME

III. The Radiological Environmental Monitoring Programme

III.A Introduction

In 2015, the FANR Environmental Laboratory established an independent, intensive, and long-term Radiological Environmental Monitoring Program to monitor radiation and radioactive materials throughout the UAE, based on a quality assurance program and standard analytical procedures.

The first radiological environmental monitoring programme report, that summarised the results for different environmental samples collected in calendar year 2015, was issued by FANR in 2018.

This report, which documents all sample results from 2019, is the fifth in a series of reports to be published on the levels of radiation and radioactivity in the environment of the UAE.

III.B Programme Overview

One of the largest sources of external radiation exposure to the average person in the UAE is gamma radiation emitted by natural radioactivity in from rocks and soil (often referred to as natural, terrestrial, background radiation). Radiation emitted by the sun, stars and from outer space (often referred to as natural, cosmic, background radiation) is another significant source of external exposure to the average person in the UAE. Estimates of these exposures are found in this report. These natural sources of radiation are the primary sources of exposure for a person in the UAE. Identifying and monitoring these natural sources of exposure establishes a radiological baseline for radiation exposure in the UAE.

Once the baseline level of radiation has been characterised throughout the UAE, the programme monitors the normal variations in the baseline. Some radiation baseline measurements vary with the time of day, the seasons of the year, the prevailing weather conditions, the soil characteristics, and the local geology. The observed changes in baseline radiation are measured and categorised. With this extensive collection of radiological baseline measurements, it is possible to determine whether any radiation measurement is natural background or whether it exceeds the natural baseline.

Although terrestrial and cosmic radiation represent some of the largest sources of exposure to the average person in the UAE, FANR is also interested in other potential sources of exposure. Hospitals, universities, industrial facilities, and commercial nuclear power plants can also be potential sources of exposure. Techniques exist which are able to differentiate between natural sources of radiation and man-made sources of radiation. Using these techniques in concert with the historical baseline radiation measurements, very small deviations from the natural background radiation can be detected and the source of the deviations can be identified.

According to respective FANR's Regulation, it is important to collect measurements and samples near nuclear facilities prior to initial operation and throughout the lifetime of the nuclear facility. It is also important to collect samples from areas that are unlikely to be affected by the operation of a nuclear facility in order to have a thorough understanding of the baseline levels of radiation in the UAE.

The measurements in this report establish the levels of radiation and radioactive materials naturally present in the general environment of the UAE. This is commonly referred to as 'background radiation'. Background radiation includes cosmic radiation, naturally radioactive material (including radon from natural sources), and global fallout (e.g. from nuclear weapons testing and nuclear accidents in other countries) that are not under the control of the licensee. The FANR may use the measurements in this report to determine whether a radiological measurement is (or is not) different from background radiation. Any measurement significantly higher than the background is evaluated to determine the significance (i.e. the exposure) and cause (i.e. the origin). In this way, FANR works to ensure the health and safety of the people of the UAE.

III.B.1 Objectives

The objectives of FANR's radiological environmental monitoring programme are to:

1) Survey local radiological conditions before and during operation of nuclear facilities;
2) Document the level of baseline radiation in UAE' environment
3) Determine the source of man-made radionuclides, if found in the environment
4) Publish a summary of the FANR REMP's results
5) Independent validation and inspection of Licensee REMP programs

III.B.2 Sample Collection and Sample Preparation

FANR is implementing a radiological environmental monitoring programme using a stepped approach. In accordance with this stepped approach, samples of surface water, soil, sediment, fish, tomato and date palm fruit were analysed in FANR's Environmental Laboratory. Additionally, measurements from a network of gamma monitoring stations (configured with Geiger-Muller tubes and sodium iodide detectors) and from Optically Stimulated Luminescent (OSL) dosimeters are using for environmental monitoring determining the ambient gamma radiation throughout the UAE.

FANR expanded the environmental monitoring programme to include monitoring of all components of the United Arab Emirates environment; including atmospheric environment (e.g. airborne particulates and airborne iodine for environmental monitoring) and to report those measurements in this report and future reports.

The Laboratory has samples preparation and analysis Standard Operating Procedures (SOPs) for non-destructive analysis using gamma spectrometry based on (HPGe) detector. All the collected samples prepared and analysed in the laboratory according to FANR laboratory's respective procedures. All samples analysed in the laboratory were weighed to the nearest tenth of a gram and placed into containers (e.g. 0.5 litre or 1-litre marinelli beakers) for analysis. Water samples were typically prepared in 1-litre (1 L) marinelli beakers. Soil samples were dried, screened to approximately 2 mm grain size, and placed into 0.5- litre marinelli beakers. Sediment samples are dried, crushed to conform to the shape of the container, and placed into 0.5-litre marinelli beakers. The date palm fruit (i.e. in fresh flesh form) samples prepared by placing fresh flesh (without pits) into a 0.5 -litre marinelli beaker and similarly the tomato sample was grinded and prepared fresh in 0.5- litre marinelli beaker. Fish (i.e. in wet form) samples prepared by placing fresh flesh (edible flesh without bone and skin) into a 0.5-litre marinelli beaker.

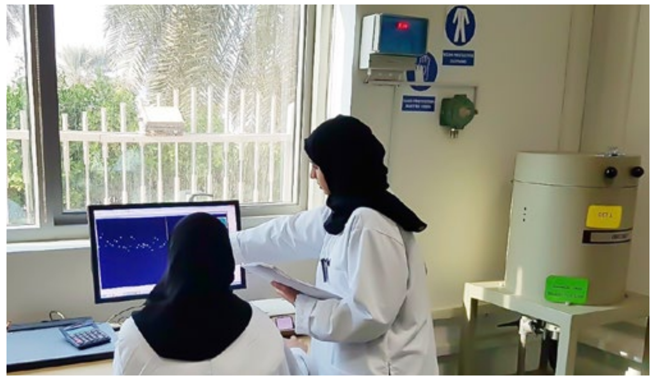
All containers were sealed tightly to retain radon gas and stored for 30 days to allow the radionuclides to come to secular equilibrium. A 60% efficient gamma spectrometer was used for laboratory measurements. The typical measurement time was between 15 to 18 hours with some measurements taking as long as 3.5 days. A summary of FANR's Radiological Environmental Monitoring Programme for 2019 is shown below in Table 1.

Table 1 - Synopsis of FANR Radiological Environmental Monitoring Programme

Sample Type	Sampling Frequency[1]	Number of Locations	Number of Samples Collected	Analysis	Analysis Frequency[1]	Number Analysed
Seawater, Nearshore	M	1 (1 CO)	24	Gamma Isotopic, Tritium	M	24
	Q	1 (1 BA)	7	Tritium	Q	7
Ground Water	SA	1	2	Gamma Isotopic	SA	2
Sediment	q	2	8	Gamma Isotopic	Q	8
Fish	Once per location	1	4	Gamma Isotopic	A	6
Direct Radiation	Continuous	17	775,213	Gross Gamma (Gamma Monitoring Network)	10-min avg	775,213
Direct Radiation (OSL)	Q	17	17	Ambient Dose	Q	17
Atmospheric Environment, Air Filters	Twice a month	3	79	Gamma Isotopic	M	79
Atmospheric Environment, Charcoal	Twice a month	3	80	Iodine-131	M	50
Soil/ Sand	Q (1 BA), Once per location	7	19	Gamma Isotopic	A	19
Vegetation (Date Palm Fruit)	S (Growing Season)	6	7	Gamma Isotopic	S	5
Vegetation (Tomato)	S (Growing Season)	1	1	Gamma Isotopic	S	1

1) W=Weekly, M=Monthly, Q=Quarterly, SA=Semi-annual, A=Annual, S= Seasonal

III.B.3 Data Interpretation



Due to the low environmental radiation background, the time of measurement for collected samples are 18 hours to 3.5 days for having an accurate data. As a result, extremely small levels of activity can be detected in the environment. If the activity of a particular radionuclide is not reported for a particular measurement, it means that the radionuclide is either not present or its activity is too small to be measured with the standard, established analytical method. In these cases, the activity of the radionuclide is reported as 'not measured' or 'not detected'. The typical limits of detectability for FANR's Environmental Laboratory are listed in Table B-11.

For different respective radionuclides to be 'detected' in a sample, the activity concentration level of the radionuclide must be higher laboratory's background activity concentration level. The laboratory's background was determined by taking the average of many (e.g., typically 20), long-duration, background measurements, each of which had undergone extensive review. The average laboratory background was then subtracted from all sample measurements in order to provide a true, net activity of each radionuclide in the environment.

When activity is 'detected', it means there is a high level of confidence that activity is present in the sample, and the amount of activity concentration will be reported with the uncertainty associated with the measurement.

In this report, FANR's Environmental Laboratory has adopted a 95% confidence level for the laboratory measurements. This is the typical standard for uncertainties in radiological environmental monitoring reports. This means that when activity concentration is reported for a particular radionuclide, there is greater than 95% confidence that the activity reported is within the range of uncertainties provided. This is sometimes referred to as a 2 sigma (2σ) confidence level.

III.B.4 Programme Exceptions

Some gamma monitoring stations were out of service for maintenance for extended periods in 2019. The overall average availability of all gamma monitoring stations in 2019 was 93%.

Out of the seven (7) sampled vegetation samples (date palm fruit) for analysis in 2019, two samples were not appropriate for laboratory preparation, as per FANR's Laboratory SOPs. Therefore, these two samples were discarded, and no analysis was performed.

In the atmospheric section, 30 out of 80 charcoal cartridges (air-iodine) samples were not analyzed radioiodine species due to unavailability of the Gamma- analysis detection towards the year-end.

III.C Results and Discussion

All water, vegetation, soil, and sediment samples collected in 2019 were analysed for gamma emitters in FANR's Environmental Laboratory in Abu Dhabi. Analysis of Tritium in all water samples were carried out in the Central Testing Laboratory of the Abu Dhabi Quality and Conformity Council. All direct radiation measurements from the gamma monitoring network were automatically collected. All OSL Dosimeters collected were analyzed by LANDAUER laboratory.

