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الهيئة الاتحادية للرقابة النووية
Federal Authority for Nuclear Regulation

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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

Table of Contents

List of Figures

List of Tables

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 2018 FANR measured the radioactivity concentration of hundred and fifty four (154) samples of soil, water, sediment, fish, airborne particulate and date palm fruit samples 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 2018, the laboratory collected five hundred and thirty-seven thousand one hundred and twelve (537,112) individual 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 bodies[1]. 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 and radiological related activities in the country.

FANR's Radiation Safety Department is dedicated to ensure protecting the health and safety of the public (and 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.

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 state or condition of being subject to irradiation (Occupational and/or public exposure), whereas Dose is the amount of energy absorbed by an organ or tissue from exposure to ionizing radiation, expressed as (absorbed dose) or as the relative and effective impact to a person (effective dose). Absorbed dose is measured using SI unit called a Gray (Gy). The effective dose is measured using SI unit called a Sievert (Sv). When dealing with small exposures such as the exposures commonly associated with natural radioactive sources, 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 due to different sources of ionising radiation, please refer to Figure 1 for world average public exposure by radiation sources published by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[4].

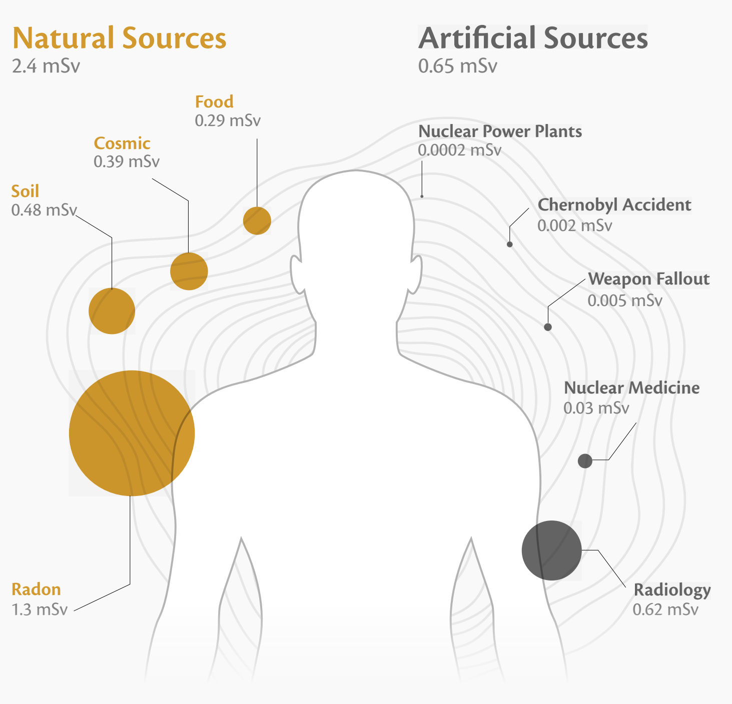
[4] See reference (4) in section IV

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).

Generally, public exposure to radiation from natural sources dominates the total exposure. UNSCEAR (UNSCEAR, 2016) estimated the average annual effective dose to an individual at about 3 mSv. On average, the annual dose from natural sources is 2.4 mSv and two thirds of it comes from radioactive substances in the air we breathe, the food we eat and the water we drink. The main source of exposure from man-made sources is radiation used in medicine, with an individual average annual effective dose of 0.62 mSv. It is worth to mention here that the exposure differ from country to another.[6]

Although these numbers do not necessarily reflect the levels of exposure in the UAE, it provides a true representation of the various sources of ionising radiation that the population might be exposed to in an industrialised society with advanced nuclear facilities.

[5] See reference (3) in section IV
[6] See reference (3) in section IV

III.
THE RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAMME

III. The Radiological Environmental Monitoring Programme

III.A Introduction

In 2009, FANR began conducting environmental gamma radiation measurements in the UAE. In 2013, FANR started collecting environmental samples of water and soil for laboratory analysis. By 2015 FANR's Environmental Laboratory had established a quality control and quality assurance programme, an analytical method for gamma isotopic analysis, and an extensive long-term environmental monitoring programme. In 2018, FANR issued the first radiological environmental monitoring programme report, which summarised the results for different environmental samples collected in calendar year 2015.

This report, which documents all sample results from 2017, is the third 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; and

4) Publish a periodic public report containing a summary of the results of the programme.

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, Airborne, 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 (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 dried form) samples prepared by placing fresh flesh (without pits) into a 1-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 2018 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	16	Tritium Gamma Isotopic	M M	12 16
Seawater, Offshore	SA	5	10	Gamma Isotopic	SA	10
Sediment	SA	7	14[2]	Gamma Isotopic	SA	14
Fish	Once per location	1	4	Gamma Isotopic	A	4
Direct Radiation	Continuous	17	537,112	Gross Gamma (Gamma Monitoring Network)	10-min avg	537,112
Direct Radiation	Q	17	17	Ambient Gamma Radiation (OSL)	Q	17
Atmospheric Environment, Air Filters	Twice a month	3	34	Gamma Isotopic	M	12
Atmospheric Environment, Charcoal	Twice a month	3	30	Iodine-131	M	11
Soil/ Sand	Once per location	6	18[2]	Gamma Isotopic	A	18
Vegetation (Date Palm Fruit)	S (Growing Season)	2	28	Gamma Isotopic	S	28

1) W=Weekly, M=Monthly, Q=Quarterly, SA=Semi-annual, A=Annual, S= Seasonal.
2) At some locations, multiple samples were collected.

III.B.3 Data Interpretation

Due to the low environmental radiation background, the time of measurement for collected samples are 18 hours to 3 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-9.

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 reports4. 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

This year, there is no exceptions for the environmental monitoring programme.

III.C Results and Discussion

All water, vegetation, soil, and sediment samples collected in 2018 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.

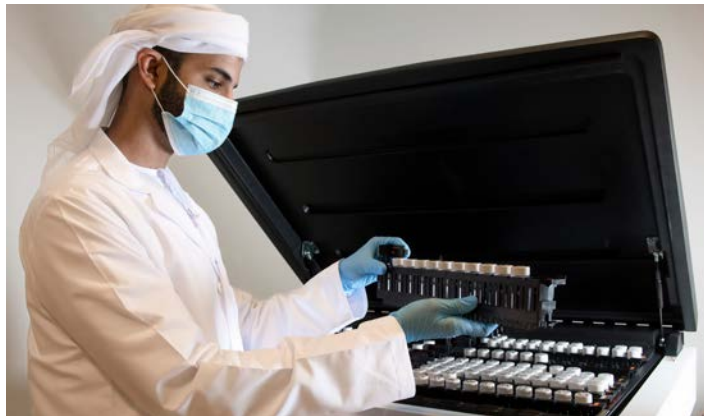
All analysis results are shown in Appendix B. For discussion, the analytical results are divided into four categories. The categories are Aquatic Environment, Atmospheric Environment, Terrestrial Environment, and Direct Radiation. These categories are further divided into subcategories according to sample 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, seawater from offshore locations in the Arabian Gulf, sediment from the exposed wetted shoreline at low tide, and bottom sediment from offshore locations. Each of these sample types are discussed in the paragraphs below.

III.C.1.a Water

Gamma Analysis:



Twenty-six seawater samples were collected for analysis in 2018; FANR's Environmental Laboratory collected sixteen of those samples and the Environment Agency - Abu Dhabi (EAD) collected ten samples. 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 2014. In addition, for 2018, FANR's Environmental Laboratory collected four samples from Barakah Site's discharge canal and the Environment Agency - Abu Dhabi collected two seawater sample from each of the five offshore locations, which were accessed by boat.

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 26 seawater samples are shown in Table B-1.