All analysis results are shown in Appendix B. For discussion, the analytical results are divided into four categories. The categories are Aquatic Environment, Atmospheric Environment, Terrestrial Environment, and Direct Radiation. These categories are further divided into subcategories according to sample type (e.g. water, sediment, fish for Aquatic Environment).

III.C.1 Aquatic Environment

The aquatic environment in the UAE was monitored by analysing shallow surface water near the shoreline of the Arabian Gulf, ground water samples from two wells, sediment from the exposed wetted shoreline at low tide, and fish samples from a control location in Abu Dhabi and at the vicinity of Barakah NPP site samples. Each of these sample types are discussed in the paragraphs below.

III.C.1.a Sea Water

Gamma Analysis:

FANR's Environmental Laboratory collected Thirty-one seawater samples for analysis in 2019. The sampling locations are depicted in Figure A-1. The sample location codes and additional details regarding the locations where samples are collected are shown in Table A 1.

FANR's Environmental Laboratory collected seawater samples monthly from one location in shallow water near the shore on Corniche Beach in Abu Dhabi. This is a routine sample location where seawater has been collected every year since 2015. In addition, for 2019, FANR's Environmental Laboratory collected seven samples from Barakah Site's discharge canal. All seawater samples exhibited detectable amounts of naturally occurring potassium-40 (K 40). No other naturally occurring nuclides or man-made nuclides were detected in any of the water samples. The analysis results for all 19 seawater samples are shown in Table B 1.

The average K-40 concentration of the twelve samples from Corniche Beach was 19.5 ± 4.6 Bq/kg. The sample collected in September from Barakah site had the highest K-40 concentration of 35.7 ± 3.1 Bq/kg and the samples collected from Corniche in March and April had the lowest K-40 concentration of 15.5 ± 1.0 Bq/kg and 15.6 ± 1.0 Bq/kg respectively.

Due to the unique characteristics of the Arabian Gulf with high local air temperatures, relatively shallow water and limited fresh water input, the salinity of the Gulf is higher than typical seawater. As a result, the potassium concentration of Gulf water is elevated relative to typical seawater. This leads to higher K-40 concentrations in Gulf water as the measurements in this report.

Tritium Analysis:
In 2019, 12 seawater samples were sent to the Central Testing Laboratory, of the Abu Dhabi Quality and Conformity Council, to be analysed for tritium. All the samples were collected from Corniche Beach in Abu Dhabi The sampling locations are depicted in Figure A1 and the sampling location codes and additional location details are shown in Table A1. The analysis results for all 12 seawater samples are shown in Table B-2.

III.C.1.b Ground Water

Tritium Analysis:
In 2019, two groundwater samples were sent to the Central Testing Laboratory, of the Abu Dhabi Quality and Conformity Council, to be analysed for tritium. All the samples were collected from water wells located in Abu Dhabi. The sampling locations are depicted in Figure A1 and the sampling location codes and additional location details are shown in Table A1. Both samples collected by FANR reported a concentration is < 6.5 Bq/L. The analysis results for both groundwater samples are shown in Table B-3.

III.C.1.c Sediment

Shore sediment is beach sand, soil, and other solids at the waterline of the shore. Shoreline sediment samples are collected at low tide from wetted areas that are underwater at high tide.

Eight shoreline sediment samples were collected for analysis in 2019. Figure A-1 shows the locations where samples were collected. The sampling location code and additional location details are shown in Table A-1.

One samples was collected from Abu Dhabi Corniche, and seven samples were collected from Barakah site Barakah Site's discharge canal. All sediment samples were composed primarily of sand and shell fragment.

All of the samples were analysed at FANR's Environmental Laboratory.

As expected, all sediment samples exhibited detectable amounts of naturally occurring potassium 40 (K--40), Uranium-235 (U-235), along with the expected progeny for the U-238 and Th-232 decay chains. The analysis results for all sediment samples are shown in Table B 4. The analysis results are reported as Becquerel per kilogram of dry sediment.

The Potassium-40 (K-40) activity in sediment is less than that reported in soil samples in section II.C.2.b, as expected, since it is soluble in water.

The variation of activity levels measured in the different samples can be explained by mineralogy and physical characteristics, in particular the granulometry, of the sediments.

Other than K-40, and the nuclides in the uranium and thorium decay chains, no other naturally occurring nuclides or man-made nuclides were detected in any of the sediment samples. The analysis results for all eight sediment samples are shown in Table B-4.

III.C.1.d Fish

Six fish samples were collected for inclusion in this report from two locations. These samples were collected from A Butain in Abu Dhabi Emirate and at the vicinity of Barakah site.
The location of the samples and other information are described in Table A-1. The location of the fish samples can be found on the map in Figure A-1.

Fishing and harvesting marine resources are part of UAE culture. Fish is economically important and is part of local diet throughout the UAE.

The concentrations of gamma emitters in all fish samples are shown in Table B 5. All fish samples showed detectable amounts of naturally occurring K-40. The analysis results are reported as becquerels per kilogram (wet) of fresh fish fillet without skin and bone.

III.C.2 Terrestrial Environment

The terrestrial environment was monitored by analysing soil and date fruit taken from various locations throughout the United Arab Emirates.

Samples of vegetation were collected during the growing season. Two type of vegetation date palm fruit and Tomato samples were sampled during the growing season.

III.C.2.a Vegetation

III.C.2.a.1 Date Palm Fruit

Date fruit (Phoenix dactylifera linnaeus) as a food crop was selected for analysis in 2019, taken from palm trees All of the date fruit samples were sampled by FANR from several farms across Abu Dhabi emirates. In the UAE, date palm trees are economically important and widely cultivated throughout the UAE. The date palm fruit is part of the local diet.

In total, seven (7) date fruit samples were collected from six location. The samples locations and other sample information are described in Table A-1. The sample locations for vegetation samples can be found on the map in Figure A-1.

The concentrations of gamma emitters in all date palm fruit samples are shown in Table B-6. All date fruit samples showed detectable amounts of naturally occurring K-40. The analysis results are reported as Becquerel per kilogram of fresh flesh of date palm fruit, without pits.

For date fruit samples, the average K-40 activity concentration was 184.4 Bq/kg with a 2-sigma uncertainty of ±8.0 Bq/kg. No other naturally-occurring nuclides or man-made nuclides were detected in any of the date fruit samples.

III.C.2.a.2 Tomato

One tomato samples (Solanum lycopersicum) was collected in 2019 for analysis, as it represents a food crop that is part of the local diet. The sample was collected from a farm in Bida'a Al Mutawa'a, Al Dhafra region in Abu Dhabi. The sample location and other sample information are described in Table A-1. The sample location for the tomato sample can be found on the map in Figure A-1.

The tomato sample was anlayzed for gamma-emitters. As expectd, the sample showed detectable amount of naturally occurring K-40 (56.5 ± 2.6). The analysis results are reported as Becquerel per kilogram of fresh. No other naturally-occurring nuclides or man-made nuclides were detected in this sample. The analysis results for the tomato sample are shown in Table B-7.

III.C.2.b Soil

Nineteen (19) surface soil samples were collected for analysis in 2019 by FANR's Environmental Laboratory. The locations of the soil samples are shown in Figure A-1; the location codes and additional location details are shown in Table A-1.

As expected, all soil samples exhibited detectable amounts of naturally occurring K- 40, uranium 238 (U-238), and thorium 232 (Th-232) along with the expected progeny for the U-238 and Th-232 decay chains.

The analysis results are reported as Becquerel per kilogram of dry soil.

Caesium 137 (Cs-137) was detected in four samples (4) only at very low concentration between 0.13 Bq/kg to 0.30 Bq/kg with an average activity of 0.23 Bq/kg, which is consistent with expected concentrations due, primarily, to residual fallout from past atmospheric nuclear weapons testing in other countries. Cesium-137 was not detected in the other soil sample.

Other than K-40, Cs-137 and the nuclides in the uranium and thorium decay chains, no other naturally-occurring nuclides or man-made nuclides were detected in any of the soil samples. The analysis results for all soil samples are shown in Table B-8.

III.C.3 Direct Radiation

In 2019, Direct radiation was measured with Geiger-Muller detectors and a sodium iodide detector and from Optically Stimulated Luminescent (OSL) dosimeters are used for environmental monitoring determining the ambient gamma radiation throughout the UAE.

The Geiger-Muller detectors and the sodium iodide detector are part of the gamma monitoring network, which is a series of fixed stations located throughout the UAE. All of these devices measure the effective gamma dose rate in units of nSv/h.

OSLs dosimeters used for environmental monitoring of external ambient dose, and the measured doses are expressed in the quantity of dose equivalent in unit of mSv.

III.C.3.a Gamma Monitoring Network (GMN)

FANR maintains a set of radiation detectors located in various areas throughout the UAE. Several of these detectors are located around the Barakah Nuclear Power Plant. This set of radiation detectors is referred to in this report as the gamma monitoring network (GMN). The location of each gamma monitoring station active in 2019 is shown in Figure A-3. The locations of the different gamma monitoring stations are shown in Table A 1.

The gamma monitoring network consists of fixed stations that are designed to run continuously and provide real-time measurements of background radioactivity in the UAE. The gamma monitoring network also provides early warning in the event of radiological and nuclear events. The gamma monitoring network also provides critical information for deciding the protective actions to be taken in the case of emergency.

> Equipment and Monitoring Locations for the GMN

In 2019 FANR had seventeen (17) gamma monitoring stations, 15 of which were configured with Geiger–Muller detectors, and Two station with a combination of a Geiger-Muller detector and a scintillation detector. These Geiger-Muller detectors can measure low dose rates (from 10 nSv/h to 2,000,000 nSv/h) and high dose rates (up to 10 billion nSv/h). All the dose rate measurements in this report are from the low-dose-rate detectors. The gamma monitoring station configured with a scintillation detector contains a sodium iodide (i.e. NaI) detector and a Geiger-Muller detector with a collective measuring range of 1 to 100,000,000 nSv/h. The sodium iodide detector is able to identify specific radionuclides whereas the Geiger-Muller detectors do not have that capability.