The average K-40 concentration of the twelve samples from Corniche Beach was 15.7 ± 1 Bq/kg. The sample collected in February had the highest K-40 concentration of 17.4 ± 1.1 Bq/kg and the samples collected in May and December had the lowest K-40 concentration of 14.2 ± 0.7Bq/kg and 14.2 ± 0.8 Bq/kg respectively.

The ten (10) seawater samples taken from offshore locations exhibited higher K-40 activity than the Corniche Beach samples. The average K-40 concentration of the ten offshore samples was 16.4 ± 0.9 Bq/kg. The sample collected in October from Al Salamiyah Channel had the highest K-40 concentration of 18.3 ± 1.2 Bq/kg and the sample collected in October from Taweela had the lowest K-40 concentration of 9.7 ± 0.7 Bk/kg.

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 2018, 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 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. Bottom sediment is sand, soil, and other solids from a location that is typically always underwater. Shore sediment and bottom sediment are considered aquatic samples. Generally, bottom sediment has little value in dose monitoring, but was collected in 2017 as part of a broader baseline monitoring of radionuclides in the UAE however no bottom sediment were collected in 2018.

Fourteen shoreline sediment samples were collected for analysis in 2018; FANR's Environmental Laboratory collected four of those samples and the Environment Agency - Abu Dhabi (EAD) collected the other ten samples. Figure A-1 shows the locations where samples were collected. The sampling location code and additional location details are shown in Table A-1.

Two samples were collected from each of the following locations: Abu Dhabi Corniche, Taweela, Al Salamiyah Channel, Al Ruwais, Al Marfa, Al Yasat, and Barakah. All sediment samples were composed primarily of sand and shell fragments except the samples from Al Salamiyah, which was primarily silt and clay, with a markedly muddy appearance (prior to drying).

All of the samples were analysed at FANR's Environmental Laboratory and two samples collected in October were sent to the Central Testing Laboratory, of the Abu Dhabi Quality and Conformity Council to be analyzed for gamma emitters.

As expected, all sediment samples exhibited detectable amounts of naturally occurring potassium 40 (K 40), uranium 238 (U-238), thorium 234 (Th-234), and protactinium 234m (Pa-234m) along with the expected progeny for the U-238, U 235, and Th 232 decay chains. The analysis results for all sediment samples are shown in Table B-3. 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 samples collected from Al Salamiyah Channel have higher K-40 activity, similar to that reported in previous years (2016 and 2017), which are primarily silt and clay, as expected, since silt and clay contain more potassium than sand.

For the fourteen sediment samples, radionuclides of the Uranium-238 series (U-238, Th-234, Pa-234m, and Ra-226) were the main gamma-emitting natural radionuclides measured at activities of between 19.7 ± 1.0 and 51.7 ± 2.5 Bq/kg of dry sediment.

Cesium-137 (Cs-137) was detected in five sediment samples at a concentration very close to the lower limit of detection. Cs-137 activity in sediment ranged from non-detectable to 0.3 Bq/kg, with an average of 0.16 Bq/kg of dry sediment. Low concentrations of Cs-137 are expected in sediment and are consistent with residual fallout from past atmospheric nuclear weapons testing activities in other countries. Traces of Thorium-227 (Th-227), in the natural Uranium-235 decay chain, were also detected in four samples at very low concentrations, between 0.9 ± 01 and 2.4 ± 0.2 Bq/kg of dry sediment.

Traces of cosmogonic radionuclide know berillyum-7 (Be-7) was also detected in only four samples at very low levels. This is expected as it is a tracer of sediment mixing on a seasonal time-scale due to its short half-life (53.3 days).

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, Cs-137, Be-7, 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 14 sediment samples are shown in Table B-3.

III.C.1.c Fish

Four fish samples were collected for inclusion in this report from one location. These samples were collected from Al Bateen Fish Market in Abu Dhabi. 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. Two types of fish species were selected for analysis in 2018: Hamour (Epinephelus coioides) and Jesh (Carangoides bajad).

The concentrations of gamma emitters in all fish samples are shown in Table B 4. 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.

For all fish samples, the average K-40 activity was 132 Bq/kg with a 2-sigma uncertainty of ± 8.24 Bq/kg for Hamour samples and 133 Bq/kg with a 2-sigma uncertainty of ± 8.43 Bq/kg for Jesh samples.

All fish samples showed detectable amounts of natural potassium-40 (K-40), as expected. The average K-40 activity was 132.4 Bq/kg with a 2-sigma uncertainty of ± 5.9 Bq/kg of fresh, wet fish fillet.

Low levels of Cesium-137 (Cs-137) Cs-137 were observed in almost all fish samples at an average concentration of 0.08 Bq/kg with a 2-sigma uncertainty of ±0.02 Bq/kg wet, which is consistent with expected concentrations due, primarily, to residual fallout from past atmospheric nuclear weapons testing in other countries. Apart from few naturally occurring nuclides of the Uranium-238 (U-238) series detected in some samples, no other naturally occurring or man-made nuclides were detected in any of the fish samples.

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 date fruits were collected during the growing season. One type of vegetation (i.e. date palm fruit) was sampled monthly during the growing season

III.C.2.a Vegetation

One type of food crops was selected for analysis in 2018 which is Date fruit from palm trees (Phoenix dactylifera linnaeus). All of the date fruit samples were supplied by the Al Foah Company. 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, twenty-eight (28) date fruit samples were collected from four locations for this year: Ghayathi, Liwa, Seih Al Khair, and Al Marfa. These locations represent the reception centres of Al Foah Company; each centre serves nearby farms in the region. The sample 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.

Over 100 varieties of dates are grown in the region[7]. Eleven (11) varieties (cultivars) of dates were sampled for inclusion in this report. The cultivar varieties of dates include Khenaizi, Shishi, Khallas, Dabbas, Lulu Red, Bumaan and Rezaiz. These date fruit samples were collected from many different farms located in the growing areas within the Western Region.

The concentrations of gamma emitters in all date palm fruit samples are shown in Table B-5. All date fruit samples showed detectable amounts of naturally occurring K-40. The analysis results are reported as Becquerel per kilogram of fresh, whole date palm fruit, without pits.

For date fruit samples, the average K-40 activity concentration was 252.6 Bq/kg with a 2-sigma uncertainty of ±10.3 Bq/kg. No other naturally-occurring nuclides or man-made nuclides were detected in any of the date fruit samples.

[7] See reference (4) in section IV

III.C.2.b Soil

Eighteen (18) surface soil samples were collected for analysis in 2018 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 the fourteen (14) samples at a concentration between 0.04 Bq/kg to 0.6 Bq/kg with an average activity of 0.22 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 four soil sample; this is most probably due to a soil disturbance where top soil containing Cesium-137 was removed for grading or some other sort of construction effort.

Traces of cosmogonic radionuclide berillyum-7 (Be-7) was also detected in ten samples at very low levels.

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-6.

III.C.3 Direct Radiation

In 2018, Direct radiation was measured with Geiger-Muller detectors and a sodium iodide detector and from Optically Stimulated Luminescent (OSL) dosimeters are using 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.

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 2018 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 2018 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 2018, 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. In 2018, a total of 537,112 individual measurements were collected from the low-range detectors at 17 locations and transmitted to the network monitoring centre. All of this data is summarized in this report.

Graphs of all 537,112 gamma dose rate measurements collected in 2018 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 2018, 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 40.1 nSv/h. Figure A-3 contains the results of all 537,112 individual dose-rate measurements from the 17 gamma monitoring stations for 2018.

In 2018, 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 Port Rashid Dxb (DG07) with 0.226 mSv. The station with the highest annual dose was Al Ain farm (DG12) with 0.446 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-10. 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 starting from the May. Out of 34 samples, twelve were measured and analysed for gamma emitters. Gamma spectrometric analyses of air particulate samples exhibited no detectable concentrations of any man-made radionuclides in any of these samples as shown in Table B-10.

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 30 samples, 11 were analyzed for radioiodine species and exhibited no detectable concentrations of I-131 during the year (Table B-11).

III.D Conclusion

Natural radionuclides were detected in all samples in 2018 as expected.

In general, the dose rates in the UAE are very low when compared to most other countries in the world[8]. 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 almost all soil samples, fish and sediment samples collected in 2018. This is normal and is consistent with expected concentrations due, primarily, to residual fallout from past atmospheric nuclear weapons testing in other countries. No other man-made radionuclides were observed in any of the samples in 2018.

The analysis results from 2018 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.

[8] 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.

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

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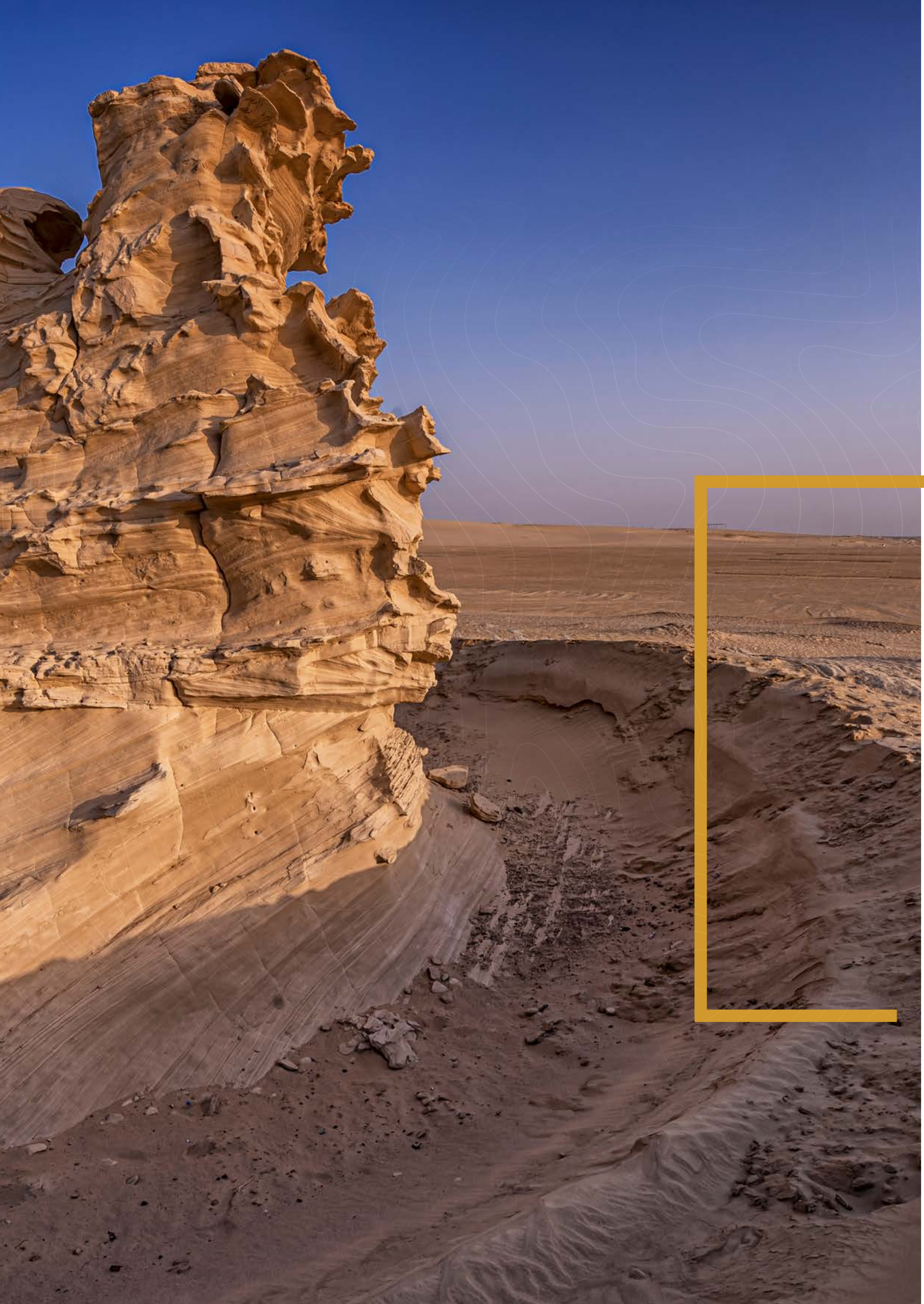
4. **Receiving centres across the UAE. (2021, June).** Retrieved from Alfoah.ae: https://www.alfoah.ae/receiving-center-locations

5. **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.**



APPENDIX A
SAMPLING LOCATIONS

Appendix A summarises detailed information regarding the different locations where samples were collected in 2018

Table A-1
Locations of Environmental Sampling Stations

Sample Location Code	Region	Location Name	Latitude	Longitude
		Water		
WS-1BA	Abu Dhabi	Barakah	23.976430	52.256320
WS-1CO	Abu Dhabi	Abu Dhabi Corniche Beach	24.475501	54.341186
WS-1TW	Abu Dhabi	Taweela	24.796760	54.636850
WS-1SC	Abu Dhabi	Al Salamiyah Channel	24.260670	54.386200
WS-1YS	Abu Dhabi	Al Yasat	24.168080	52.007410
WS-1RU	Abu Dhabi	Al Ruwais	24.256720	52.760750
		Sediment		
WM-1CO	Abu Dhabi	Abu Dhabi Corniche Beach	24.475690	54.341430
WM-1TW	Abu Dhabi	Taweela	24.789170	54.639230
WM-1SC	Abu Dhabi	Al Salamiyah Channel	24.260670	54.386200
WM-1RU	Abu Dhabi	Al Yasat	24.167970	52.007430
WM-1MF	Abu Dhabi	Al Ruwais	24.256720	52.760750
WM-1YS	Abu Dhabi	Al Mafra	24.142010	53.403270
WM-1BA	Abu Dhabi	Barakah	23.976430	52.256320
		Fish		
IF-1AD	Abu Dhabi	Abu Dhabi	24.45251	54.33921
		Vegetation (Date Palm Fruit)		
ID-1LI	Abu Dhabi	Liwa	23.035511	53.6502
ID-1GY	Abu Dhabi	Ghayathi	23.684511	52.9097
ID-1SK	Abu Dhabi	Seih Al Khair	23.035511	53.6502
ID-1MF	Abu Dhabi	Al Marfa	32.341711	36.2020
		Airborne		
AB-1RU	Abu Dhabi	Ruwais	24.112750	52.607375
AB-1BA	Abu Dhabi	Barakah	23.957830	52.237470
AB-1CO	Abu Dhabi	Abu Dhabi Corniche	24.485314	54.350880

Table A-1 (Continued)
Locations of Environmental Sampling Stations

Sample Location Code	Region	Location Name	Latitude	Longitude
		Soil		
DS-1CO	Abu Dhabi	Corniche beach, Abu Dhabi	24.476152	54.343083
DS-1BA	Abu Dhabi	Barakah	23.957840	52.237550
DS-1DP	Umm Al Qwain	Dream Land Park Umm Al Qwain	25.591650	55.660483
DS-1SI	Abu Dhabi	Al Sila	24.032826	51.757206
DS-1OW	Abu Dhabi	Owatid	23.39559	53.1119
DS-1AA	Abu Dhabi	Al Ain Farm	25.13218	55.88909
		Direct Radiation, Gamma Monitoring Network		
DG02	Ras Al Khaimah	Al Jeer, School	-----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, Met Tower	-----2	-----2
DG08	Abu Dhabi	Marina, Helipad	-----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
DN02	Abu Dhabi	Barakah G2	-----2	-----2
DG12	Abu Dhabi	Al Ain, Farm	-----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, Helipad	-----2	-----2