In 2019, dose rate measurements were collected from a total of seventeen (17) gamma monitoring stations.

> Data Collection and Data Storage for the GMN

The gamma monitoring network is controlled by a central computer called the network monitoring centre (NMC) located at FANR's Headquarters in Abu Dhabi. During routine operation, gamma dose rates are continuously measured at 17 stations. Fifteen (15) of these stations each have three (3) Geiger-Muller detectors: two (2) detectors for measuring low activity concentration and one detector reserved for high-range measurements. Two stations are specially configured with a sodium iodide detector for low-range measurements and a Geiger-Muller detector for high-range measurements.

Every minute a dose rate measurement is recorded, and every 10 minutes an average dose rate is calculated based on the previous 10-minute period. Every eight hours, the data from each station is automatically sent to the network monitoring centre. In case of emergency, the measurement data will be received more frequently from the stations. All of this data is summarized in this report.

Graphs of all dose rate measurements collected in 2019 from all 17 gamma monitoring stations are shown on Figure A-3. The gamma dose rates (nSv/h) from each gamma monitoring station are summarized in more detail on Table B-7. Additionally, the quarterly and annual doses at each location are shown on Table B-8.

> Quality Control and Data Analysis for the GMN

In 2019, each gamma station passed an annual accuracy test to ensure the operability and functionality of the radiation detector and the accuracy of the measurements. Furthermore, each station is standardised (±5 nSv/h) against a reference station which allows direct comparisons of the measurements between all stations. In order to ensure the validity of the data, all data from the gamma monitoring network are reviewed automatically by the network monitoring centre software. An analyst then evaluates the data, and the valid dose-rate measurements are flagged in the database for inclusion in this report. Invalid data such as data collected from detectors that are under maintenance or from detectors that are experiencing technical failures are flagged as invalid data, and, although the invalid data is stored in the database, it is not displayed in this report.

The annual average dose rates for all 17 gamma monitoring stations are included in Table B 7. The average annual dose rate for all 17 stations is 40 nSv/h. Figure A-3 contains the results of all dose-rate measurements from the 17 gamma monitoring stations for 2019.

In 2019, the annual average cumulative dose for the 17 gamma monitoring stations (i.e. Geiger-Muller detectors) was 0.350 mSv. The station with the lowest annual dose was Sharjah University (DG04) with 0.244 mSv. The station with the highest annual dose was Al Ain (DG12) with 0.450 mSv.

Annual and quarterly doses for the 17 gamma monitoring stations can be found in Table B-8.

III.C.3.b Optically Stimulated Luminescence (OSL) Dosimeters

The Federal Authority of Nuclear Regulation (FANR) started the monitoring of environmental dose rates in the 4th quarter of 2017 and will continue to be taken each quarter in the coming years. Direct radiation was measured by using optically stimulated luminescence (OSL) provided by LANDAUER Laboratory, which is ISO/IEC 17025 accredited for requirements of Testing and Calibration Laboratories, and was installed about 1 m above ground in several locations around the UAE and surrounding the Barakah Nuclear Power Plant. The dosimeters were placed in the seventeen (17) selected locations listed in Table A-1 and shown in Figure A-2. The control dosimeter is also provided to measure exposure during transportation and storage time of dosimeters before deployment and after collection. The control dosimeter was kept in the dosimeter rack at FANR headquarter (reference location) for the corresponding exposure period (quarterly).

All the Dosimeters collected were analysed by LANDAUER laboratory. The analytical results for this reporting period are presented in Table B-12. The Dose equivalent for the monitoring period and above the dose equivalent of the reference location (dosimeter rack at FANR) was shown below the minimum reporting threshold of the dosimeter which is 0.05 mSv.

III.C.4 Atmospheric Environment

The atmospheric environment was monitored by analyzing air particulate filters and charcoal cartridges (for trapping radioiodine species). Samples were collected from three locations at Baraka site, Ruwais and Abu Dhabi which listed in Table A-1.

III.C.4.a Air Particulate Filters

Twice a month air particulate filter samples were collected from the three locations, referenced above. All 79 filter samples were analysed for gamma emitters. Gamma spectrometric analyses of air particulate samples exhibited no detectable concentrations of any plant-related radionuclides in any of these samples as shown in Table B-13.

III.C.4.b Air Iodine

Twice a month charcoal cartridges (for trapping radioiodine species) were collected from the three locations, referenced above, starting from May. Out of 80 samples, 50 were analyzed for radioiodine species and exhibited no detectable concentrations of I-131 during the year (Table B-14).

III.D Conclusion

Natural radionuclides were detected in all samples in 2019 as expected.

In general, the dose rates in the UAE are very low when compared to most other countries in the world . The mountainous areas of the UAE have higher gamma dose rates than the coastal regions, as expected. Low levels of Cs-137 were observed in only four soil samples, at very low level. This is normal and is consistent with expected concentrations due, primarily, to residual fallout from past atmospheric nuclear weapons testing in other countries[6]. No other man-made radionuclides were observed in any of the samples in 2019.

The analysis results from 2019 shown in Appendix B of this report establish a radiological baseline for radioactivity in the environment of the UAE. All of the results of the analysis obtained prior to the operation of the Barakah Nuclear Power Plant will establish the baseline level of radiation in the UAE. If the baseline level of radiation changes in future years, the data in this report may be used to determine the cause of such changes.

[6] See reference (1) in section IV

IV. References

1. **United Nations Scientific Committee on the Effects of Atomic Radiation. (1988). Sources, Effects and Risks of Ionizing Radiation. New York: United Nations. IAEA. (n.d.). Radiation in Everyday Life.**

2. **IAEA. (n.d.). Radiation in Everyday Life.** Retrieved 2018 from: https://www.iaea.org/Publications/Factsheets/English/radlife

3. **Radiation: effects and sources, United Nations Environment Programme, (2016). United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). ISBN: 978-92-807-3517-8.** https://www.unscear.org/unscear/en/publications/radiation-effects-and-sources.html

4. **NUREG-1301, Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors," Generic Letter 89-01, Supplement 1, U.S. Nuclear Regulatory Commission, Washington DC, April, 1991.**

5. **Abu Dhabi State Of Environment Report 2017 Fisheries, (2017) Marine Biodiversity Environment Agency – Abu Dhabi Environment Agency.**

6. **United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). Sources, Effects and Risks of Ionizing Radiation. New York: United Nations.**

7. **IAEA Technical Report Series No. 476, The Environmental Behaviour of Radium: Revised Edition, Vienna, 2014, pages 81-88.**

APPENDIX A
SAMPLING LOCATIONS

Appendix A summarises detailed information regarding the different locations where samples were collected in 2019

Table A-1
Locations of Environmental Sampling, 2019

Sample Location Code	Region	Location Name	Latitude	Longitude
		Water		
WS-1BA	Abu Dhabi	Barakah	23.97643	52.256320
WS-1CO	Abu Dhabi	Abu Dhabi Corniche Beach	24.475501	54.341186
		Ground Water		
WG-1BM	Abu Dhabi	Bida'a Al Mutawa'a	23.78121167	52.567475
WG-1MS	Abu Dhabi	Al Dhafra	23.94019	51.98956
		Sediment		
WM-1CO	Abu Dhabi	Abu Dhabi Corniche Beach	24.47569	54.34143
WM-1BA	Abu Dhabi	Barakah	23.97643	52.25632
		Fish		
IF-1AD	Abu Dhabi	Abu Dhabi	24.47569	54.34143
IF-1BA	Abu Dhabi	Barakah	23.97643	52.25632
		Vegetation (Tomato & Date Palm Fruit)[1]		
ID-1BA	Al Dhafra	Barakah	23.96082	52.19322
ID-1MF	Al Dhafra	Al Marfa	32.34171	36.202
ID-1GY	Al Dhafra	Ghayathi	23.68451	52.9097
ID-1LI	Al Dhafra	Liwa	23.03551	53.6502
ID-1BM	Al Dhafra	Bida'a Al Mutawa'a	23.78137	52.5667
ID-1HM	Al Dhafra	Al Hamra	24.04647	52.452
		Airborne		
AB-1RU	Abu Dhabi	Ruwais	24.11275	52.607375
AB-1BA	Abu Dhabi	Barakah	23.95783	52.23747
AB-1CO	Abu Dhabi	Abu Dhabi Corniche	24.485314	54.35088
		Soil		
DS-1BA	Abu Dhabi	Barakah	23.95784	52.23755

Table A-1 (Continued)
Locations of Environmental Sampling, 2019

Sample Location Code	Region	Location Name	Latitude	Longitude
		Soil (continued)		
DS-1AA	Abu Dhabi	Al Ain Farm	25.13218	55.88909
DS-1CO	Abu Dhabi	Corniche beach, Abu Dhabi	24.476152	53.343083
DS-1OW	Abu Dhabi	Owatid	23.39559	53.1119
DS-1SI	Abu Dhabi	Al Sila	24.03282626	51.75720647
DS-1DP	Umm Al Qwain	Dream Land Park Umm Al Qwain	25.59165	55.66048333
DS-1BM	Abu Dhabi	Bida'a Al Mutawa'a	23.78137	52.5667
		Direct Radiation, Gamma Monitoring Network		
DG02	Ras Al Khaimah	Al Jeer	----2	----2
DG03	Umm al-Quwain	Dream Park	----2	----2
DG04	Sharjah	Sharjah, University	----2	----2
DG06	Dubai	Port Rashid	----2	----2
DG07	Sharjah	Mleiha	----2	----2
DG08	Abu Dhabi	Marina	----2	----2
DG09	Abu Dhabi	Barakah S G1	----2	----2
DG10	Abu Dhabi	Barakah WSW G4	----2	----2
DG11	Abu Dhabi	Barakah ENE G6	----2	----2
DG17	Abu Dhabi	Barakah G2	----2	----2
DG12	Abu Dhabi	Al Ain	----2	----2
DG13	Abu Dhabi	Ruwais	----2	----2
DG14	Abu Dhabi	Silaa	----2	----2
DG15	Abu Dhabi	Owatid	----2	----2
DG16	Abu Dhabi	Madinat Zayed	----2	----2
DN01	Abu Dhabi	Marina	----2	----2
DN02	Abu Dhabi	Barakah G2	----2	----2

Table A-1 (Continued)
Locations of Environmental dosimeters (OSL), 2019

Sample Location Code	Location
OSL	
DR-01	Barakah-SSE G2
DR-02	Barakah-WSW – G4
DR-03	Barakah-E
DR-04	Ruwais Laboratory
DR-05	Al Sila-NCMS
DR-06	Owtaid-NCMS
DR-07	Madinat Zayed
DR-08	Marina AD
DR-09	Port Rashid-DXB
DR-10	Dream Park-UAQ
DR-11	Al Jeer-RAK
DR-12	Kalba- Sharjah
DR-13	Mleiha-Sharjah
DR-14	Al Ain farm
DR-15	Masafi
DR-16	Jumeirah-Dubai
DR-17	Al Qatara- Al Ain
Control	Transit (FANR Headquarter Office)

1) Although a single latitude and longitude is listed for this sample, in actuality date fruit in one sample may have been collected from many different trees in the general vicinity of the sample location listed. The exact latitude and longitude of the sample (or samples) at this location was not available at the time this report was written.
2) These locations are not being published at this time.

Figure A-1
Map of Water, Airborne, Sediment, Fish, Vegetation and Soil Sampling Locations

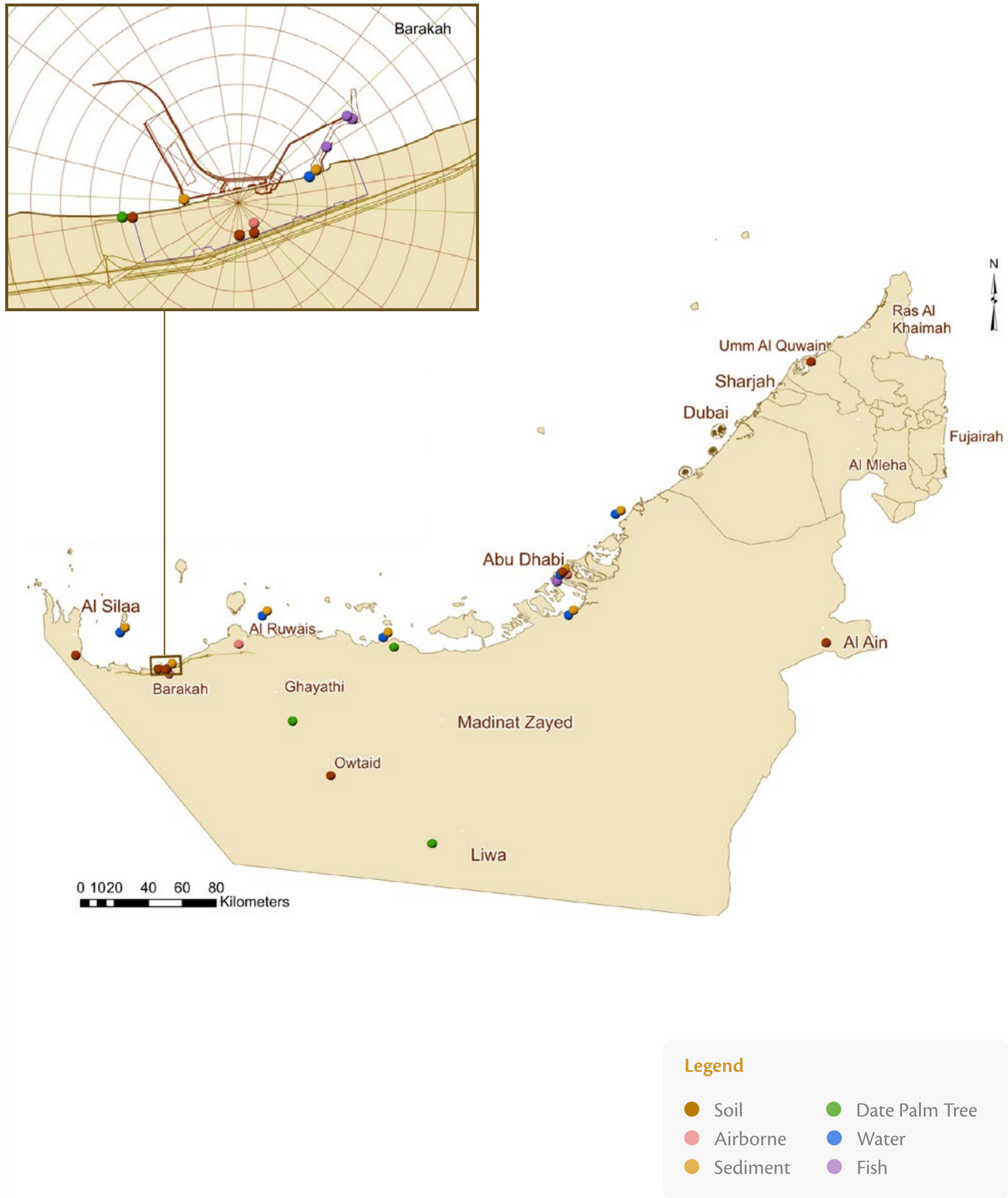
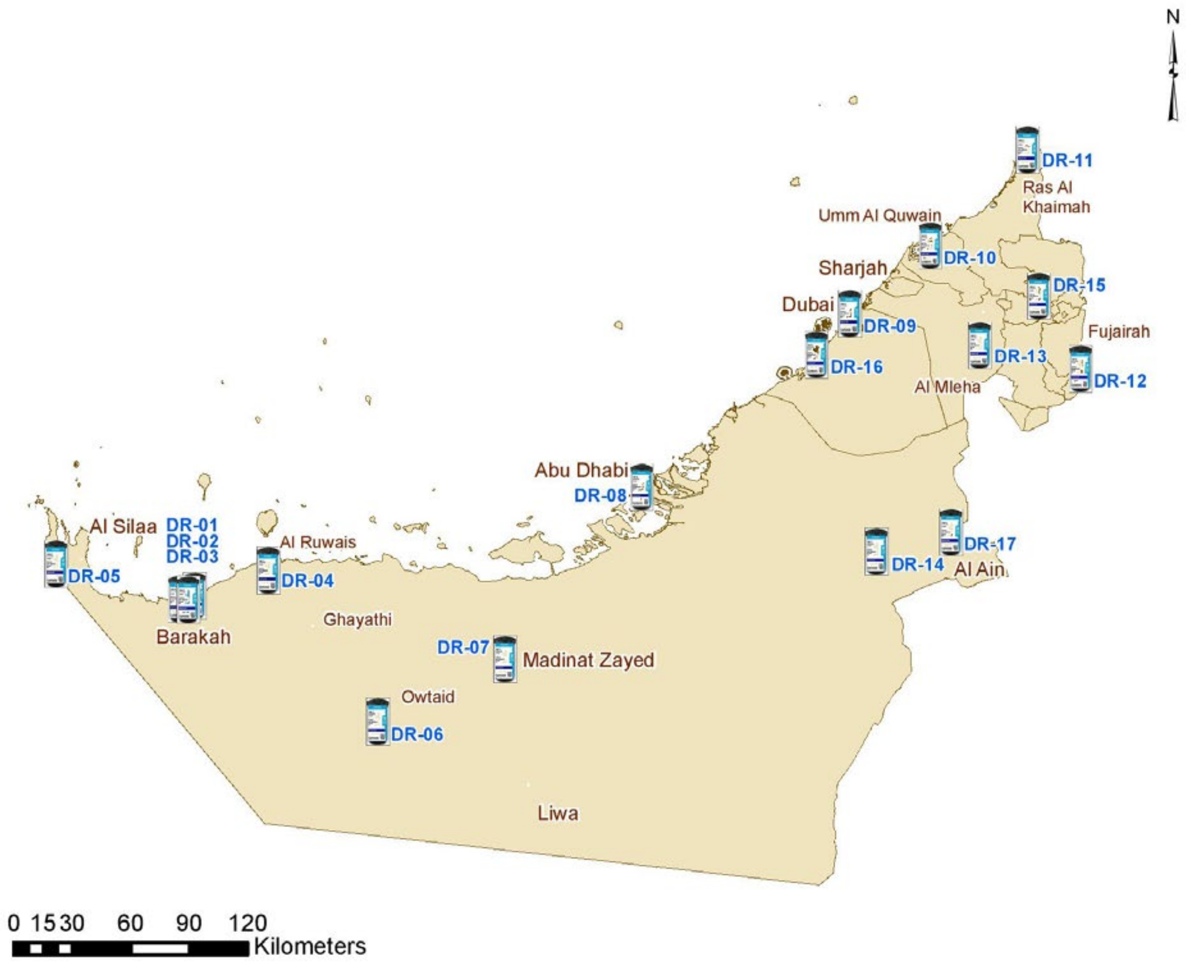


Figure A-2

Map of Environmental Optically Stimulated Luminescent Dosimeters (OSL) Sampling Locations