Table A-1 (Continued)
Locations of Environmental Sampling Stations

Sample Location Code	Region	Location Name	Latitude	Longitude
Environmental Optically Stimulated Luminescence (OSL) Dosimeters				
DR-01	Abu Dhabi	Barakah-SSE G2	-----2	-----2
DR-02	Abu Dhabi	Barakah-WSW – G4	-----2	-----2
DR-03	Abu Dhabi	Barakah-E	-----2	-----2
DR-04	Abu Dhabi	Ruwais Laboratory	-----2	-----2
DR-05	Abu Dhabi	Al Sila-NCMS	-----2	-----2
DR-06	Abu Dhabi	Owtaid-NCMS	-----2	-----2
DR-07	Abu Dhabi	Madinat Zayed	-----2	-----2
DR-08	Abu Dhabi	Marina AD	-----2	-----2
DR-09	Dubai	Port Rashid-DXB	-----2	-----2
DR-10	Umm al-Quwain	Dream Park-UAQ	-----2	-----2
DR-11	Ras Al Khaimah	Al Jeer-RAK	-----2	-----2
DR-12	Sharjah	Kalba- Sharjah	-----2	-----2
DR-13	Sharjah	Mleiha-Sharjah	-----2	-----2
DR-14	Abu Dhabi	Al Ain farm	-----2	-----2
DR-15	Fujairah	Masafi	-----2	-----2
DR-16	Dubai	Jumeirah-Dubai	-----2	-----2
DR-17	Abu Dhabi	Al Qatara- Al Ain	-----2	-----2
Control	Abu Dhabi	Transit (FANR Head-quarter Office)	-----2	-----2

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 written2) At some locations, multiple samples were collected.
2) These locations are not being published at this time

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

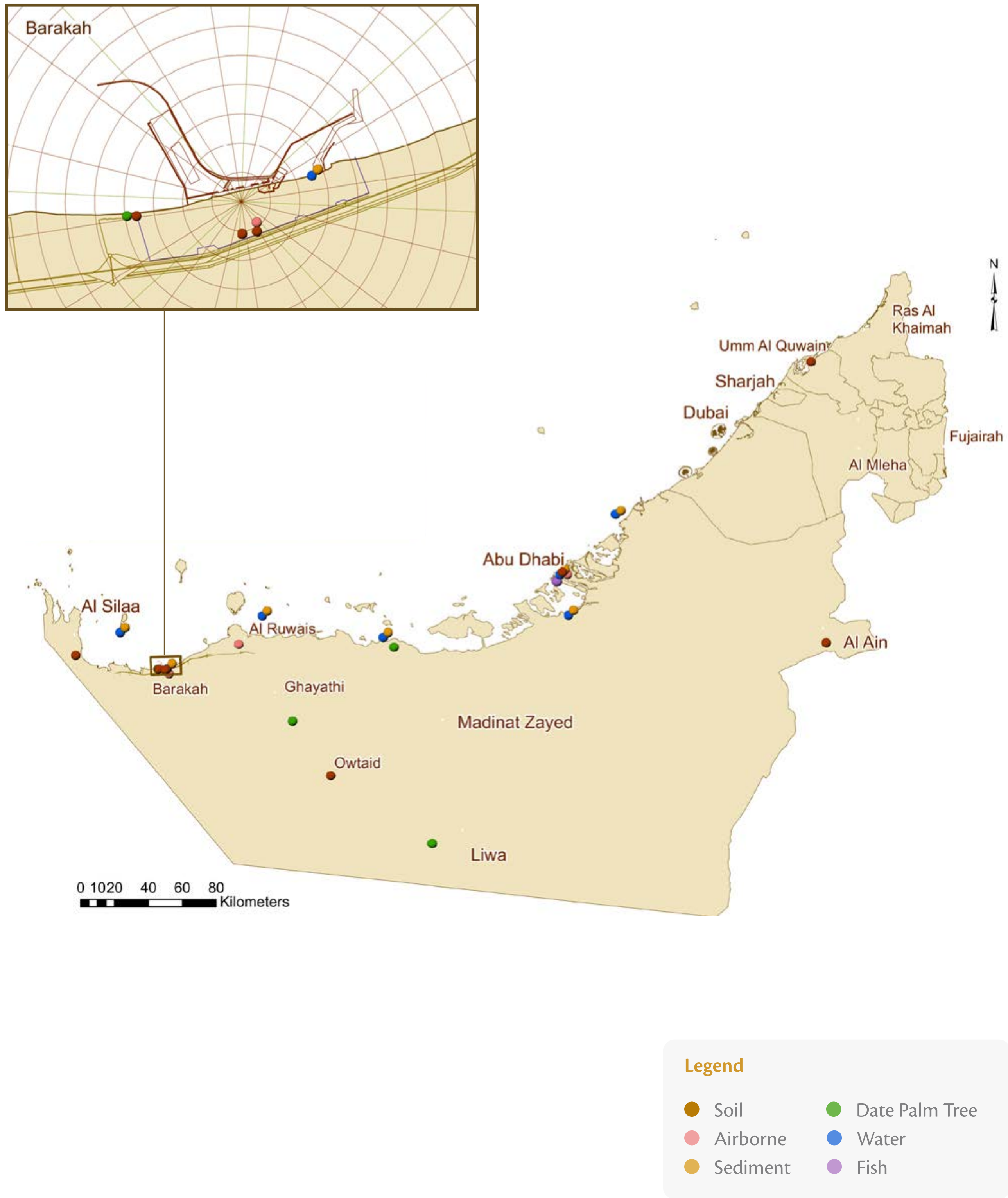
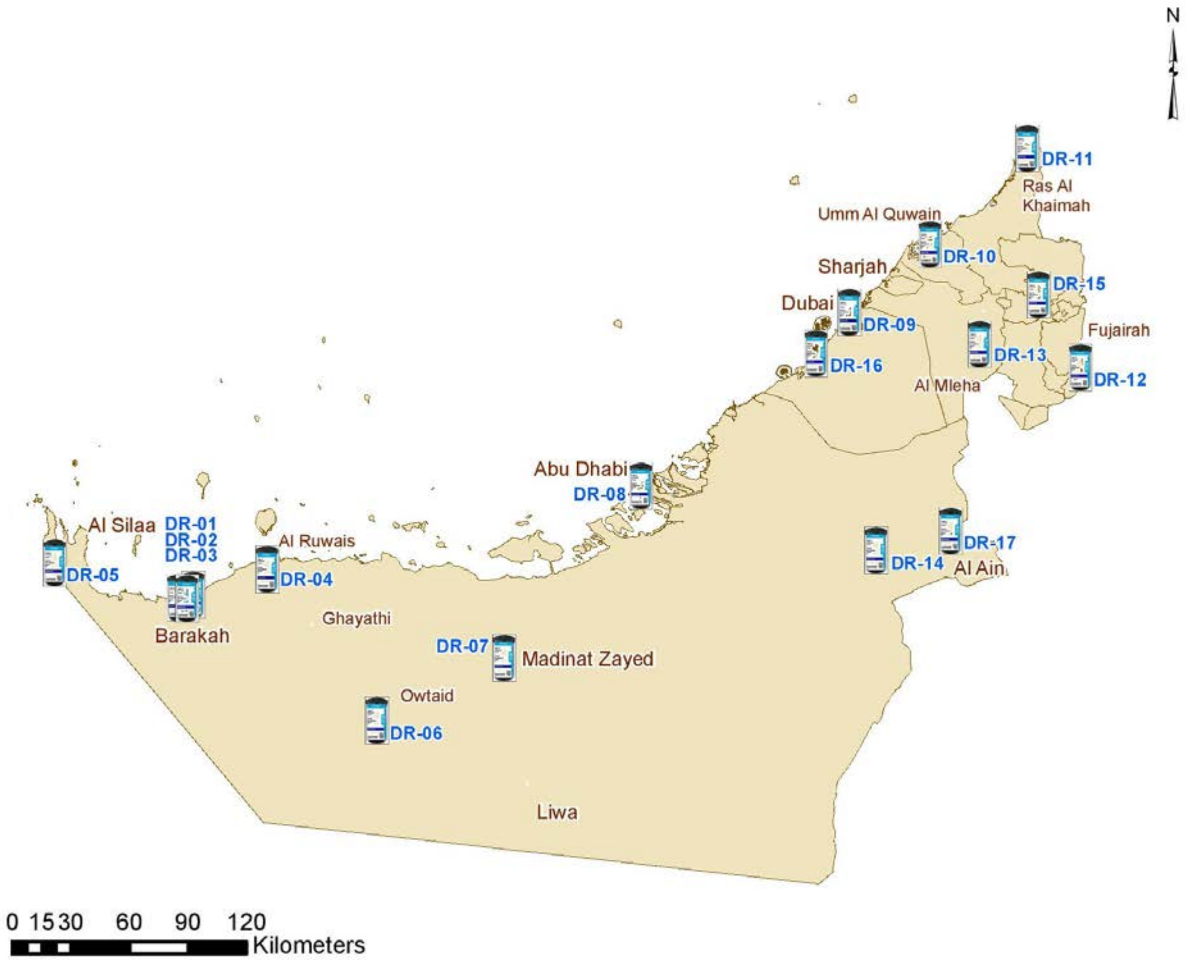


Figure A-2

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



Legend

Environemental Dosmimeters

Figure A-3

Map of Gamma Monitoring Network Locations Including Trends in Dose Rates

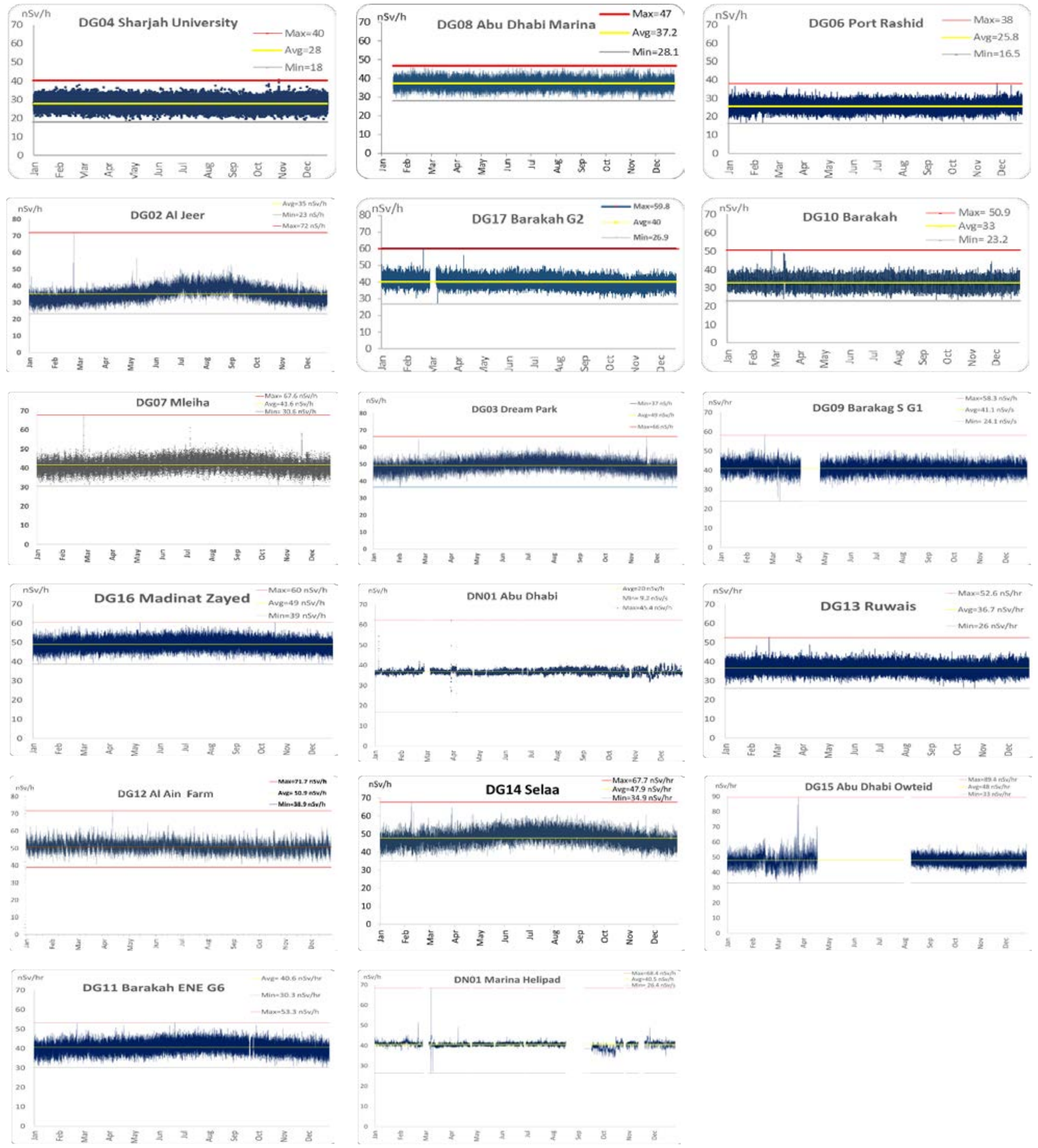
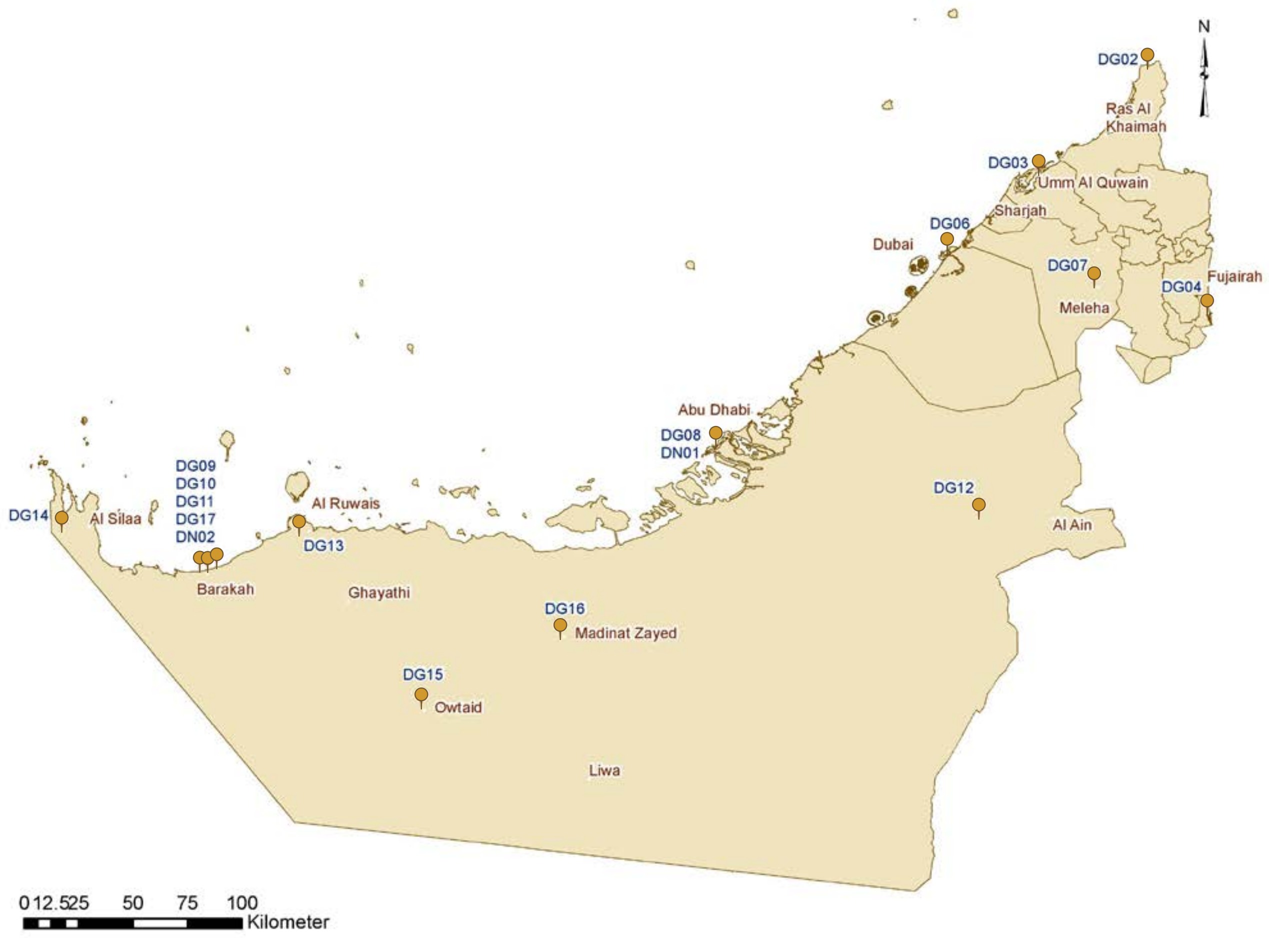