Legend

Environemental Dosmimeters

Figure A-3

Map of FANR's Gamma Monitoring Network including Trends in Dose Rates

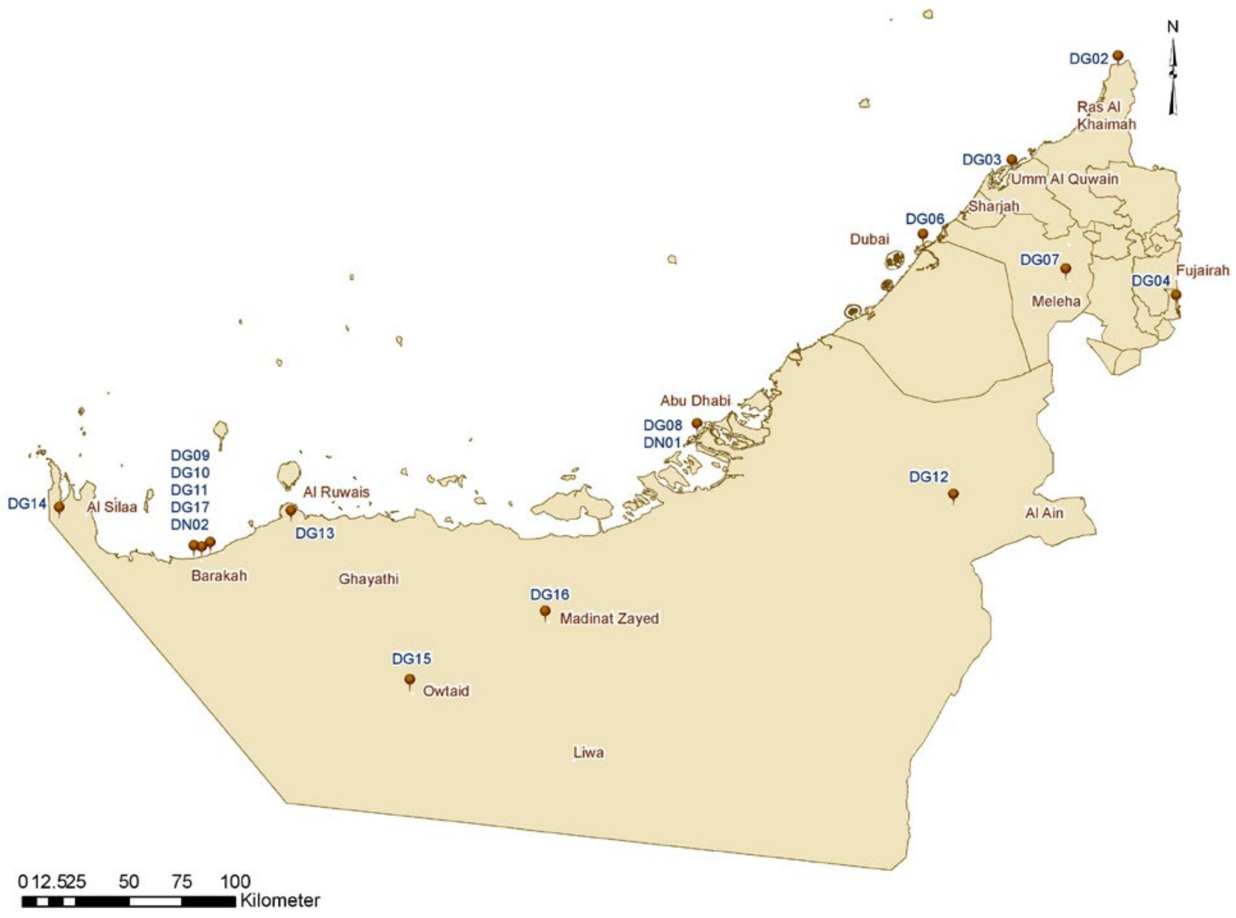
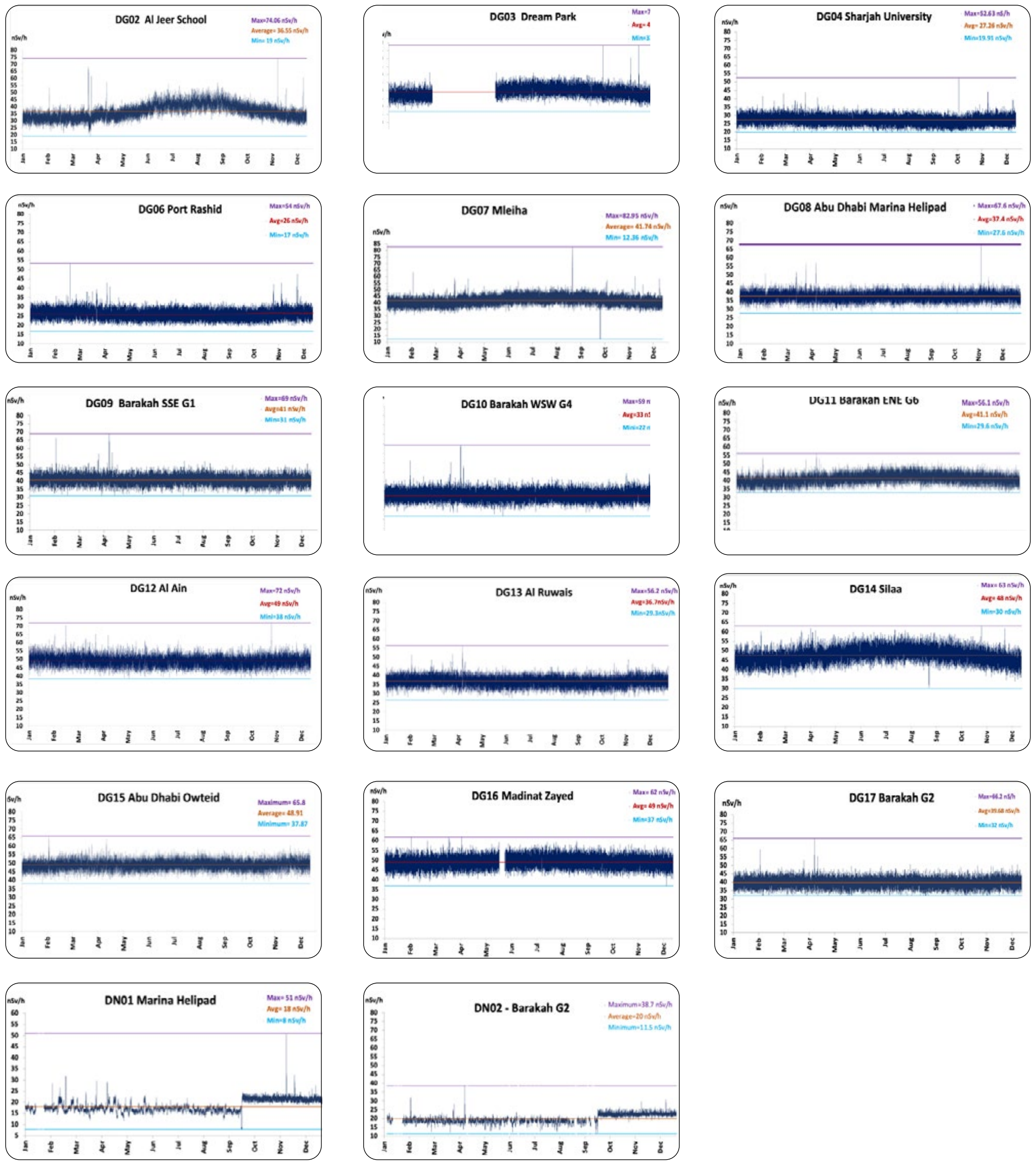


Figure A-3 (Continued)
Map of FANR's Gamma Monitoring Network including Trends in Dose Rates



APPENDIX B
ANALYSIS RESULTS

Appendix B summarises the analytical results for all of the radiological analyses conducted in 2019 as part of FANR's radiological environmental monitoring programme.

Table B-1
Gamma Activity in Sea Water

Sampling Location Code	Sampling Date	K-40 Bq/kg	Uncertainty ± 2σ Bq/kg	Other Gamma Emitters
WS-1CO	22-Jan	8.3	0.6	ND*
	20-Feb	15.9	1.1	ND*
	19-Mar	15.5	1.0	ND*
	21-Apr	15.6	1.0	ND*
	23-May	16.1	0.8	ND*
	25-Jun	16.7	1.0	ND*
	22-Jul	16.5	1.1	ND*
	15-Aug	31.3	2.8	ND*
	26-Sep	23.1	1.7	ND*
	24-Oct	23.9	1.7	ND*
	28-Nov	23.8	1.7	ND*
	18-Dec	21.8	1.6	ND*
WS-1BA	2-Jan	17.1	1.1	ND*
	2-Apr	16.8	1.0	ND*
		16.4	0.8	ND*
	3-Jul	18.2	1.1	ND*
		16.5	1.1	ND*
	25-Sep	35.7	3.1	ND*
		20.5	1.3	ND*

* ND: Not Detected

Table B-2
Tritium Activity in Sea Water

Sampling Location Code	Sampling Date	H3- Bq/L	LLD Bq/L
WS-1CO	January	< 4.7	4.7
WS-1CO	February	< 4.7	4.7
WS-1CO	March	< 4.7	4.7
WS-1CO	April	< 4.7	4.7
WS-1CO	May	< 4.7	4.7
WS-1CO	June	< 4.7	4.7
WS-1CO	July	<0.6	0.6
WS-1CO	August	< 4.7	4.7
WS-1CO	September	< 4.7	4.7
WS-1CO	October	< 4.7	4.7
WS-1CO	November	< 4.7	4.7

Table B-3
Tritium Activity in Ground Water

Sampling	Sampling Date	H3- Bq/L	LLD Bq/L
WG-1BM	26-Aug	< 6.50	6.5
WG-1MS	26-Aug	< 6.48	6.5

Table B-4
Gamma Activity in Sediment (Bq/Kg) and Uncertainty (Bq/Kg±2σ)

Sample Code	Sample Date 2019	K-40		U-238[1]		Th-232[2]		Other Nuclides
		Activity	Uncertainty	Activity	Uncertainty	Activity	Uncertainty	
WM-1CO	20-Feb	32.7	2.4	5.10	0.44	3.10	0.37	ND[3]
WM-1BA	02-Jan	184.9	7.8	8.22	0.56	3.21	0.61	ND[3]
	04-May	138.4	3.5	8.60	0.24	6.89	0.28	ND[3]
	04-May	99.2	5.3	3.55	0.34	4.36	0.40	ND[3]
	03-Jul	223.7	10.9	9.55	0.25	4.03	0.15	ND[3]
	03-Jul	122.9	3.2	4.33	0.17	5.02	0.22	ND[3]
	25-Sep	195.4	10.4	9.47	0.68	6.82	0.65	ND[3]
	25-Sep	101.1	5.9	4.04	0.39	3.98	0.42	ND[3]