Figure A-3 (Continued)

Map of Gamma Monitoring Network Locations including Trends in Dose Rates



APPENDIX B
ANALYSIS RESULTS

Appendix B summarises the analytical results for all of the radiological analyses conducted in 2018 as part of FANR's radiological environmental monitoring programme.

Table B-1
Gamma Activity in Water

Sampling Location Code	Sampling Date	K-40 Bq/kg	Uncertainty ± 2σ Bq/kg	Other Gamma Emitters
WS-1CO	January	17.35	1.1	ND[1]
WS-1BA	February	17.0	0.8	ND[1]
WS-1CO	March	16.9	1.2	ND[1]
WS-1CO		15.3	0.8	ND[1]
WS-1BA	April	17.0	0.8	ND[1]
WS-1SC		16.8	1.09	ND[1]
WS-1TW		15.3	0.8	ND[1]
WS-1CO		16.0	1.0	ND[1]
WS-1MF		15.9	1.0	ND[1]
WS-1YS		16.7	1.1	ND[1]
WS-1RU		17.6	1.2	ND[1]
WS-1CO	May	14.2	0.7	ND[1]
WS-1CO	June	15.5	1.0	ND[1]
WS-1BA	July	17.4	0.8	ND[1]
WS-1CO		16.6	1.1	ND[1]
WS-1CO	August	August	1.1	ND[1]
WS-1CO	September	14.8	1.0	ND[1]
WS-1BA	October	16.9	0.8	ND[1]
WS-1TW		9.7	0.7	ND[1]
WS-1YS		17.0	0.8	ND[1]
WS-1SC		18.3	1.2	ND[1]
WS-1MF		17.1	1.1	ND[1]
WS-1RU		17.0	0.8	ND[1]
WS-1CO		16.2	1.0	ND[1]
WS-1CO	November	14.6	1.0	ND[1]
WS-1CO	December	14.2	0.8	ND[1]

1) ND= Not Detected

Table B-2
Tritium Activity in Water

Sampling Location Code	Sampling Date	H3- Bq/L	LLD Bq/L
WS-1CO	January	<0.60	0.60
WS-1CO	February	<0.60	0.60
WS-1CO	March	<0.60	0.60
WS-1CO	April	<0.60	0.60
WS-1CO	May	<0.60	0.60
WS-1CO	June	<0.60	0.60
WS-1CO	July	<0.60	0.60
WS-1CO	August	<0.60	0.60
WS-1CO	September	<0.60	0.60
WS-1CO	October	<0.60	0.60
WS-1CO	November	<0.60	0.60
WS-1CO	December	<0.60	0.60

Table B-3

Gamma Activity in Sediment (Bq/Kg) and Uncertainty (Bq/Kg±2σ)

Sample Code	Sample Date 2018	K-40		Cs-137		Be-7		U-238[1]		Th-232[2]		Ra-226[3]		Other Nuclides
		Uncertainty	Activity	Uncertainty	Activity	Uncertainty	Activity	Uncertainty	Activity	Uncertainty	Activity	Uncertainty	Activity	
WM-1CO	14 February	12.8	0.8	ND[4]	ND[4]	ND[4]	ND[4]	31.9	1.4	0.5	0.1	3.7	0.2	ND[4]
	29 October	45.4	8.30	ND[4]	ND[4]	NM[5]	NM[5]	NM[5]	NM[5]	NM[5]	NM[5]	12.0	0.6	ND[4]
WM-1TW	16 April	26.4	1.4	ND[4]	ND[4]	0.5	0.09	28.2	1.4	1.0	0.1	3.6	0.2	ND[4]
	7 October	134.4	5.7	ND[4]	ND[4]	0.6	0.03	35.5	1.7	4.0	0.2	11.5	0.5	ND[4]
WM-1SC	12 April	158.8	6.8	0.33	0.04	ND[4]	ND[4]	33.3	1.6	5.7	0.3	15.0	0.70	ND[4]
	16 October	176.4	7.6	0.23	0.01	ND[4]	ND[4]	39.4	1.9	6.1	0.3	16.0	0.7	ND[4]
WM-1RU	22 April	236	10	ND[4]	ND[4]	0.8	0.6	51.7	2.5	6.5	0.3	10.7	0.5	ND[4]
	17 October	20.1	4.0	ND[4]	ND[4]	NM[5]	NM[5]	NM[5]	NM[5]	NM[5]	NM[5]	4.5	0.3	ND[4]
WM-1MF	22 April	56.6	2.8	0.05	0.01	ND[4]	ND[4]	44.8	2.2	1.6	0.2	7.3	0.4	ND[4]
	17 October	22.8	1.3	ND[4]	ND[4]	ND[4]	ND[4]	47.5	2.4	1.1	0.1	7.7	0.4	ND[4]
WM-1YS	22 April	11.2	0.8	0.03	0.001	0.6	0.2	26.0	1.3	0.8	0.1	2.5	0.2	ND[4]
	17 October	18.0	1.1	ND[4]	ND[4]	ND[4]	ND[4]	45.5	2.8	0.7	0.1	2.2	0.2	ND[4]
WM-1BA	12 February	159.6	6.7	ND[4]	ND[4]	ND[4]	ND[4]	19.7	1.0	2.5	0.2	7.3	0.4	ND[4]
	10 October	167.8	6.7	0.04	0.02	ND[4]	ND[4]	30.4	1.3	3.3	0.2	9.0	0.4	ND[4]

1) U-238 activity is based on U-235 activity and activity ratio of 21.7%
2) Th-232 activity is based on Tl-208, Pb-212 and Ac-228 activity.
3) Ra-226 activity is based on (PB-214) daughter radionuclide (Bi-214 & PB-214)
4) ND= Not Detected
5) NM=Not Measured

Table B-4

Gamma Activity in Fish (Bq/Kg) and Uncertainty (Bq/Kg±2σ)

Sample Code	Sample Date 2018	K-40		Cs-137		U-238[1]		Other Nuclides
		Uncertainty	Activity	Uncertainty	Activity	Uncertainty	Activity	
WM-1CO	01 May	145	6.3	0.07	0.02	0.19	0.14	ND[2]
	01 May	156	6.9	0.11	0.02	0.28	0.14	ND[2]
WM-1TW	27 September	119	5.3	0.05	0.01	ND2	ND2	ND[2]
	10 October	109.6	4.9	ND[2]	ND[2]	0.12	0.13	ND[2]

1) U-238 activity is based on U-235 activity and activity ratio of 21.7% %
2) ND= Not Detected

Table B-5
Gamma Activity in Date Palm Fruit

Sampling Location Code	Sampling Date	K40-, Bq/kg (and Uncertainty, 2±σ) Fresh Whole Dates, without its	Other Nuclides
ID-1GY	12 August	258 (±11)	ND[1]
	19 August	249 (±10)	ND[1]
	05 September	196(±8)	ND[1]
	08 September	08 September	ND[1]
	08 September	236 (±9)	ND[1]
	09 September	253 (±10)	ND[1]
	09 September	204 (±9)	ND[1]
	06 October	261 (±11)	ND[1]
	06 October	247 (±10)	ND[1]
	06 October	222 (±9)	ND[1]
	24 October	344 (±14)	ND[1]
	15 November	286 (±11)	ND[1]
ID-1LI	09 August	273 (±11)	ND[1]
	19 August	274 (±11)	ND[1]
	19 August	221 (±9)	ND[1]
	12 September	263 (±10)	ND[1]
	06 October	281 (±12)	ND[1]
	06 October	266 (±11)	ND[1]
	06 October	290 (±12)	ND[1]
	06 October	267 (±11)	ND[1]
ID-1MF	09 September	197 (±8)	ND[1]
	09 September	189 (±8)	ND[1]
	06 October	195 (±8)	ND[1]
	06 October	253 (±10)	ND[1]
ID-1SK	08 September	308 (±13)	ND[1]
	08 September	281 (±12)	ND[1]
	08 September	251 (±10)	ND[1]
	10 September	229 (±10)	ND[1]

1) ND= Not Detected

Table B-6
Gamma Activity in Soil (Bq/Kg) and Uncertainty (Bq/Kg±2σ)

Sample Location Code	Sample Date 2018	K-40		Cs-137		U-238[1]		Th-232[2]		Be-7		Other Nuclides
		Uncertainty ± 2 σ	Activity	Uncertainty ± 2 σ	Activity	Uncertainty ± 2 σ	Activity	Uncertainty ± 2 σ	Activity	Uncertainty ± 2 σ	Activity	
DS-1BA	12 February	279.2	11.3	0.04	0.02	16.6	0.7	7.2	0.3	041	0.2	ND[3]
DS1-BA	12 February	165.5	6.6	0.04	0.002	7.3	0.3	2.8	0.2	0.4	0.2	ND[3]
DS-1AA	02 April	257.9	10.2	ND[3]	ND[3]	16.9	0.7	12.3	0.5	ND[3]	ND[3]	ND[3]
DS5-DP	03 April	221.2	9.1	0.1	0.004	14.7	0.6	6.2	0.3	0.6	0.4	ND[3]
DS-1SI	04 April	351.3	14.2	0.4	0.02	22.4	1.0	11.1	0.5	0.6	0.5	ND[3]
DS1-OW	05 April	208.1	8.6	ND[3]	ND[3]	18.7	0.8	4.3	0.2	0.9	0.4	ND[3]
DS-1CO	05 April	37.3	1.7	0.07	0.003	33.8	1.5	0.5	0.1	1.0	0.2	ND[3]
DS1-BA	18 September	307.7	12.5	ND[3]	ND[3]	14.6	0.6	6.0	0.3	ND[3]	ND[3]	ND[3]
DS-1BA	18 September	293.8	11.6	0.6	0.02	16.5	0.7	6.7	0.3	0.2	0.2	ND[3]
DS1-BA	18 September	277.6	11.3	0.30	0.01	15.9	0.7	5.4	0.3	ND[3]	ND[3]	ND[3]
DS-1BA	18 September	285.9	11.3	0.4	0.02	15.7	0.6	6.3	0.3	0.1	0	ND[3]
DS1-BA	18 September	296.0	12.1	0.05	0.002	16.5	0.7	6.4	0.3	ND[3]	ND[3]	ND[3]
DS1-AA	30 September	250.0	10.18	0.35	0.01	20.5	0.86	12.3	0.51	ND[3]	ND[3]	ND[3]
DS5-DP	01 October	202.1	8.32	0.07	0.002	13.5	0.6	5.2	0.2	0.35	0.4	ND[3]
DS1-BA	02 October	207.4	8.7	0.07	0.003	6.8	0.4	2.6	0.2	ND[3]	ND[3]	ND[3]
DS1-SI	02 October	350.2	14.1	0.5	0.02	18.4	0.8	9.0	0.4	0.4	0.4	ND[3]
DS-1BA	02 October	307.2	12.6	0.04	0.002	16.2	0.7	5.3	0.3	0.4	0.2	ND[3]
DS1-OW	03 October	262.1	10.4	ND[3]	ND3[3]	19.6	0.8	11.7	0.5	ND[3]	ND[3]	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) ND= Not Detected

Table B-7
Gamma Dose Rates, Measured, Gamma Monitoring Network (GMN)

Station Name	Sample Code	Annual Average Dose Rate, nSv/h	Minimum Dose Rate, nSv/h	Maximum Dose Rate, nSv/h	Range nSv/h	Availability[1]
Al Ain Farm	DG12	50.9	38.9	71.7	32.8	100%
Dream Park	DG03	49.2	36.6	66.4	29.8	99%
Silaa	DG14	47.8	37.3	67.7	30.3	100%
Madinat Zayed	DG16	49.1	38.8	60.4	21.7	100%
Owatid	DG15	48.3	33.1	89.4	55.3	69%
Mleiha	DG07	41.6	30.6	67.6	37.0	99%
Barakah G1	DG09	41.1	24.1	58.3	24.8	94%
Barakah G6	DG11	40.6	51.0	53.3	2.3	99%
Barakah G2	DN02	40.5	26.4	68.4	42.0	80%
Barakah G2	DG17	40.2	32.2	59.8	27.6	98%
Marina	DG08	37.2	28.1	46.9	18.8	96%
Marina	DN01	36.8	16.8	62.2	45.4	95%
Ruwais	DG13	36.7	29.6	52.7	26.6	99.8%
Al Jeer	DG02	35.3	23.3	72	48.7	99%
Barakah G4	DG10	33.0	23.2	50.9	25.4	100%
Sharjah	DG04	27.9	18.3	40.5	22.2	99%
Port Rashid	DG06	25.8	16.5	38.1	21.6	100%
Average, all stations, nSv/h		**40.1**	**Average availability for all stations**			**96%**

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-8
Doses Measured with the Gamma Monitoring Network (GMN)