1) U-238 activity is based on Pb-214 and Bi-214 activity
2) Th-232 activity is based on Tl-208, Pb-212 and Ac-228 activity
3) ND=Not Detected

Table B-5
Gamma Activity in Fish (Bq/Kg) and Uncertainty (Bq/Kg±2σ)

Sample Code	Sample Date 2019	K-40		Cs-137		U-238[1]		Th-232[2]		Other Nuclides
		Activity	Uncertainty	Activity	Uncertainty	Activity	Uncertainty	Activity	Uncertainty	
IF-1AD	10-Mar	127.2	5.6	ND[3]	-	ND[3]	-	ND[3]	-	ND[3]
IF-1AD	11-Mar	121.2	5.4	ND[3]	-	ND[3]	-	ND[3]	-	ND[3]
IF-1BA	04-May	44.3	2.3	ND[3]	ND[3]	0.36	0.10	ND[3]	-	ND[3]
IF-1BA	04-May	43.3	2.3	ND[3]	-	0.40	0.09	0.25	0.07	ND[3]
IF-1BA	04-May	33.1	1.9	ND[3]	-	0.83	0.12	0.18	0.05	ND[3]
IF-1BA	05-May	41.3	2.2	ND[3]	ND[3]	0.33	0.08	0.25	0.06	ND[3]

1) U-238 activity is based on of Pb-214 and Bi-214 activity
2) Th-232 activity is based on Tl-208, Pb-212 an Ac-228 activity
3) ND= Not Detected

Table B-6
Gamma Activity in Date Palm Fruit

Sampling	Sampling Date	K40-, Bq/kg (and Uncertainty, 2±σ) Fresh Flesh Dates, without Pits	LLD Bq/L
ID-1BA	31-Jul	114 (±6)	ND[1]
ID-1BA	31-Jul	135 (±4)	ND[1]
ID-1MF	18-Sep	244 (±13)	ND[1]
ID-1GY	19-Sep	217 (±11)	ND[1]
ID-1LI	19-Sep	214 (±11)	ND[1]
ID-1BM	26-Aug	NA[2]	ND[1]
ID-1HM	26-Nov	NA[2]	ND[1]

1) [1]Not Detected
2) [2]Not Analyzed

Table B-7
Gamma Activity in Tomato

Sampling	Sampling Date	K40-, Bq/kg (and Uncertainty, 2±σ)	LLD Bq/L
IT-1BM	3-Apr	57 (±3.0)	ND[1]

1) [1]Not Detected

Table B-8
Gamma Activity in Soil (Bq/Kg) and Uncertainty (Bq/Kg±2σ)

Sample Location Code	Sample Date 2018	K-40 Uncertainty ± 2σ	K-40 Activity	Cs-137 Uncertainty ± 2σ	Cs-137 Activity	U-238[1] Uncertainty ± 2σ	U-238[1] Activity	Th-232[2] Uncertainty ± 2σ	Th-232[2] Activity	Other Nuclides
DS-1BA	02-Jan	284.6	11.6	0.3	0.01	16.46	0.71	5.98	0.49	ND[3]
	02-Jan	231.2	11.0	ND[3]	ND[3]	11.2	0.6	9.96	0.87	ND[3]
	02-Apr	192.0	9.3	ND[3]	ND[3]	8.5	0.5	7.71	0.71	ND[3]
	02-Apr	255.8	12.3	ND[3]	ND[3]	15.4	0.7	10.63	0.70	ND[3]
	03-Jul	167.1	9.1	ND[3]	ND[3]	6.6	0.5	0.00	0.59	ND[3]
	03-Jul	289.3	11.8	0.13	0.01	17.39	0.75	6.12	0.50	ND[3]
	25-Sep	270.3	12.9	ND[3]	ND[3]	15.4	0.7	12.74	0.90	ND[3]
	25-Sep	199.4	10.2	ND[3]	ND[3]	6.8	0.5	5.54	0.58	ND[3]
DS-1AA	06-Jan	260.9	10.6	0.3	0.01	19.70	0.83	10.82	0.82	ND[3]
	31-Mar	237.3	11.5	ND[3]	ND[3]	18.8	0.8	23.43	1.72	ND[3]
	01-Jul	234.4	11.3	ND[3]	ND[3]	17.8	0.8	24.87	1.38	ND[3]
	23-Sep	246.5	11.8	ND[3]	ND[3]	15.8	0.9	18.17	1.30	ND[3]
DS1-CO	20-Feb	35.0	7.2	ND[3]	ND[3]	3.30	0.40	ND[3]	ND[3]	ND[3]
	02-Jul	69.3	12.2	ND[3]	ND[3]	6.73	0.43	ND[3]	ND[3]	ND[3]
DS1-OW	03-Apr	338.0	15.9	ND[3]	ND[3]	10.9	0.6	18.48	1.17	ND[3]
	04-Jul	316.4	14.9	ND[3]	ND[3]	10.7	0.5	15.97	1.04	ND[3]
DS-1SI	02-Jan	319.4	15.1	ND[3]	ND[3]	16.4	1.0	22.54	1.70	ND[3]
DS-1DP	07-Jan	194.9	9.5	ND[3]	ND[3]	13.8	0.7	14.94	1.09	ND[3]
DS1-BM	03-Apr	409.2	16.7	0.2	0.43	12.3	0.57	9.93	0.76	ND[3]

1) U-238 activity is based on of Pb-214 and Bi-214 activity
2) Th-232 activity is based on Tl-208, Pb-212 and Ac-228 activity
3) Not Detected

Table B-9
Availability and Gamma Dose Rates Measured from Gamma Monitoring Network (GMN)

Station Name	Sampling Code	Annual Average Dose Rate, nSv/h	Minimum Dose Rate, nSv/h	Maximum Dose Rate, nSv/h	Range nSv/h	Availability[1]
Al Ain	DG12	49	38	72	34	100%
Dream Park	DG03	49	37	78	41	78%
Barakah SSE G1	DG09	41	31	65	34	97%
Barakah G2	DG17	41	32	66	34	92%
Mleiha	DG07	42	30	64	35	99%
Barakah ENE G6	DG11	41	29	63	34	99%
Barakah WSW G4	DG10	33	22	59	38	100%
Barakah G2	DN02	41	36	59	23	90%
Marina	DG08	33	16	56	40	97%
Marina	DN01	33	26	46	20	94%
Al Jeer	DG02	34	24	52	28	99%
Sharjah University	DG04	28	19	62	43	99%
Owatid	DG15	42	29	56	27	59%
Port Rashid	DG06	26	17	54	37	100%
Selaa	DG14	48	30	63	33	100%
Madinat Zayed	DG16	49	37	62	25	98%
Ruwais	DG13	35	25	61	36	99%
Average dose rate for all stations, nSv/h		**40**	Average dose rate for all stations, nSv/h			**93%**

1) Availability refers to the fraction of time the monitor is in service. Availability is calculated based on the date the gamma monitoring station was initially declared operable.

Table B-10
Doses Measured with the Gamma Monitoring Network (GMN)

Station Location Code	Location Name	Qtr. 1 mSv	Qtr. 2 mSv	Qtr. 3 mSv	Qtr. 4 mSv	Average Dose/Qtr. mSv	Annual Dose mSv
DG12	Al Ain	0.108	0.106	0.107	0.108	0.107	0.429
DG03	Dream Park	0.1019	0.1103	0.1123	0.1062	0.1077	0.431
DG09	Barakah SSE G1	0.090	0.089	0.090	0.090	0.090	0.360
DG17	Barakah G2	0.092	0.090	0.090	0.090	0.090	0.362
DG07	Mleiha	0.088	0.091	0.094	0.091	0.091	0.365
DG11	Barakah ENE G6	0.087	0.090	0.092	0.089	0.089	0.357
DG10	Barakah WSW G4	0.071	0.071	0.072	0.072	0.072	0.287
DN02	Barakah G2	0.089	0.090	0.091	0.091	0.090	0.361
DG08	Marina	0.072	0.071	0.073	0.072	0.072	0.288
DN01	Marina	0.072	0.072	0.073	0.073	0.072	0.290
DG02	Al Jeer	0.071	0.074	0.079	0.074	0.075	0.298
DG04	Sharjah University	0.060	0.061	0.061	0.062	0.061	0.244
DG15	Owatid	0.090	0.097	0.096	0.093	0.094	0.377
DG06	Port Rashid	0.058	0.056	0.056	0.058	0.057	0.228
DG14	Selaa	0.098	0.106	0.110	0.102	0.104	0.416
DG16	Madinat Zayed	0.105	0.108	0.110	0.107	0.107	0.429
DG13	Ruwais	0.078	0.077	0.077	0.078	0.078	0.310
Average dose for all stations, mSv						**0.087**	**0.350**

Table B-11
Calculated Lower Limit of Detection (LLD)[3] for Gamma Isotopic Analysis

Selected Nuclides	Water (Bq/kg)	Dates (Bq/kg)	Soil (Bq/kg)	Fish (Bq/kg)	Sediment (Bq/kg)
K-40	0.26	0.37	0.30	0.45	0.43
Tl-208	0.08	0.10	0.08	0.12	0.12
Pb-212	0.09	0.11	0.09	0.13	0.14
Pb-214	0.13	0.13	0.11	0.15	0.16
Bi-212	0.29	0.41	0.34	0.49	0.49
Bi-214	0.09	0.12	0.10	0.15	0.15
Ra-226	0.09	0.12	0.10	0.15	0.15
Ac-228	0.10	0.13	0.11	0.16	0.16
Th-232[1]	0.24	0.13	0.11	0.16	0.16
Th-234	1.44	1.67	1.37	1.99	2.29
Pa-234m	2.31	3.45	2.81	4.13	4.02
U-235	0.08	0.10	0.08	0.12	0.13
U-2382	0.08	0.12	0.10	0.15	0.15
Cs-137	0.06	0.03	0.01	0.06	0.03

1) Th-232 sensitivity is based on Tl-208, Pb-212, and Ac-228 activity.
2) U-238 sensitivity is based on Pb-214 and Bi-214 activity.
3) Lower limit of detection (LLD) as calculated with US NRC NUREG-1301 (Reference 4)

Table B-12
Direct Radiation, Optically Stimulated Luminescence (OSL) Dosimeters

Sample Location Code	Sample Installation Date	Sample Retrieval Date	Dose Equivalence msv	Sample Location Code	Sample Installation Date	Sample Retrieval Date	Dose Equivalence msv
DR-01	02-Jan	02-Apr	< 0.05	DR-07	03-Apr	04-Jul	< 0.05
DR-02	02-Jan	02-Apr	< 0.05	DR-08	01-Apr	02-Jul	< 0.05
DR-03	02-Jan	02-Apr	< 0.05	DR-09	01-Apr	02-Jul	< 0.05
DR-04	02-Jan	02-Apr	< 0.05	DR-10	01-Apr	02-Jul	< 0.05
DR-05	02-Jan	02-Apr	< 0.05	DR-11	01-Apr	01-Jul	< 0.05
DR-06	03-Jan	03-Apr	< 0.05	DR-12	31-Mar	01-Jul	< 0.05
DR-07	03-Jan	03-Apr	< 0.05	DR-13	31-Mar	01-Jul	< 0.05
DR-08	07Jan	01-Apr	< 0.05	DR-14	31-Mar	01-Jul	< 0.05
DR-09	07-Jan	01-Apr	< 0.05	DR-15	31-Mar	01-Jul	< 0.05
DR-10	07-Jan	01-Apr	< 0.05	DR-16	01-Apr	02-Jul	< 0.05
DR-11	07-Jan	01-Apr	< 0.05	DR-17	31-Mar	01-Jul	< 0.05
DR-12	06-Jan	31-Mar	< 0.05	DR-01	03-Jul	25-Sep	< 0.05
DR-13	06-Jan	31-Mar	< 0.05	DR-02	03-Jul	25-Sep	< 0.05
DR-14	06-Jan	31-Mar	< 0.05	DR-03	03-Jul	25-Sep	< 0.05
DR-15	06-Jan	31-Mar	< 0.05	DR-04	03-Jul	25-Sep	< 0.05
DR-16	07-Jan	01-Apr	< 0.05	DR-05	03-Jul	25-Sep	< 0.05
DR-17	07-Jan	31-Mar	< 0.05	DR-06	04-Jul	26-Sep	< 0.05
DR-01	02-Apr	03-Jul	< 0.05	DR-07	04-Jul	26-Sep	< 0.05
DR-02	02-Apr	03-Jul	< 0.05	DR-08	02-Jul	24-Sep	< 0.05
DR-03	02-Apr	03-Jul	< 0.05	DR-09	02-Jul	24-Sep	< 0.05
DR-04	02-Apr	03-Jul	< 0.05	DR-10	02-Jul	24-Sep	< 0.05
DR-05	02-Apr	03-Jul	< 0.05	DR-11	01-Jul	24-Sep	< 0.05
DR-06	03-Apr	04-Jul	< 0.05	DR-12	01-Jul	23-Sep	< 0.05

Table B-12 (Continued)
Direct Radiation, Optically Stimulated Luminescence (OSL) Dosimeters

Sample Location Code	Sample Installation Date	Sample Retrieval Date	Dose Equivalence msv	Sample Location Code	Sample Installation Date	Sample Retrieval Date	Dose Equivalence msv
DR-13	01-Jul	23-Sep	< 0.05	DR-07	26-Sep	09-Jan-20	< 0.05
DR-14	01-Jul	23-Sep	< 0.05	DR-08	24-Sep	09-Jan-20	< 0.05
DR-15	01-Jul	23-Sep	< 0.05	DR-09	24-Sep	07-Jan-20	< 0.05
DR-16	02-Jul	24-Oct	< 0.05	DR-10	24-Sep	06-Jan-20	< 0.05
DR-17	01-Jul	23-Sep	< 0.05	DR-11	24-Sep	06-Jan-20	< 0.05
DR-01	25-Sep	08-Jan-20	< 0.05	DR-12	23-Sep	06-Jan-20	< 0.05
DR-02	25-Sep	13-Jan-20	< 0.05	DR-13	23-Sep	06-Jan-20	< 0.05
DR-03	25-Sep	08-Jan-20	< 0.05	DR-14	23-Sep	06-Jan-20	< 0.05
DR-04	25-Sep	08-Jan-20	< 0.05	DR-15	23-Sep	06-Jan-20	< 0.05
DR-05	25-Sep	08-Jan-20	< 0.05	DR-16	24-Oct	07-Jan-20	< 0.05
DR-06	26-Sep	09-Jan-20	< 0.05	DR-17	23-Sep	06-Jan-20	< 0.05

1- Quarterly dose is calculated based on the days in the calendar quarter.

Table B-13
Airborne Filter Samples Gamma Spectrometric Analyses Results

Sample Location Code	Sample Collection Date	Plant-related radionuclides	Sample Location Code	Sample Collection Date	Plant-related radionuclides
AB-1CO	3-Jan	ND[1]	AB-1CO	24-Oct	ND[1]
AB-1CO	10-Jan	ND[1]	AB-1CO	7-Nov	ND[1]
AB-1CO	31-Jan	ND[1]	AB-1CO	21-Nov	ND[1]
AB-1CO	14-Feb	ND[1]	AB-1CO	4-Dec	ND[1]
AB-1CO	28-Feb	ND[1]	AB-1CO	19-Dec	ND[1]
AB-1CO	14-Mar	ND[1]	AB-1CO	31-Dec	ND[1]
AB-1CO	28-Mar	ND[1]	AB-1RU	2-Jan	ND[1]
AB-1CO	11-Apr	ND[1]	AB-1RU	16-Jan	ND[1]
AB-1CO	25-Apr	ND[1]	AB-1RU	30-Jan	ND[1]
AB-1CO	9-May	ND[1]	AB-1RU	13-Feb	ND[1]
AB-1CO	23-May	ND[1]	AB-1RU	27-Feb	ND[1]
AB-1CO	5-Jun	ND[1]	AB-1RU	13-Mar	ND[1]
AB-1CO	20-Jun	ND[1]	AB-1RU	27-Mar	ND[1]
AB-1CO	4-Jul	ND[1]	AB-1RU	10-Apr	ND[1]
AB-1CO	18-Jul	ND[1]	AB-1RU	24-Apr	ND[1]
AB-1CO	1-Aug	ND[1]	AB-1RU	8-May	ND[1]
AB-1CO	15-Aug	ND[1]	AB-1RU	22-May	ND[1]
AB-1CO	29-Aug	ND[1]	AB-1RU	5-Jun	ND[1]
AB-1CO	12-Sep	ND[1]	AB-1RU	19-Jun	ND[1]
AB-1CO	29-Sep	ND[1]	AB-1RU	3-Jul	ND[1]
AB-1CO	9-Oct	ND[1]	AB-1RU	17-Jul	ND[1]

Table B-13 (Continued)
Airborne Filter Samples Gamma Spectrometric Analyses Results

Sample Location Code	Sample Collection Date	Plant-related radionuclides	Sample Location Code	Sample Collection Date	Plant-related radionuclides
AB-1RU	31-Jul	ND[1]	AB-1BA	8-May	ND[1]
AB-1RU	15-Aug	ND[1]	AB-1BA	22-May	ND[1]
AB-1RU	28-Aug	ND[1]	AB-1BA	5-Jun	ND[1]
AB-1RU	11-Sep	ND[1]	AB-1BA	19-Jun	ND[1]
AB-1RU	25-Sep	ND[1]	AB-1BA	3-Jul	ND[1]
AB-1RU	9-Oct	ND[1]	AB-1BA	17-Jul	ND[1]
AB-1RU	23-Oct	ND[1]	AB-1BA	31-Jul	ND[1]
AB-1RU	6-Nov	ND[1]	AB-1BA	15-Aug	ND[1]
AB-1RU	20-Nov	ND[1]	AB-1BA	28-Aug	ND[1]
AB-1RU	4-Dec	ND[1]	AB-1BA	11-Sep	ND[1]
AB-1RU	18-Dec	ND[1]	AB-1BA	25-Sep	ND[1]
AB-1RU	31-Dec	ND[1]	AB-1BA	9-Oct	ND[1]
AB-1BA	2-Jan	ND[1]	AB-1BA	23-Oct	ND[1]
AB-1BA	16-Jan	ND[1]	AB-1BA	6-Nov	ND[1]
AB-1BA	30-Jan	ND[1]	AB-1BA	20-Nov	ND[1]
AB-1BA	13-Feb	ND[1]	AB-1BA	4-Dec	ND[1]
AB-1BA	27-Feb	ND[1]	AB-1BA	18-Dec	ND[1]
AB-1BA	13-Mar	ND[1]	AB-1BA	31-Dec	ND[1]
AB-1BA	2-Apr	ND[1]	AB-1BA	18-Dec	ND[1]
AB-1BA	24-Apr	ND[1]	AB-1BA	31-Dec	ND[1]

Table B-14
Airborne Charcoal Cartridges Samples Gamma Spectrometric Analyses Results