Station Location Code	Station Name	Qtr. 1 mSv	Qtr. 2 mSv	Qtr. 3 mSv	Qtr. 4 mSv	Average Dose/Qtr. mSv	Annual Dose mSv
DG12	Al Ain Farm	0.112	0.113	0.111	0.111	0.112	0.446
DG03	Dream Park	0.103	0.109	0.112	0.107	0.108	0.431
DG14	Silaa	0.099	0.106	0.111	0.103	0.105	0.419
DG16	Madinat Zayed	0.105	0.108	0.110	0.107	0.107	0.430
DG15	Owatid	0.103	0.108	0.107	0.105	0.106	0.423
DG07	Mleiha	0.088	0.092	0.095	0.090	0.091	0.364
DG09	Barakah G1	0.090	0.089	0.091	0.090	0.090	0.360
DG11	Barakah G6	0.086	0.089	0.092	0.088	0.089	0.356
DN02	Barakah G2	0.088	0.089	0.089	0.090	0.089	0.356
DG17	Barakah G2	0.089	0.089	0.088	0.086	0.088	0.353
DG08	Marina	0.073	0.074	0.074	0.074	0.074	0.294
DN01	Marina	0.072	0.072	0.073	0.073	0.072	0.289
DG13	Ruwais	0.080	0.080	0.081	0.080	0.080	0.322
DG02	Al Jeer	0.081	0.081	0.082	0.082	0.082	0.326
DG10	Barakah G4	0.072	0.072	0.073	0.072	0.072	0.289
DG04	Sharjah	0.061	0.061	0.061	0.061	0.061	0.244
DG07	Port Rashid	0.056	0.056	0.057	0.057	0.057	0.226
					Average, all stations, nSv/h	**0.087**	**0.35**

Table B-9

Typical Detection Sensitivities (i.e. LLDs)[3] for Gamma Isotopic Analysis

Sampling Location Code	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-2321	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 5)

Table B-10

Direct Radiation, Optically Stimulated Luminescence (OSL) Dosimeters, Dose Equivalence mSv

Sampling Location Code	Sample Installation Date	Sample Retrieval Date	Dose Equivalence[1] mSv
DR-01	09 January	04 April	<0.05
	04 April	04 July	
	04 July	02 October	
	02 October	02 January 2019	
DR-02	09 January	04 April	<0.05
	04 April	04 July	
	04 July	02 October	
	02 October	02 January 2019	
DR-03	09 January	04 April	<0.05
	04 April	04 July	
	04 July	02 October	
	02 October	02 January 2019	
DR-04	09 January	04 April	<0.05
	04 April	04 July	
	04 July	02 October	
	02 October	02 January 2019	
DR-05	09 January	04 April	<0.05
	04 April	04 July	
	04 July	02 October	
	02 October	02 January 2019	
DR-06	09 January	04 April	<0.05
	04 April	04 July	
	04J uly	02 October	
	02 October	02 January 2019	
DR-07	09 January	04 April	<0.05
	04 April	04 July	
	04 July	02 October	
	02 October	02 January 2019	
DR-08	09 January	04 April	<0.05
	04 April	04 July	
	04July	02 October	
	02 October	02 January 2019	
DR-09	09 January	04 April	<0.05
	04 April	04 July	
	04 July	02 October	
	02 October	02 January 2019	

Table B-10 (Continued)

Direct Radiation, Optically Stimulated Luminescence (OSL) Dosimeters, Dose Equivalence mSv

Sampling Location Code	Sample Installation Date	Sample Retrieval Date	Dose Equivalence[1] mSv
DR-10	09 January	04 April	<0.05
	04 April	04 July	
	04July	02 October	
	02 October	02 January 2019	
DR-11	09 January	04 April	<0.05
	04 April	04 July	
	04July	02 October	
	02 October	02 January 2019	
DR-12		02 January 2019	<0.05
	09 January	04 April	
	04 April	04 July	
	04July	02 October	
DR-13	02 October	02 January 2019	<0.05
	09 January	04 April	
	04 April	04 July	
	04July	02 October	
DR-14	02 October	02 January 2019	<0.05
	09 January	04 April	
	04 April	04 July	
	04July	02 October	
DR-15	02 October	02 January 2019	<0.05
	09 January	04 April	
	04 April	04 July	
	04July	02 October	
DR-16	02 October	02 January 2019	<0.05
	09 January	04 April	
	04 April	04 July	
	04July	02 October	
DR-17	02 October	02 January 2019	<0.05
	09 January	04 April	
	04 April	04 July	
	04July	02 October	

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

Table B-11

Gamma Spectrometric Analyses Results, Air filters, Airborne particulate Activity Bq/kg

Sample Location Code	Sample Collection Date	Man-Made Radionuclides
AB-1RU	13-Jun	ND[1]
AB-1RU	30-May	ND[1]
AB-1RU	04-Jul	ND[1]
AB-1RU	18-Jul	ND[1]
AB-1RU	01-Aug	ND[1]
AB-1RU	15-Aug	ND[1]
AB-1RU	29-Aug	ND[1]
AB-1CO	12-Sep	ND[1]
AB-1RU	12-Sep	ND[1]
AB-1RU	10-Oct	ND[1]
AB-1CO	11-Oct	ND[1]
AB-1CO	25-Oct	ND[1]

1) ND= Not Detected

Table B-12

Gamma Spectrometric Analyses Results, Charcoal Cartridges, Airborne Gaseous Activity Bq/m^3

Sample Location Code	Sample Collection Date	I131-
AB-1RU	13-Jun	ND[1]
AB-1RU	30-May	ND[1]
AB-1RU	04-Jul	ND[1]
AB-1RU	18-Jul	ND[1]
AB-1RU	01-Aug	ND[1]
AB-1RU	15-Aug	ND[1]
AB-1RU	29-Aug	ND[1]
AB-1RU	12-Sep	ND[1]
AB-1RU	26-Sep	ND[1]
AB-1CO	11-Oct	ND[1]
AB-1CO	22-Nov	ND[1]
AB-1CO	22-Nov	ND[1]

1) ND= Not Detected

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 193 laboratories in 89 countries at this time. The appendix also includes a brief description of the accreditation of the Central Testing Laboratory, of the Abu Dhabi Quality and Conformity Council, where FANR seawater samples were analysed for Tritium (H-3).

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 2018, 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-2018-04). 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 water samples and submitted the analysis results to the IAEA in September 2018. The IAEA published the results in December 2018. In summary, FANR's Environmental Laboratory passed all of the acceptance criteria for almost all of the identified radionuclides. 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.

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, ±Bq/kg	Accuracy	Precision	Final Score
Ba-133	27.6	28.6	-1.0	4.3	Accepted	Accepted	Accepted
Am-241	NR	29.3	NR	4.4	NR	NR	NR
Co-60	95.9	97.6	-1.7	14.6	Accepted	Accepted	Accepted
Cs-134	53.6	58.2	-4.6	8.7	Accepted	Accepted	Accepted
Cs-137	28	29	-1.0	4.4	Accepted	Accepted	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, ±Bq/kg	Accuracy	Precision	Final Score
Be-7	432	440	-7.9	66	Accepted	Accepted	Accepted
Mn-54	62.6	61.3	1.3	12.3	Accepted	Accepted	Accepted
Co-58	15.0	15.5	-0.5	4.6	Accepted	Accepted	Accepted
Co-60	15.2	14.3	1.0	4.2	Accepted	Accepted	Accepted
RB-86	246.6	240	6.8	72	Accepted	Accepted	Accepted
Mo-99	460	470	-9.8	141	Accepted	Accepted	Accepted
I-131	235.2	241	-5.7	48.2	Accepted	Accepted	Accepted
I-133	2965	2760	220.3	828	Accepted	Accepted	Accepted
Cs-134	2885	3010	-119.7	451	Accepted	Accepted	Accepted
Cs-136	27.8	29.2	-1.3	8.7	Accepted	Accepted	Accepted
Cs-137	1984	2010	-25.6	301	Accepted	Accepted	Accepted
Na-24	25700	21900	4459	5475	Accepted	Not Accepted	Warning*
Sb-124	33.4	33.5	-0.1	10.05	Accepted	Accepted	Accepted
Br-82	209.3	224	-13.7	67	Accepted	Accepted	Accepted
K-42	444700	444000	711.5	111000	Accepted	Accepted	Accepted
W-187	NR	425	NR	85	NR	NR	NR

NR = Nuclide not reported by FANR lab
*Na-24, is greater than IAEA's expectations, FANR received a "warning" (but not a "failure") for this one uncertainty

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