Sample Location Code	Sample Collection Date	I131-, Bq/m3	Sample Location Code	Sample Collection Date	I131-, Bq/m3
AB-1CO	3-Jan	ND[1]	AB-1CO	29-Sep	NA[2]
AB-1CO	3-Jan	ND[1]	AB-1CO	9-Oct	NA[2]
AB-1CO	17-Jan	ND[1]	AB-1CO	24-Oct	NA[2]
AB-1CO	17-Jan	ND[1]	AB-1CO	7-Nov	NA[2]
AB-1CO	31-Jan	ND[1]	AB-1CO	21-Nov	NA[2]
AB-1CO	14-Feb	ND[1]	AB-1CO	4-Dec	NA[2]
AB-1CO	28-Feb	ND[1]	AB-1CO	19-Dec	NA[2]
AB-1CO	14-Mar	ND[1]	AB-1CO	31-Dec	NA[2]
AB-1CO	28-Mar	ND[1]	AB-1RU	2-Jan	ND[1]
AB-1CO	11-Apr	ND[1]	AB-1RU	16-Jan	ND[1]
AB-1CO	25-Apr	ND[1]	AB-1RU	30-Jan	ND[1]
AB-1CO	9-May	ND[1]	AB-1RU	13-Feb	ND[1]
AB-1CO	23-May	ND[1]	AB-1RU	27-Feb	ND[1]
AB-1CO	5-Jun	ND[1]	AB-1RU	13-Mar	ND[1]
AB-1CO	20-Jun	ND[1]	AB-1RU	27-Mar	ND[1]
AB-1CO	4-Jul	ND[1]	AB-1RU	10-Apr	ND[1]
AB-1CO	18-Jul	ND[1]	AB-1RU	24-Apr	ND[1]
AB-1CO	1-Aug	ND[1]	AB-1RU	8-May	ND[1]
AB-1CO	15-Aug	ND[1]	AB-1RU	22-May	ND[1]
AB-1CO	29-Aug	NA[2]	AB-1RU	5-Jun	ND[1]
AB-1CO	12-Sep	NA[2]	AB-1RU	19-Jun	ND[1]

Table B-14 (Continued)
Airborne Charcoal Cartridges Samples Gamma Spectrometric Analyses Results

Sample Location Code	Sample Collection Date	I131-, Bq/m3	Sample Location Code	Sample Collection Date	I131-, Bq/m3
AB-1RU	3-Jul	ND[1]	AB-1BA	2-Apr	ND[1]
AB-1RU	17-Jul	ND[1]	AB-1BA	24-Apr	ND[1]
AB-1RU	31-Jul	ND[1]	AB-1BA	8-May	ND[1]
AB-1RU	15-Aug	ND[1]	AB-1BA	22-May	ND[1]
AB-1RU	28-Aug	NA[2]	AB-1BA	19-Jun	ND[1]
AB-1RU	11-Sep	NA[2]	AB-1BA	3-Jul	ND[1]
AB-1RU	25-Sep	NA[2]	AB-1BA	17-Jul	ND[1]
AB-1RU	9-Oct	NA[2]	AB-1BA	31-Jul	ND[1]
AB-1RU	23-Oct	NA[2]	AB-1BA	15-Aug	ND[1]
AB-1RU	6-Nov	NA[2]	AB-1BA	28-Aug	NA[2]
AB-1RU	20-Nov	NA[2]	AB-1BA	11-Sep	NA[2]
AB-1RU	4-Dec	NA[2]	AB-1BA	25-Sep	NA[2]
AB-1RU	18-Dec	NA[2]	AB-1BA	9-Oct	NA[2]
AB-1RU	31-Dec	NA[2]	AB-1BA	23-Oct	NA[2]
AB-1BA	2-Jan	ND[1]	AB-1BA	6-Nov	NA[2]
AB-1BA	16-Jan	ND[1]	AB-1BA	20-Nov	NA[2]
AB-1BA	30-Jan	ND[1]	AB-1BA	4-Dec	NA[2]
AB-1BA	13-Feb	ND[1]	AB-1BA	18-Dec	NA[2]
AB-1BA	27-Feb	ND[1]	AB-1BA	31-Dec	NA[2]
AB-1BA	13-Mar	ND[1]			

1Not Detected
2Not Analyzed

APPENDIX C
QUALITY ASSURANCE AND QUALITY CONTROL PROGRAMME

APPENDIX C
Quality Assurance and Quality Control Programme

Appendix C is a summary of the FANR Environmental Laboratory's quality assurance programme. It consists of Table C-1, which summarises the results of FANR's participation in the International Atomic Energy Agency (IAEA) proficiency testing (i.e. inter-laboratory comparison) programme. The IAEA coordinates the proficiency-testing programme called ALMERA (or Analytical Laboratories for the Measurement of Environmental Radioactivity) for a network of approximately 195 laboratories in 90 countries at this time.

The ALMERA proficiency-testing programme tests the ability of radiochemistry laboratories to analyse radioactive samples and accurately report the results. The ALMERA testing programme is designed to monitor the performance and capabilities of analytical laboratories and, if necessary, to identify problem areas where further development is needed. At least one exercise is organised per year by the IAEA for the ALMERA network. The IAEA worldwide proficiency-testing programme is open to all radiochemistry laboratories across the world. FANR participated in this programme (designated IAEA-TEL-2015-04) for the first time in 2015.

The IAEA provides each participating laboratory with various environmental samples to be characterised for man-made and natural alpha, beta and gamma-emitting radionuclides. In 2019, FANR continued to implement the quality assurance and quality control program started in 2015, and participated in the inter-laboratory comparison programme (designated IAEA-TEL-2019-03). This included written procedures, trend charts, and the use of standard reference materials traceable to the National Institute of Science and Technology (NIST).

FANR analysed two environmental media water samples and simulated aerosols filters. The analysis results were submitted to the IAEA in November 2019. The IAEA published the results in December 2019. For a result to be accepted, all radionuclides had to be identified correctly, the result for each nuclide had to pass an accuracy test, and the result for each radionuclide had to pass a precision test. FANR's Environmental Laboratory results are shown in Tables C-1 and C-2

In summary, FANR's analysis was acceptable for all of the anthropogenic nuclides in all samples (samples #01, #02, #05, #06, and #07), but failed several of the naturally occurring nuclides in samples #01 and #02. In fact, none of the participating 254 laboratories passed the acceptance criteria for many of the naturally occurring nuclides. The issues for the NORM nuclides in IAEA-TEL-2019-03 were the result of not decay correcting the measurement results. FANR's results were not decay corrected because (1) the proficiency test instructions did not clearly indicate that decay corrections were required, and (2) FANR's laboratory does not routinely decay correct any NORM nuclides (in disequlibrium) because the reference date is not known for typical sample.

The Central Testing Laboratory of the Abu Dhabi Quality and Conformity Council is a UAE National Accreditation System (ENAS) accredited laboratory in ISO/IEC 17025:2017 for the analysis of Tritium in water by Liquid Scintillation Counting (LSC) method. Accreditation means that the laboratory has met the Management and Technical Requirements of ISO17025 and is deemed technically competent to produce testing results.

Table C-1
Results of FANR Participation in IAEA ALMERA Proficiency Testing Programme, Sample No.1

Sample No. 1	Activity Reported by FANR, Bq/kg	IAEA Published Activity, Bq/kg	FANR Bias, Bq/kg	Max. Allowed Bias, ± %	Accuracy	Precision	Final Score
Cs-134	8.90	9.30	0.34	20%	Accepted	Accepted	Accepted
Cs-137	8.62	8.92	0.20	20%	Accepted	Accepted	Accepted
Ac-228	21.3	22.08	0.39	20%	Accepted	Accepted	Accepted
Ra-224	3.31	0.80	0.71	75%	Not Accepted	Not Accepted	Not Accepted
Ra-226	4.06	7.50	0.14	25%	Not Accepted	Not Accepted	Not Accepted
Pb-212	3.30	0.80	0.10	75%	Not Accepted	Not Accepted	Not Accepted
Bi-212	3.03	0.80	0.55	75%	Not Accepted	Not Accepted	Not Accepted
Pb-214	4.11	7.50	0.15	25%	Not Accepted	Not Accepted	Not Accepted
Bi-214	4.06	7.50	0.14	25%	Not Accepted	Not Accepted	Not Accepted
TL-208	0.973	0.29	0.05	75%	Not Accepted	Not Accepted	Not Accepted

Table C-2
Results of FANR Participation in IAEA ALMERA Proficiency Testing Programme, Sample No.2

Sample No. 1	Activity Reported by FANR, Bq/kg	IAEA Published Activity, Bq/kg	FANR Bias, Bq/kg	Max. Allowed Bias, ± %	Accuracy	Precision	Final Score
Cs-134	4.45	5.05	0.08	40%	Accepted	Not Accepted	Warning
Cs-137	4.19	4.19	0.08	40%	Accepted	Accepted	Accepted
Ac-228	3.81	3.98	0.08	40%	Accepted	Accepted	Accepted
Pb-214	1.4	0.769	0.03	50%	Accepted	Not Accepted	Warning
Bi-214	1.4	0.759	0.03	50%	Accepted	Not Accepted	Warning
Ra-226	1.4	0.760	0.26	40%	Not Accepted	Accepted	Not Accepted

Table C-3

Results of FANR Participation in IAEA ALMERA Proficiency Testing Programme, Sample No.5

Sample No. 1	Activity Reported by FANR, Bq/kg	IAEA Published Activity, Bq/kg	FANR Bias, Bq/kg	Max. Allowed Bias, ± %	Accuracy	Precision	Final Score
Cs-134	10.8	10.71	0.14	20%	Accepted	Accepted	Accepted
Cs-137	13.9	13.25	0.24	20%	Accepted	Accepted	Accepted

Table C-4

Results of FANR Participation in IAEA ALMERA Proficiency Testing Programme, Sample No.6

Sample No. 1	Activity Reported by FANR, Bq/kg	IAEA Published Activity, Bq/kg	FANR Bias, Bq/kg	Max. Allowed Bias, ± %	Accuracy	Precision	Final Score
Cs-134	20.2	20.28	0.40	20%	Accepted	Accepted	Accepted
Cs-137	13.2	13.02	0.22	20%	Accepted	Accepted	Accepted

Table C-5

Results of FANR Participation in IAEA ALMERA Proficiency Testing Programme, Sample No.7

Sample No. 1	Activity Reported by FANR, Bq/kg	IAEA Published Activity, Bq/kg	FANR Bias, Bq/kg	Max. Allowed Bias, ± %	Accuracy	Precision	Final Score
Cs-134	6.46	6.37	0.10	20%	Accepted	Accepted	Accepted
Cs-137	26.0	24.93	0.44	20%	Accepted	Accepted	Accepted

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